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Expert systems for the planning and management of personnel training in public institutions in the city of Esmeraldas

Sistemas expertos para la planificación y gestión de la formación del personal en las instituciones públicas de la ciudad de Esmeraldas

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Abstract

This study focuses on developing a theoretical-practical framework for the implementation of an expert system for the planning and management of personnel training in public institutions in the city of Esmeraldas. The main objective is to analyze and systematize existing information on expert systems to optimize human talent management. The methodology used was based on an exhaustive documentary review, evaluating the current literature on training needs, knowledge representation techniques and the inclusion of explanation modules in expert systems. The results indicate that

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expert systems can significantly improve the efficiency of training planning, ensuring that staff competencies are aligned with organizational objectives. Notable findings of the study include the need for a pre-functional manual system, the integration of advanced knowledge representation techniques, and the validation of prototypes using qualitative methods. This approach not only optimizes training resources, but also increases staff performance and satisfaction, contributing to the socioeconomic development of Esmeraldas.

Keywords: expert systems, training planning, human talent management, public institutions.

Resumen

El presente estudio se centra en desarrollar un marco referencial teórico-práctico para la implementación de un sistema experto destinado a la planificación y gestión de la capacitación del personal en instituciones públicas de la ciudad de Esmeraldas. El objetivo principal es analizar y sistematizar la información existente sobre sistemas expertos para optimizar la gestión del talento humano. La metodología empleada se basó en una revisión documental exhaustiva, evaluando la literatura actual sobre necesidades de capacitación, técnicas de representación del conocimiento y la inclusión de módulos de explicación en sistemas expertos. Los resultados indican que los sistemas expertos pueden mejorar significativamente la eficiencia en la planificación de la capacitación, asegurando que las competencias del personal estén alineadas con los objetivos institucionales. Conclusiones destacadas del estudio incluyen la necesidad de un sistema manual funcional previo, la integración de técnicas avanzadas de representación del conocimiento y la validación de prototipos mediante métodos cualitativos. Este enfoque no solo optimiza los recursos de capacitación, sino que también eleva el desempeño y satisfacción del personal, contribuyendo al desarrollo socioeconómico de Esmeraldas.

Palabras clave: sistemas expertos, planificación de la capacitación, gestión del talento humano, instituciones públicas.

Introduction

In an increasingly globalized world, organizations, both public and private, face the challenge of remaining competitive and efficient. Staff training is essential to improve the competencies and skills needed to respond to the changing demands of the work environment. In this context, expert systems have emerged as a powerful tool to automate and optimize various organizational processes. An expert system is an artificial intelligence application that emulates the judgment and behavior of an expert in a specific field, allowing decision making based on vast accumulated knowledge and predefined rules (Jackson, 1998).

In recent years, the COVID-19 pandemic has accelerated the adoption of digital technologies, including the use of expert systems, in personnel training. The need for rapid and efficient adaptation to changes in the work environment has highlighted the importance of these tools. According to ECLAC and UNESCO (2020), educational institutions and organizations have had to reevaluate and adapt their training strategies to ensure continuity and effectiveness of learning in a context of social distancing and remote work. In addition, recent research has shown that the implementation of expert systems in knowledge management and training can result in a significant improvement in the operational efficiency and quality of training processes.

The integration of artificial intelligence in training has proven to be especially useful in industrial and service environments. A study by Montoya and Valencia (2020) highlights how artificial intelligence can increase efficiency and productivity in auditing processes, which are also applicable to training, optimizing time management and reducing human errors. These systems not only automate repetitive tasks, but also provide personalized recommendations based on the analysis of large volumes of data.

On the other hand, the use of expert systems in personnel training has been highlighted in several systematic reviews of recent literature. Artificial intelligence techniques allow the creation of more adaptive and personalized training programs, improving continuous learning and adaptation to new technologies and methodologies. The review by Montoya and Valencia (2020) also highlights the benefits of these technologies in reducing long-term costs and improving accuracy in assessing training needs and staff performance.

In Ecuador, modernization of the public sector has been a priority in recent years. Public institutions seek to improve their efficiency and effectiveness through the implementation of new technologies. Staff training in these institutions is crucial to ensure that employees can adapt to new tools and working methods. However, the planning and management of training programs often face significant challenges due to lack of resources and the need for specialized personnel (Méndez and Álvarez, 2004).

The adoption of advanced technologies in Ecuador has found support in government initiatives and international collaborations. A study by Gómez and Ruiz (2021) reveals that the integration of artificial intelligence systems in training programs has allowed several Ecuadorian public institutions to improve the efficiency of their administrative and operational processes. This is especially relevant in the context of the pandemic, where the need for remote and adaptive training has increased considerably.

Ecuador's National Innovation Strategy has emphasized the role of emerging technologies in driving economic and social development. According to the Ministry of Telecommunications and Information Society (MINTEL, 2021), the implementation of expert systems and other artificial intelligence technologies has been identified as a priority to improve the education and training of personnel in the public sector. This includes the development of digital and advanced technical competencies that are essential for the efficient management of public services.

In the province and city of Esmeraldas, public institutions face significant challenges due to the restricted availability of trained personnel and limited financial resources. Currently, training is carried out manually by the human talent department, without the use of advanced technologies, which, although functional, is neither efficient nor effective enough to address the growing demands for staff training and development. This manual approach, used in most public institutions, does not take advantage of the benefits that modern technologies can offer.

However, large national institutions such as FLOPEC, PETROECUADOR and TERMOESMERALDAS have implemented advanced training management systems, which has significantly improved their operational efficiency and employee development. These organizations use Learning Management Systems (LMS) and other advanced tools to centralize training, track employee progress, and automate many of the administrative tasks related to training (Paradiso Solutions, 2023; Arlo, 2024). The implementation of such systems in public institutions in Esmeraldas could optimize existing manual processes, providing a systematic and efficient solution to identify training needs, plan appropriate programs, and manage the execution of these programs more effectively.

For an expert system to be effective in this context, it is crucial that there is first a functional manual system that can be improved and automated. The transition from a manual to an automated system would not only optimize the use of available resources, but also improve performance and staff satisfaction, contributing to the socio-economic development of the region. This improvement is particularly relevant for public institutions that currently rely on manual methods for training management, establishing a solid foundation on which an effective expert system can be built.

Similarly, in a recent study conducted by the Luis Vargas Torres Technical University of Esmeraldas, Mendoza-Zambrano and Villafuerte-Holguín (2022) highlight that technological barriers and lack of adequate infrastructure are significant challenges to staff training in the region. The research suggests that the implementation of expert systems could be a viable solution to overcome these barriers, allowing for more accessible and personalized training for public sector employees.

In addition, collaboration with academic institutions and international organizations has been fundamental to advance the implementation of advanced technologies in Esmeraldas. According to a report by the Decentralized Autonomous Government of Esmeraldas (2024), strategic alliances have been established with universities and non-governmental organizations to develop training programs that incorporate expert systems and other artificial intelligence technologies. These efforts seek not only to improve the competencies of current personnel, but also to prepare the next generation of public servants to face the challenges of the future.

From the above, the need to incorporate information technologies, specifically expert systems, in the management of personnel training in public institutions is evident, this according to previous research, where expert systems have proven to be effective in various fields, including production planning and knowledge management (Alvarez et al., 2010). The application of an expert system in the planning and management of training in Esmeraldas could offer significant benefits, such as reducing the time and costs associated with these processes, and improving the accuracy and relevance of the trainings offered (Loza, 2017).

With all this, the following research questions arise: How can the implementation of an expert system improve the planning and management of personnel training in public institutions in the city of Esmeraldas, and what knowledge representation techniques (such as semantic networks and frameworks) are most effective for modeling competencies and training programs in an expert system designed for public institutions

For this purpose, it has been proposed to analyze and systematize the existing information on expert systems for the planning and management of personnel training in public institutions, focusing on their application and effectiveness in improving the management of human talent, following specifically the aspects related to the review and sintering of the existing literature on the training needs of personnel in public institutions, to evaluate the knowledge representation techniques used in expert systems, where the inclusion of explanation modules in expert systems is examined, to analyze the impact of expert systems in the optimization of resources and the improvement of personnel performance, all this with the intention of proposing a theoretical framework for the development of an expert system in the planning and management of personnel training in public institutions. In this way, these approaches are oriented to establish a solid base for the future development of an expert system, considering all the necessary phases for its effective implementation, but without proceeding to the creation of the system at this initial stage.

As technology has been evolving over the years, concepts and definitions have also evolved in this area, where an expert system is understood as an artificial intelligence application designed to emulate the judgment and behavior of a human expert in a specific field, as these systems use a knowledge base and an inference engine to solve complex problems that normally require significant human expertise. Expert systems store data and knowledge, draw logical conclusions, and can explain decisions made, providing solutions or alternatives for specific problems (Harmon & King, 1988).

Similarly, according to Puri and Skillsoff (2018), "expert systems are computational materials that represent the behavior, skill, understanding, and practice of the human expert, which encompasses a specific domain" (Puri & Skillsoff, 2018, p. 235). While, Montoya and Valencia (2020), state that "expert systems are computational systems designed to simulate the decision-making process of a human expert, applying a structured set of knowledge and rules to solve specific problems in various domains" (Montoya & Valencia, 2020, p. 214). Furthermore Puri and Skillsoff (2018) define an expert system as:

An advanced computer system that integrates the knowledge and reasoning techniques of human experts to provide recommendations, diagnoses, or solutions to specific problems in specialized areas. These systems are capable of handling large volumes of information and applying complex rules to emulate expert critical thinking (Puri & Skillsoff, 2018, p. 235).

The knowledge base of an expert system is the central component that stores the specialized knowledge and rules needed to solve problems in a specific domain. This knowledge may include facts, heuristics and relationships between data that have been obtained from human experts. According to Hernandez and Duque, (2020) , "the knowledge base is essentially a set of organized data that represents the accumulated wisdom in a particular field" (p. 234). This base can be updated and expanded as new information is acquired, allowing the system to improve its accuracy and usefulness over time.

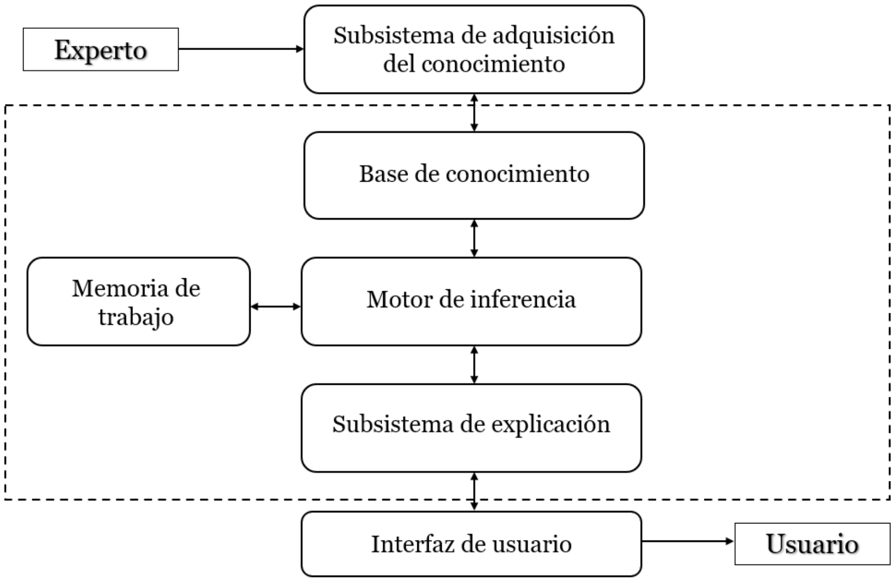
The inference engine is the component of the expert system that applies the rules stored in the knowledge base to deduce new information or make decisions. It works through logic and reasoning techniques, comparing the current data with the established rules to generate conclusions. According to Montoya and Valencia (2020), "the inference engine acts as the brain of the expert system, evaluating and applying rules to produce answers or solutions based on existing knowledge" (p. 215). This process allows the system to mimic the thought process of a human expert.

The explanation module in an expert system is the component that provides the user with the justification of the decisions or recommendations made by the system. This module is crucial for the transparency and acceptance of the system, since it allows understanding how a specific conclusion was reached. According to Alvarez et al. (2010), "the explanation module helps users to trust the system by showing the logic and rules applied in each case" (p. 128). This is especially important in contexts where decisions have a significant impact and require high reliability.

The working memory is the temporary storage area where intermediate data and partial results generated during the inference process are stored. It acts as a workspace where the inference engine can manipulate information before reaching a final conclusion. According to Hernandez and Valencia (2020) , "the working memory is essential to handle the complexity of reasoning processes, allowing the system to hold and process multiple pieces of information simultaneously" (p. 215). This facilitates the management of complex and dynamic problems.

The user interface is the component of the expert system that allows interaction between the user and the system. This interface must be intuitive and user-friendly, allowing users to enter data, formulate queries and receive answers in a clear and understandable manner. Montoya and Valencia (2020) point out that "a well-designed interface is crucial for the usability of the expert system, as it facilitates data entry and the interpretation of the results provided by the system" (p. 216). An effective interface improves the accessibility and efficiency of the system.

Figure 1. Structure of an expert system



Note: (Álvarez et al., 2011).

The figure presents the basic structure of an expert system, which consists of several interconnected components. First, the human expert provides the initial knowledge, which is captured through the knowledge acquisition subsystem, this knowledge is stored in the knowledge base, which contains data, rules and heuristics necessary for decision making. The inference engine is responsible for applying these rules to the data present in the knowledge base and working memory to derive conclusions or solutions.

The explanation subsystem is crucial to provide transparency, explaining to the user the reasons behind each decision or recommendation made by the system; in this way, the user interface allows interaction between the system and the end user, facilitating the input of data and the reception of results. This structure ensures that the expert system can emulate the human reasoning process, providing accurate and justified solutions to complex problems.

Expert systems have several distinctive characteristics that make them valuable in solving complex problems. First, their ability to handle and apply large volumes of specialized knowledge makes them ideal for tasks that require high expertise. According to Hernandez and Valencia (2020) , "these systems can process information faster and more accurately than humans, significantly reducing the time needed to make informed decisions" (p. 45). In addition, expert systems are able to learn and adapt, continuously improving as they are fed with new data.

Another important characteristic is the ability of expert systems to explain their decisions, which is crucial for trust and acceptance by users. Montoya and Valencia (2020) emphasize that "transparency and the ability to explain allow users to understand how and why a decision was made, increasing confidence in the accuracy and reliability of the system" (p. 218). In addition, expert systems are highly consistent in the application of their rules, eliminating the variability that can arise from human judgment in similar situations.

There are several types of expert systems, each designed to meet different needs and applications. Rule-based systems are the most common, using a series of "if-then" to model knowledge and make decisions. According to Puri and Skillsoff (2018), "these systems are effective for problems where knowledge can be clearly defined in terms of rules" (p. 240). Another important type is the case-based system, which solves new problems by comparing them to past experiences stored in a database of cases.

There are also hybrid expert systems that combine multiple techniques, such as rules and neural networks, to improve accuracy and flexibility. These systems can be better adapted to complex and dynamic problems. Alvarez Pomar et al. (2010) mention that "hybrid systems are particularly useful in areas where data are incomplete or uncertain, as they can use multiple approaches to arrive at a solution" (p. 130). In addition, distributed expert systems use intelligent agents that collaborate to solve problems, which is useful in environments where information is distributed among several sources.

Table 1. *Types of Expert Systems and their Application.*

Expert System Type	Description	Application
Based on Rules	It uses a series of "if-then" to model knowledge and make decisions.	Medical diagnostics, technical assistance, system configuration.
Case Based	Solves problems by comparing new cases with	Legal assistance, dispute resolution,

	past experiences stored in a case database.	engineering technical diagnostics.
Based on Neural Networks	Emulates the structure and functioning of the human brain to recognize patterns and learn from data.	Voice and image recognition, financial forecasting, machinery failure diagnosis.
Hybrid	It combines multiple techniques, such as rules and neural networks, to improve accuracy and flexibility.	Supply chain management, strategic planning, financial risk analysis.
Based on Models	Uses mathematical models and simulations to represent complex systems and predict their behavior.	Simulation of industrial processes, prediction of market behavior, resource planning.
Based on Fuzzy Logic	It handles imprecise or incomplete information through the application of fuzzy rules that allow degrees of truth between 0 and 1.	Control of robotic systems, uncertainty management in medicine, optimization of manufacturing processes.
Multiagent	It uses several agents that collaborate with each other to solve problems, each one specialized in a specific task.	Telecommunications network management, rescue team coordination, traffic simulations.
Ontology-based	Uses formal representations of a set of concepts within a domain and the relationships between them to facilitate reasoning.	Knowledge management, integration of heterogeneous information, decision support in biomedicine.
Based on Genetic Algorithms	Apply evolutionary techniques such as selection, crossover and mutation to optimize solutions to complex problems.	Optimization of logistic routes, design of electronic circuits, adjustment of parameters in artificial intelligence models.
Based on Propositional Logic	It uses a formal logical structure based on propositions and logical	Software verification, scientific hypothesis

	operators to deduce conclusions from known premises.	testing, security system design.

Note: Own elaboration

The table presented on the types of expert systems and their applications provides a comprehensive overview of the various ways in which these technologies can be implemented in different fields. This analysis is essential for research, as it allows the specific capabilities of each type of expert system to be identified and compared. By better understanding these applications, more effective strategies can be formulated for the development of an expert system in human talent management, optimizing the training and personnel management processes in public institutions in Esmeraldas. In addition, this classification helps to highlight the versatility and adaptability of expert systems, underlining their potential to improve decision making and operational efficiency in various contexts.

Methodology

This research was developed through a documentary review, focusing on the collection and analysis of existing information on expert systems and their application in human talent management. Documentary review is a methodology that allows analyzing and synthesizing the findings of previous studies to build a robust theoretical framework and update knowledge on a specific topic (Bowen, 2009).

To ensure the validity and quality of the information collected, recognized academic and scientific sources will be selected, these included peer-reviewed journal articles, specialized books, doctoral theses and technical reports published between the years 2018 and 2023. Academic databases such as Scopus, IEEE Xplore, ScienceDirect and Google Scholar were the main search sources. The selection focused on papers that addressed the following topics:

- Definitions and structures of expert systems.
- Characteristics and types of expert systems.
- Applications of expert systems in human talent management.

- Case studies and analysis of implementation in similar contexts.
- Expert systems applied to human talent

Documentary review is a widely validated and recognized methodology in academic research for its ability to provide a comprehensive and updated view of a topic. According to Bowen (2009), desk review is particularly useful for exploring historical and current contexts, identifying relationships between variables and establishing a solid theoretical framework. In addition, Hart (1998) and Kitchenham (2004) emphasize the importance of a systematic approach to document review to ensure the quality and reliability of the results.

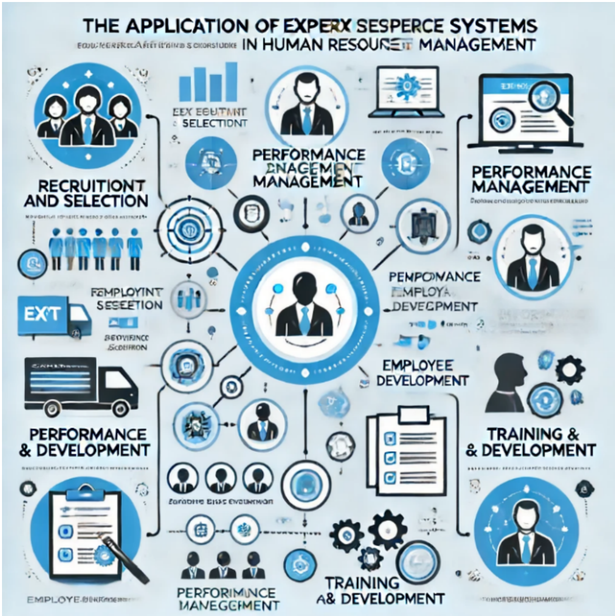
Results

Application of expert systems in Human Talent Administration

Expert systems have a wide range of applications in human talent management, where they can significantly improve the efficiency and effectiveness of various processes. For example, they can be used for recruitment and selection of personnel, helping to identify candidates that best fit the needs of the organization. Montoya and Valencia (2020) point out that "expert systems can quickly evaluate large volumes of resumes and perform comparative analysis based on predefined criteria" (p. 220). This not only saves time, but also improves accuracy in candidate selection.

Another important application is in performance management and personnel development. Expert systems can identify training and development needs, recommending specific programs based on employees' skills and competencies. According to Alvarez Pomar et al. (2010), "these systems can create customized development plans that align individual objectives with organizational goals" (p. 132). In addition, they can monitor and evaluate employee performance, providing continuous feedback and facilitating informed decisions about promotions and salary increases.

Figure 2. *Infographics - Expert systems applied to human talent*



Note: Own elaboration

The infographic presented illustrates how expert systems can be applied to various aspects of human talent management, providing a clear and concise view of their benefits and applications in this field. The following is a description of each of the sections included in the infographic:

Recruitment and selection

This section shows how expert systems can be used to optimize recruitment and selection processes, where they quickly evaluate large volumes of resumes and perform comparative analysis based on predefined criteria, identifying the candidates that best fit the organization's needs. This not only saves time, but also improves the accuracy of candidate selection.

Performance management

Performance management is another area where expert systems can have a significant impact; these systems can monitor and evaluate employee performance on an ongoing basis, providing real-time feedback and facilitating informed decisions on promotions and salary increases. By applying established rules and criteria, expert systems ensure a fair and consistent evaluation of staff performance.

Training and development

The training and development section highlights how expert systems can identify training needs and recommend specific programs based on employees' skills and competencies. These systems can create customized development plans that align individual objectives with organizational goals, ensuring that employees receive the right training for their professional growth.

Employee retention

Employee retention is crucial to the long-term success of any organization, so expert systems can analyze employee satisfaction and performance data to identify factors that contribute to retention or attrition. With this information, organizations can implement effective strategies to improve satisfaction and retain talent, reducing the costs associated with employee turnover.

In this regard, the infographic highlights how expert systems can transform human talent management by automating and optimizing key processes such as recruitment, performance management, training and employee retention. By integrating these technologies, organizations can improve efficiency, accuracy and overall employee satisfaction, thus contributing to their long-term success and competitiveness.

Expert systems in public sector companies in Ecuador

In Ecuador, Expert Systems (ES) and even Information Technology Systems have been implemented in various government institutions to improve the effectiveness and efficiency of administrative processes. A notable example is the Port Authority of Puerto Bolivar, where the implementation of these systems has demonstrated several key benefits, including alignment with public administration objectives, automation of administrative tasks, clear segregation of roles and responsibilities, and greater transparency in information management. However, the need to improve user manuals and training processes to maximize the effective use of these systems has been identified (Armijos-Neira et al., 2018).

Expert systems also play a crucial role in the public procurement process, with teams of experts, such as those at GovTec, providing advice and training to both public and private entities throughout the procurement cycle. This support demonstrates how technology and advanced systems can positively influence public management and improve efficiency in procurement processes (GovTec, 2023).

Similarly, the Office of the Comptroller General of Ecuador conducts performance audits of public enterprises, evaluating their performance against predetermined indicators. These audits not only measure performance, but also contribute to the continuous improvement of administrative practices, strengthening transparency and efficiency in public management (Zambrano, 2022).

For this reason, the implementation of expert systems in the Ecuadorian public sector has resulted in significant improvements in administration and decision making. However, there are always opportunities to further improve these systems, especially in terms of training and support for users, which is crucial to take full advantage of their benefits.

In Ecuador, several intelligent systems have been implemented in various contexts. The Universidad Bolivariana del Ecuador UBE offers a specialization in Intelligent Systems Engineering, where students develop solutions based on mathematical sciences, computer science and artificial intelligence (UBE, 2023). However, artificial intelligence also plays an important role in sustainable development, contributing to the protection of natural resources and improving the quality of life of citizens; in addition, smart cities and smart buildings are under evaluation and development, using advanced technology to create more sustainable environments and improve social harmony and life satisfaction (El Universo, 2023).

THEORETICAL AND PRACTICAL FRAME OF REFERENCE FOR THE PHASES OF AN EXPERT SYSTEM FOR THE PLANNING AND MANAGEMENT OF PERSONNEL TRAINING IN PUBLIC INSTITUTIONS IN THE CITY OF ESMERALDAS.

The development of an expert system for the planning and management of personnel training in public institutions in the city of Esmeraldas represents a significant advance in the modernization and optimization of human resources processes. In an environment where efficiency and effectiveness are crucial for the fulfillment of organizational objectives, the implementation of advanced technologies such as expert systems can radically transform the way in which personnel competencies and skills are managed.

This framework focuses on describing the different phases of an expert system, meticulously addressing each one of them from knowledge acquisition, choice of the development tool, prototype construction and validation. Through a systematic approach and based on scientific knowledge through the review of the literature on expert systems, we seek to provide a robust and efficient solution that improves the training of personnel and, ultimately, the performance of public institutions in the city of Esmeraldas, Ecuador

Phase 1: Knowledge Acquisition

Knowledge acquisition is the first crucial phase in the development of an expert system; this process involves gathering relevant information through various sources, such as interviews with human resources experts, analysis of existing documentation, questionnaires and surveys of employees and supervisors, and direct observation of required competencies and training needs. According to Alvarez Pomar et al. (2010), this phase must be carefully structured to ensure the capture of accurate and complete knowledge needed to build the knowledge base of the system. Specific steps in this phase include:

1. **Interviews with experts:** Conduct structured and unstructured interviews with human resources and training experts within public institutions in Esmeraldas. These experts will provide valuable information on competencies needed, current training processes, and areas for improvement.
2. **Documentation analysis:** Review existing documentation, including training manuals, job descriptions, performance appraisals, and human resources policies. This documentation will help to understand training needs and organizational objectives.
3. **Questionnaires and surveys:** Develop and distribute questionnaires and surveys to employees and supervisors to identify areas where training needs are perceived to be greatest and to evaluate the effectiveness of current programs.

4. **Direct observation:** Conduct observations in the workplace to better understand the tasks and competencies required for different roles within the institutions.

Phase 2: Knowledge representation and choice of development tool

In this phase, the information collected is organized using knowledge representation techniques, such as semantic networks and frames. Semantic networks allow visualizing the relationships between different concepts and competencies, while frames provide a detailed structure to represent specific situations and their solutions. According to Curiel Robles (2013), the correct structuring of knowledge is essential for the effective functioning of the expert system, as it facilitates the process of inference and decision making. From the perspective of this research, the following tools can be evaluated:

1. **CLIPS (C Language Integrated Production System):** It is a highly efficient and flexible tool for the development of rule-based systems. CLIPS is suitable for rapid prototyping and is widely used in industrial applications.
2. **Prolog:** A logic programming language that is ideal for systems that require strong symbolic reasoning and knowledge manipulation capabilities. Prolog is powerful for implementing complex logic and data structures.
3. **Jess (Java Expert System Shell):** Based on Java, Jess allows easy integration with other Java applications and is suitable for expert systems that need to be part of a larger infrastructure.
4. **Drools:** A business rules engine written in Java that is well suited for enterprise applications. Drools allows integration with existing enterprise systems and provides a robust environment for developing rule-based systems.

However, with the current advances in programming, it is evident the high potential of a tool such as Python, which is described below:

Python is a highly suitable tool for expert system development due to its flexibility, extensive library ecosystem and ease of use. Python's simple and clear syntax facilitates the development and maintenance of complex systems, while its extensive library of modules provides solutions for a variety of specific needs in the implementation of expert systems. Libraries such as *experta* and *Pyke* offer rule-based inference engines and support for logic programming, enabling the creation of systems that emulate the decision-making process of a human expert. In addition, Python's interoperability allows easy integration with other systems and technologies, which is beneficial for expert systems that need to interface with databases, web interfaces or other business applications.

In this sense, to illustrate how Python can be used in the development of an expert system, let us consider a simplified example using the *expert* library. In this example, an expert system is defined that recommends training programs for employees based on their performance and skills; the inference engine applies predefined rules to generate specific recommendations, demonstrating how expert knowledge can be captured and used efficiently. This ability of Python to handle complex logic and process data effectively makes it an ideal choice for the development of a prototype expert system for planning and managing staff training in public institutions in the city of Esmeraldas. The choice of Python not only facilitates the fast and effective implementation of expert systems, but also guarantees a high degree of flexibility and scalability in their development and use.

Phase 3: Expert System Design

The design of the expert system is a crucial stage that involves the definition of the architecture and the main components of the system. This phase ensures that the knowledge acquired and represented can be used efficiently and effectively for the planning and management of personnel training in public institutions in the city of Esmeraldas.

System Architecture

According to research conducted by Torres and Córdova (2023), the architecture of the expert system is composed of several interrelated components:

1. **Knowledge base:** This is the backbone of the expert system, where all the information gathered from experts and relevant documents is stored, including data on competencies, training needs, and training programs. According to Tabares et al. (2013), the knowledge base should be structured in a way that facilitates the efficient storage and retrieval of information in public sector companies.

2. **Inference engine:** It is the component that processes the information of the knowledge base to generate conclusions and recommendations. It uses rules and algorithms to analyze the data and provide solutions to the problems posed. Curiel Robles (2013) stresses that the inference engine must be able to handle various reasoning techniques, including fuzzy logic and Bayesian networks, to adapt to different scenarios and types of data.
3. **Explanation module:** This module is crucial for the transparency and acceptance of the system, as it allows explaining the recommendations and decisions of the expert system, providing detailed justifications based on the data and rules used, which is fundamental to gain the trust of the users. According to Castillo et al. (2018), an effective explanation module must be able to present the reasons behind each recommendation in a clear and understandable way for non-technical users.
4. **Working memory:** acts as a temporary space where intermediate data and partial results are stored during the inference process. This allows the system to handle multiple cases and scenarios simultaneously, improving its efficiency and responsiveness (Castillo et al., 2018).
5. **User interface:** The user interface should be intuitive and easy to use, allowing users to interact with the system without the need for advanced technical knowledge. It should include tools for data entry, visualization of results, and navigation through the system's recommendations and explanations. Tabares et al. (2013) emphasize the importance of a well-designed interface to ensure that the system is accessible and useful for all users.

Phase 4: Prototype construction

During the prototype construction phase, a functional version of the expert system is developed based on the previously elaborated design; this involves coding the rules and facts in a suitable programming language, such as Python, and integrating all the system components (Torres and Córdova, 2023). Similarly, the implementation should include exhaustive testing to ensure the functionality and effectiveness of the prototype, following the guidelines of methodologies such as the one proposed by Weiss and

Kulikowski (1984). The following stages are established for the construction of the prototype:

1. **Knowledge modeling:** Using the information gathered in the knowledge acquisition phase, the knowledge base will be structured. This will include the definition of rules, facts and heuristics that the system will use for decision making.
2. **Development of the inference engine:** Implement the inference engine that will process the rules and facts from the knowledge base to generate conclusions and recommendations.
3. **Design of the explanation module:** Create the explanation module that will allow the system to justify its recommendations and decisions, providing transparency and increasing user confidence in the system.
4. **User interface development:** Design a user-friendly and intuitive interface that allows users to easily interact with the system, entering data and receiving recommendations.
5. **Integration and testing:** Integrate all system components and perform extensive testing to ensure that the system functions correctly and meets the specified requirements. Functionality, usability and performance testing will be performed.

Phase 5: Prototype validation

Prototype validation is crucial to ensure that the system meets its objectives and provides value to users, each highlighting that this process includes pilot testing in a controlled environment, evaluation of the results, adjustments and improvements based on the feedback received, and finally, the full implementation of the system in public institutions. According to Méndez Giraldo et al. (2015), this iterative approach to validation ensures that the expert system is continuously refined to improve its accuracy and usefulness, which is why, prototype validation is essential to ensure that the expert system meets its objectives and provides value to users. This phase includes in detail:

1. **Pilot testing:** Implement the prototype in a controlled environment within one or more public institutions in Esmeraldas to evaluate its performance in real situations, with the intention of gathering feedback from users on the usability and effectiveness of the system.

2. **Evaluation of results:** Analyze the results of the pilot tests to identify areas for improvement and adjust the system accordingly, where the accuracy of the recommendations and user satisfaction will be evaluated.
3. **Review and adjustments:** Make adjustments and improvements to the system based on the feedback received and the results of the pilot tests, ensuring that the system is robust, efficient and easy to use.
4. **Documentation and training:** Prepare complete system documentation, including user manuals and maintenance guides, to provide training to administrators and end users to ensure successful implementation and continued use of the system.
5. **Final implementation:** Once validated and adjusted, proceed with the final implementation of the expert system in all public institutions of Esmeraldas participating in the project, ensuring its integration with existing training processes.

The development of a prototype of an expert system oriented to the planning and management of personnel training in public entities in the city of Esmeraldas is an ambitious project that requires a meticulous and systematic approach, which is why, following these described phases, will guarantee that the system will be efficient, effective and capable of significantly improving the management of human talent in the public sector, if implemented in the right way, where commitment, follow-up and control of the processes involved are integrated.

Figure 3. *Prototype Development Phases*

Note: Own elaboration. The figure shows each phase of prototype development (knowledge acquisition, choice of development tool, prototype construction, prototype validation).

In this way, through the use of advanced tools and the application of proven techniques in the field of expert systems, this project aims not only to improve the efficiency and effectiveness of training processes, but also to contribute significantly to the professional development of personnel and the achievement of organizational objectives. The implementation of this expert system will provide a solid foundation for future technological improvements and will serve as a model for other institutions seeking to optimize their human resources. With a clear and detailed approach, this proposal offers a viable path to transform training management in Esmeraldas, ensuring strategic alignment with the needs and expectations of the public environment.

Through the exhaustive evaluation of various knowledge representation techniques, such as semantic networks and frameworks, to determine their effectiveness and applicability in the context of personnel training in public institutions, it became evident that these techniques are essential for structuring and organizing the information that expert systems will use to make informed and accurate decisions.

Thus, semantic networks are used to represent knowledge in the form of graphs, where the nodes represent concepts or entities and the edges represent the relationships between them. This technique allows visualizing and understanding the interconnections between different areas of knowledge, facilitating the identification of key competencies and their relationship with training programs. According to Montoya and Valencia (2020), semantic networks are useful for mapping necessary skills and their interdependencies, allowing for more strategic and coherent planning of training programs (Montoya & Valencia, 2020, p. 215). In the context of personnel training, these networks allow a clear and structured view of the required knowledge, improving the accuracy and relevance of the expert system's recommendations.

On the other hand, frames (also known as schemas or scripts) are data structures that represent concepts as sets of attributes and values, where frames allow capturing knowledge in a more detailed and specific way, including the conditions under which certain rules or facts apply. In personnel training management, frameworks can be used to define competency profiles, describe specific training scenarios and establish criteria for performance evaluation. According to Hernandez and Duque (2020), this technique facilitates the customization of training programs and ensures that the recommendations of the expert system are relevant and contextually appropriate (Hernandez & Duque, 2020, p. 234).

Therefore, both techniques, semantic networks and frameworks, have proven to be effective in knowledge representation for expert systems, whereby semantic networks provide a global and structured view of knowledge, while frameworks offer a level of detail and specificity that is crucial for accurate decision making. The combination of these techniques in the development of an expert system allows taking advantage of their complementary strengths, resulting in a more robust system capable of managing the complexity of the knowledge required for the training of personnel in public institutions. This evaluation has been instrumental in proposing a sound theoretical framework to guide the development of future expert systems in this area.

The implementation of expert systems in the public sector in the province of Esmeraldas should be framed within a broader digital transformation strategy, such as the one established in Ecuador's Digital Transformation Agenda 2022-2025. This agenda promotes the modernization of public services through the use of information and communication technologies (ICT), including the incorporation of expert systems to optimize human talent management. The successful experiences of other large national institutions demonstrate that technology can significantly improve the operational efficiency and quality of public services (MINTEL, 2021).

In addition, digital transformation must go beyond the simple automation of existing processes. To this end, the agenda emphasizes the need to develop digital competencies among public employees, which is crucial to maximize the benefits of expert systems. Ongoing training and technical support are essential to ensure that staff can use these new tools effectively. The combination of a well-designed expert system and a competent workforce will not only optimize available resources, but also improve staff satisfaction and contribute to the socioeconomic development of the region (Gobierno Electrónico del Ecuador, 2024).

Conclusions

Throughout this document review, a wide range of relevant studies and publications addressing different aspects of expert systems and their implementation in the public sector have been compiled, analyzed and synthesized. In addition, a comprehensive literature review was conducted, identifying key studies that describe the critical competencies and skills needed for personnel in public institutions. This review has identified the most effective methodologies for assessing training needs, providing a solid basis for future research and practical developments.

Likewise, the evaluation of various knowledge representation techniques, such as semantic networks and frameworks, has been exhaustive. These techniques have been found to be effective and applicable in the context of staff training in public institutions, providing a clear framework for structuring information and rules within an expert system. In addition, the literature review has demonstrated the importance of explanation modules in expert systems, highlighting their positive impact on system acceptance and effectiveness, and this case study shows that the inclusion of these modules significantly improves transparency and trust in the system.

Therefore, several reports and articles documenting experiences with the implementation of expert systems in public institutions and similar contexts have been analyzed, where the results indicate that expert systems contribute to a significant optimization of resources and a notable improvement in personnel performance, thus validating the effectiveness of these technologies. Thus, based on the literature review and the findings obtained, a robust framework for the development of an expert system has been proposed.

Therefore, the research has succeeded in meeting all the objectives set, providing a detailed and systematic analysis of the existing information on expert systems in the context of personnel training in public institutions. However, there is always room for improvement; therefore, it should be noted that a possible area for improvement could be to conduct additional field studies to complement the documentary review, providing empirical data and practical experiences to validate and adjust the proposed theoretical framework. In addition, future research could focus on the practical implementation and evaluation of the proposed expert system in a real environment to corroborate the theoretical findings.

For this reason, this research has laid a solid foundation for the creation of a theoretical-practical frame of reference for the development of an expert system for the planning and management of personnel training in the public institutions of Esmeraldas provides a solid basis for the development, application and implementation of expert systems for the management of personnel training in the public sector, offering valuable perspectives and guidelines for future technological initiatives in this area.

This systematic approach ensures that the expert system can be developed efficiently and effectively, optimizing existing manual processes and improving staff performance. This framework not only facilitates the transition to an automated system, but also ensures that training is aligned with specific staff development needs, contributing to the socioeconomic development of the region.

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