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A Framework for Strategic Intelligence Systems Applied to Education Management: A Pilot Study in the Community of Madrid

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ABSTRACT The management of educational policies is a complex issue. There are complexities related to the country's organizational system (competencies delegated by different areas in some cases), and to the limited resources in the educational system. In addition, there are many variables that need to be managed: ICT resources, special educational needs, human resources available, the socioeconomic characteristics of each district, etc. These types of issues are similar to those dealt with by strategic intelligence management. In this field, commonly included within innovation management, methodological frameworks are established that enable collection and consolidation of data from various sources and their subsequent exploitation to enhance decision-making based on previously identified needs. This article presents the details of a pilot plan aimed at implementing a framework for strategic intelligence management in the educational management system of the Community of Madrid (Spain). These intelligence systems are difficult to deploy in educational organizations that have highly fragmented management as in the case described in our pilot plan, although their implementation leads to more correct and agile decision-makings. This paper describes the steps carried out to define the new management platform requirements, its technical implementation issues, and the validation results that demonstrate its functional validity and acceptance by end-users participating in the described pilot project.

INDEX TERMS Education management, strategic intelligence management, data warehouse, OLAP cubes.

I. INTRODUCTION

Educational planning is a fundamental matter for of any society. With planning, issues such as the creation or transformation of educational centers, the hiring of teachers or specialized personnel, the allocation of material resources, etc. are resolved. To guarantee proper planning, efficient and accurate analysis that facilitates efficient decision-making is necessary. However, this analysis can be a complicated matter for some educational systems.

The educational system of the Community of Madrid encompasses 1.2 million students and 100,000 teachers in 3,650 educational institutions. Proper planning enables allocation of resources to meet existing social needs. In the case of the Madrid educational system, besides to tackling the difficulties inherent in an analysis involving a multitude of variables, we must add the fragmentation of its management model. There are several autonomous management units to deal with different aspects: educational management, human resources, special needs, learning outcomes, etc. Each management unit has its own governance and information systems, which means that the interaction and coordination between them can give rise to flaws and shortcomings.

Modern knowledge management systems have proven their usefulness in bringing cohesion to organizations that have a high of fragmentation, as is the case of the Community of Madrid. In fact, some types of knowledge management systems, such as strategic intelligence, have demonstrated their ability to measure the environment of the organization

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in a flexible way and provide value in the decision-making process.

A. OBJECTIVES

The main objective of this article is to present the implementation process and results of a support platform for non-university educational management for the Community of Madrid (Spain) applying a strategic intelligence system framework. The framework provides guidelines on implementation to promote cohesion, flexibility of analysis and understanding of the actual state of the system.

Implementing strategic intelligence management systems requires organizational changes within the entity where they are established. The platform is a support element that together with other technological and material elements helps organization members comply with established policies. Since the organization can be very open and widely distributed, as is the case of the Community of Madrid, this platform becomes a fundamental element for the proper functioning of the entire system. Therefore, its analysis, design and implementation must be completely aligned with the processes and information flows defined in the management system from the beginning, while also promoting acceptance by end users.

At a functional level, in addition to enabling integration of different sources of information into the organization, the platform must encompass two specific types of analyses:

- Dynamic analysis. A user-configurable dashboard will answer the most frequent questions regarding the educational planning for an academic year in an efficient and reliable way. This analysis is necessary to decide the planning actions for the following year. The scorecard can be adapted to the needs of each technician (to the decisions they must make) and is updated in real time with the existing information in the different information systems of the Community of Madrid.
- Predictive analysis. In addition to analyzing the real state of the educational system, it is of interest to incorporate the possibility of making predictions about certain key variables. Although the proposed platform will not perform this type of analysis, it is prepared to provide support to facilitate the process.

B. SCOPE

The complete implementation of a strategic intelligence system requires, as mentioned above, a thorough analysis of the organization, including its real needs, new processes and resources that support it. Our article focuses exclusively on the management platform and not on the rest of the changes that may occur within the educational management area of the Community of Madrid. It is important to note that, in any case, the platform is a reflection of most of the processes that must be carried out when collecting information from various sources and making decisions.

C. STRUCTURE OF THIS ARTICLE

First, the background of this study is presented (section II). It includes relevant concepts and research studies related to the main technologies and approaches referenced throughout the paper. Section III presents some related work with different approaches from other authors. Section IV details the methodology defined in the pilot plan. Section V presents the requirements gathering stage, which are designed and implemented as shown in Section VI and Section VII. The results obtained are described in Section VIII and the paper's conclusions are found in Section IX.

II. BACKGROUND

This section presents two relevant concepts to understand the approach presented in the paper: strategic intelligence and knowledge management in business intelligence.

A. STRATEGIC INTELLIGENCE

In today's changing and complex world, the strategic management of information takes on an increasingly relevant role in the day-to-day life of organizations, helping them to not only maintain and subsist, but also to innovate so that they can remain competitive in their respective areas and sectors. Decision makers, both in the public and private sector, concerned about the many different technological options available, as well as competition, strategies, regulations and policies, require high quality information from all these and other dimensions in order to carry out, in a reasoned manner, the complex process of decision-making [1], [16]. In this sense, strategic intelligence is an enormously valuable tool, whose main objective is to provide the right people at the right time with the right information so that they can make informed decisions about the future of their organizations.

In the literature, strategic intelligence is described as the collection, processing, analysis and dissemination of information that is highly relevant at the strategic level [15], being a tool commonly used in strategic planning, national security and military intelligence contexts, but also in strategic decision-making in large organizations.

Within strategic intelligence, technological intelligence today has become of great importance and more in contexts such as the current ones of open innovation [17]. So much so, that technology management is playing a vital role in the competitiveness of organizations. The inability to detect in time relevant changes in key technologies used, or even the appearance of disruptive technologies that could replace current ones in a near future, could imply the obsolescence of organization products, processes or services. A direct consequence is the loss of markets, and even the very survival of an organization could be at stake. This is especially relevant in domains such as ICT, where the pace of technological evolution is extremely rapid and the life cycle of products and services is becoming increasingly shorter. Organizations around the world must anticipate these changes and make the appropriate decisions to update, adopt or replace the technologies used in their processes, products or services to be competitive not only with other organizations, but also with their customers and / or users.

In the field of technology, especially in the high-tech sectors [18], industrial competitiveness is closely linked to the knowledge of technological exploitation within the company. The analysis of the short, medium- and long-term technological consequences, known globally as technological intelligence, is a key element for ensuring the future competitiveness of these organizations. Some of the most interesting technological domains correspond to the so-called enabling technologies (as is the case of ICTs, which usually are of a transversal nature), while others are more specific to the product or services created and used by organizations in a specific sector [4].

The strategic intelligence activity depends on deep analysis of the collected information, such as technological trends, but also on the objectives and limitations of the organization (which differentiates it from a simple monitoring process). The same trends could lead to a series of different responses according to the organizational context of the entity. To facilitate decisions, organizations have introduced technology watch processes. Technology watch is a component of the broader knowledge management processes within the organization, integrated into the broader concept of strategic intelligence, a concept that combines technology watch, competitive intelligence and strategic planning activities.

Technology watch is defined by the UNE 166006:2011 Standard as "*an organized, selective and systematic process to capture information from outside and from the organization itself about science and technology, select it, analyze it, disseminate it and communicate it, to convert it into knowledge in order to make decisions with less risk and be able to anticipate changes*". As for competitive intelligence, it is defined in the same standard as "*an ethical and systematic process of collecting and analyzing information about the business environment, competitors and the organization itself, and communicating its meaning and implications for decision- making*. Finally, strategic planning can be defined as the process at the strategic level that enables planning of the organization's objectives and its future actions, materialized through strategies, tactics and actions in a defined time[1], based on the knowledge obtained in the process of strategic intelligence. This knowledge must be managed so that it can be used by the organization whenever it is required. In this sense, the set of business intelligence technologies facilitates the collection, analysis and management of this valuable knowledge [5].

B. KNOWLEDGE MANAGEMENT AND BUSINESS INTELLIGENCE

Knowledge is much more than simple information: it provides added value to the products and services of any organization, thus becoming an essential element for addressing complex problems in increasingly dynamic and globalized contexts. Knowledge is an organization's greatest asset, from which outstanding performance can be obtained when properly managed. "*The competitive advantage of a company depends more than anything else on its knowledge: on what it knows, how it uses what it knows and how quickly it can learn something new*" [6].

At a conceptual level, there is often some confusion when distinguishing between the concepts of knowledge management and business intelligence. While it is true that both concepts seek to achieve greater knowledge and understanding of the organization and its business area (through the integration, capture, organization, access and use of knowledge), knowledge management has a much broader profile, while business intelligence offers a more structured approach to decision-making, with a focus on specific problems and objectives [19].

Gartner defines business intelligence as a set of all technologies that collect and analyze data to improve decision-making. Business intelligence deals with decision-making using, as main elements, data storage and online analytical processing techniques (OLAP) [5]. Specifically, according to the definition offered by Gartner [7], "*Business Intelligence services are offered to design, develop and implement business processes and integrate, support and manage applications and related technology platforms*." Business intelligence technologies range from simple ad hoc consultations to reporting, decision support systems (DSS), GDSS, balanced scorecards (Executive Information System or EIS), online analysis processes (Online Analytical Process or OLAP), analysis techniques, data warehouses and the corporate information store. Large data warehouses can contain tens of terabytes of data, while smaller, problem-specific data warehouses often contain 10 to 100 gigabytes [8].

One of the main benefits of business intelligence is that it allows IT infrastructure costs to be lowered by eliminating redundant data extraction processes and duplicate data hosted in Data Marts (a special version of the data warehouse or Data Warehouse, normally consulted using OLAP tools), which are independent throughout the organization.

III. RELATED WORK

Educational institutions frequently use data mining methods, with the intention of examining the collected data, as well as extracting information and conclusions that help to make decisions regarding students [20]–[23]. Nevertheless, these techniques are also very useful in the management of educational institutions for improving their efficiency [10], [24].

The data entry process, known as data warehousing, involves moving data from a set of source systems to an integrated data warehouse. The data entry process is probably the most challenging aspect of business intelligence (poor data quality in the source systems or data policies), as it consumes approximately 80 percent of time and effort, usually generating more than 50 percent of a project's unexpected costs [9]. Despite the widespread use of data warehousing in companies, data warehouse adoption in education is very infrequent compared to other sectors [25]. However, more and more application cases can be found.

In the study carried out in [10], where empirical work on the application of business intelligence in education was analyzed, for the period between 2008 and 2018, a high degree of interest in educational data extraction and analysis of student learning was detected. Less interest was observed in data storage infrastructure, which allows quality results to be obtained in business intelligence and data analysis. Barriers to their adoption by educational institutions can be summarized as: complex implementation processes, uncertain requirements, lack of a maintenance plan, guidance, or staff experience, the decentralized nature of data, resistance from data owners, and finally, vital in the educational context, financial costs.

Regarding the methodology used for the data warehouse design in education, Kimball's approach is the one most often applied, followed by Bill Inmon's methodology [10]. Specifically, in Inmon's methodology a top-down approach is proposed, which provides a very consistent dimensional view of the data in the data marts, because all data marts are loaded from the central data warehouse (which is a very suitable approach to support change management, since it sees the organization as a whole). On the other hand, when time and budget are limited, and data marts are developed gradually, the methodology proposed by Kimbal, of a bottom-up approach, is the most used.

In more recent studies, the use of these techniques is applied to other areas and decision-making processes. In [26] the authors show the application of a storage system for enrollment management in higher education institutions in Indonesia. In this case, the aim was the provision to significant information to managers for decision-making based on the tuition fees received. In the case of Indonesia, the disparity in the level of tuition fees, the independence of the current system and the consumption of time in reporting cause the lack of credibility of the student income data that affects the sustainability of educational institutions in this country. The development of the data warehouse system provided a way out for a single source of truth by integrating data from multiple sources. As a business intelligence approach, the data warehouse system allowed the aggregation of information at the levels desired and required by users. Thanks to the performance of a predefined OLAP analysis, the processing speed was improved, allowing obtaining a secure operational database, in the retrieval of electronic historical data.

IV. METHODOLOGY

Given the complexity of the systems designed and the number of agents involved, it is necessary to systematize the development of the educational management platform to ensure proper implementation. This section presents the methodology used. Likewise, since the platform enables predictive analysis based on data mining, the data mining methodology used will also be described in order to identify requirements that must be taken into account during development.

A. EDUCATION MANAGEMENT PLATFORM

The construction of the platform is aligned with the methodological framework for the construction of surveillance and strategic intelligence systems [11]. The following describes the phases for platform construction:

- Phase 1: Analysis of the current model. The current processes to be replaced or complemented by the new model must be studied. Specifically, these are the organizational structure, the process of obtaining data and the decision making by those responsible.
- Phase 2: Detection of needs. From the information obtained in phase 1, working sessions are created with all the technicians and functional units of the Community of Madrid educational system. The information obtained focuses on what type of data each profile requires to carry out their task, how they access the data and how the data is integrated with the self-made data. In addition, examples of common applications based on Big Data techniques are also shown so that they can assess the need for dynamic analysis, report generation and dashboard solutions.
- Phase 3: Based on the results obtained in the previous phase, existing technological tools are analyzed in order to carry out correct implementation.
- Phase 4: Implementation of the platform. After the analysis phases are completed, design and implementation of the solution begins.
- Phase 5: A functional validation of the system is carried out to guarantee the accuracy of the data.

The first three phases are considered analysis phases, while the fourth and fifth are related to implementation and validation.

All the phases take into account the characteristics of the Community of Madrid educational system and the guiding principles for development of strategic intelligence systems.

B. DATA MINING METHOD

The predictive analysis associated with the platform is carried out in the form of data mining projects. In these projects, detailed explorations of existing data can be done, obtaining a better understanding of what is happening. It is also possible to make predictions using the appropriate techniques.

There is a high degree of freedom in carrying out data mining projects. To ensure integration with the education management platform, a standard methodology has been defined: CRISP-DM [12]. This methodology clearly defines each of the actions to carry out the project, without forfeiting the flexibility required in a technologically heterogeneous environment. This allows data mining projects to be developed that are adapted to the platform.

V. ANALYSIS OF THE PLATFORM

The analysis corresponds to phases 1, 2 and 3 of the method defined for construction of the platform.

A. PHASE 1: CURRENT MODEL

The figure bellow shows an organizational scheme for the Community of Madrid information systems.

As we can observe, making any decision requires consulting different information systems. These information systems belong to distinct management units with competences to manage certain elements of the educational system: special educational needs, digital platforms, school administration, etc. At the same time, the management units have a high degree of independence in the application of their policies. This implies that the information systems have their own schemes and there is no direct communication between them.

In this scenario, the cycle of obtaining data for decision-making is slow, rigid and complex. The process requires at least three steps:

1) The technician who is faced with a decision and requires data that comes from outside his management unit must request it through a written report to a coordinating entity.
2) The technicians of the management units that receive the application analyze the request, prepare a report (which may be digital) and send it to the applicant.
3) A validation is produced by the managers of the management unit that originated the request. If there has been an error of interpretation, the process must be restarted.

B. PHASE 2: NEEDS ANALYSIS

After understanding the current state, working sessions were organized with different management units in which 40 workers (coordinators and technicians) from 15 different management units participated. Needs were defined in two phases:

- In the first phase, open intervention sessions were set up to establish what data they required, how they needed to integrate their own data with that of the other units, and what their data access requirements were. At a practical level, this analysis translates into functional requirements that the implementation of the platform must meet to adequately address the management needs of the organization.
- In the second phase, the units were shown examples of technologies that could improve management: a dynamic data analysis system based on OLAP cubes [5], a reporting system, and a dashboard for visualizations. OLAP cubes were chosen because it is the most widely used tool at the industrial level within the field of business intelligence. The specific implementation of OLAP cubes is guided by the requirements defined in the previous phase.

After the second phase, the solutions shown were assessed and were positively evaluated in all the cases:

1) Dynamic data analysis: 100% of the scores in maximum values
2) Report generation: 82.6% of the scores in maximum values.
3) Scorecards: 73.9% of the ratings in maximum values.

C. PHASE 3: TECHNOLOGY ANALYSIS

To carry out the technological analysis, the existing functional requirements were assumed, including the results from the needs analysis phase. This implied implementation of OLAP cubes for the dynamic analysis since it had been very positively evaluated by the managers. This type of analysis is usually done through data warehouse systems that, in turn, create data structures specialized in maintaining information with strategic value called Data Marts. As such, it was decided that the platform capabilities should include creation of data warehouses and analysis based on OLAP cubes.

The creation of a platform from scratch was ruled out from the beginning, so a process of searching for a support platform began. In general, technological platforms that could implement data warehouses and OLAP cubes in the Big Data environment were evaluated with the following requirements, in addition to the functional ones:

- Free software and, if possible, open source.
- Modular design to facilitate integration with different integration, processing, and visualization solutions, including the ability to connect with tools that allow data mining.
- Proven capacity in data consolidation and management.
- Possibility of including data from unstructured sources in the data cycle

The evaluation was carried out by the development team through proofs of concept and evaluating each of the requirements set out above. The evaluation finally focused on two suites: Apache Kylin [26] and Pentaho suite [13]. Pentaho suite was chosen for its versatility, existing support tools, integration with plugins, proven maturity in other domains and its alignment with the existing capabilities of the development team. For the developments, version 7.1 of its ecosystem was used. The dashboard development was partially built with LinceBI 9.0 [27]. This open source tool provides a clean interface to design and implement dashboards based on Pentaho.

In the Pentaho ecosystem there are two major subsystems that support the entire implementation:

- Data Integration: with which data will be ingested, processed, and stored in data marts.
- Business Analytics: will define the OLAP cubes and provides the tools for analysis of these cubes.

VI. DESIGN AND IMPLEMENTATION OF THE PLATFORM

This section presents the most relevant aspects to understand and reproduce the design and implementation of the support platform.

A. ARCHITECTURE

The following figure shows the implementation architecture of the educational management platform:

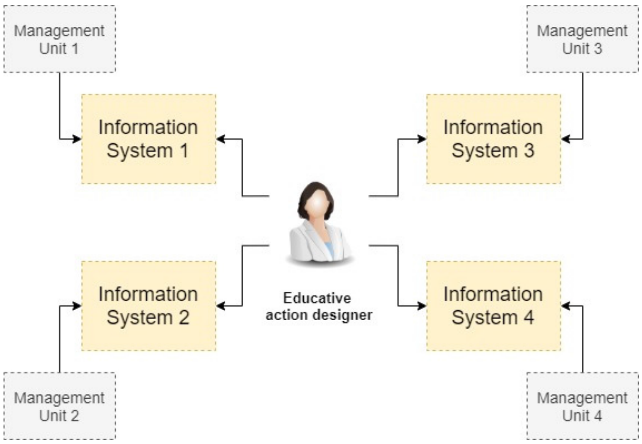

FIGURE 1. **Decoupled information systems for decision-making.**

The system entry is done through Excel files. As indicated above, each information system has its own data scheme, so it is necessary to translate it into a consolidated scheme that includes all the important aspects of the management platform. Both the transformation of the input data and its storage in the data marts is carried out through an *ETL* (*Extraction, Transformation, Load*) process, which will be explained later.

Once the information is in the data marts, it is possible to define OLAP cubes in a dedicated server. These cubes offer a concrete view of the data directly related to different strategic aspects. Finally, the OLAP client, composed of visual tools that interact with users through computers, tablets or cell phones, makes use of the OLAP cubes implemented on the server.

As can be seen, the management platform developed allows information from different sources to be obtained, consolidating the data, and its subsequent analysis. The same platform generates three different types of analysis: dashboards, pivot tables and reporting. An example of these tools will be shown later.

Additionally, the platform allows predictive analysis projects to be developed thanks to the consolidation of data from different sources and access to this information by external tools.

Figure 3 shows the deployment of Pentaho components with respect to the architecture outlined in Figure 2.

B. ETL PROCESS

One of the most critical aspects of the creation of the platform is the design and implementation of the ETL process. In order to carry out this process, the type of decisions that the platform will support were agreed upon. Then, the information sources needed to support those decisions were identified and, finally, an information model capable of storing all the consolidated data was defined.

After the process of identifying sources and defining the model, relevant information was exported to Excel files that acted as system input. Once all the entries were made, the definition of information transformation processes began,

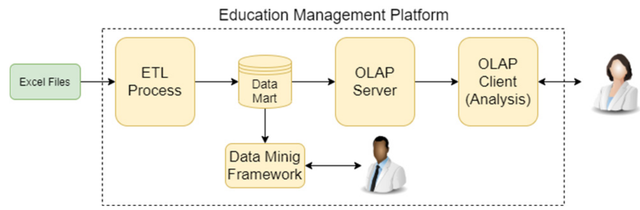

FIGURE 2. **Architecture of the Education Management Platform.**

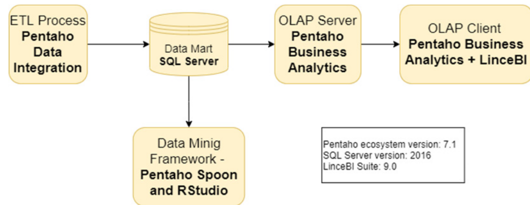

FIGURE 3. **Pentaho Deployment.**

providing syntactic and semantic consistency to the information consolidated in the platform. The *Pentaho Integration Data* tool was used for this purpose, which allows for an assisted design and implementation of this process. The first step is the creation of data flows that identify the origin of the information, its destination, and the type of transformation to be applied, as shown in Figure 4.

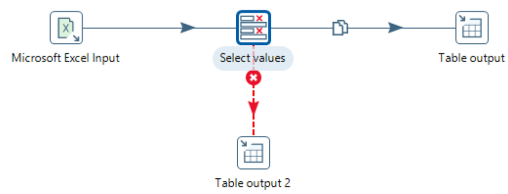

FIGURE 4. **Definition of the Data Flow.**

Once the data flows have been designed, it is necessary to specify how the defined transformations are implemented, as shown in Figure 5.

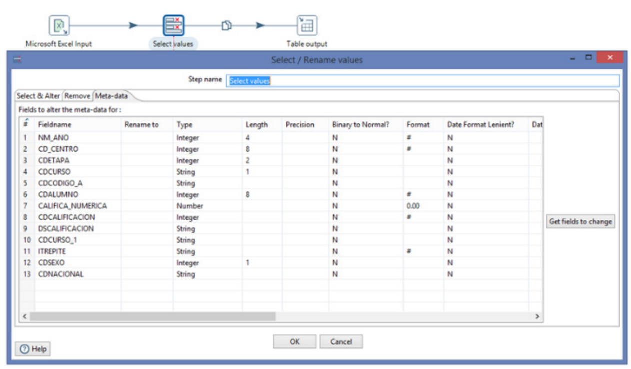

FIGURE 5. **Definition of transformations.**

In the case of the data flow shown in Figure 4, the definition of data mappings is also required. In Figure 6, we can observe

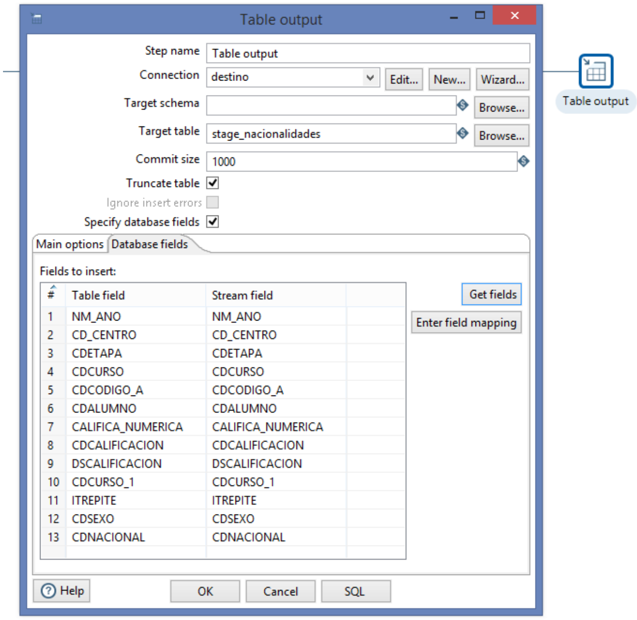

FIGURE 6. Data mapping.

how the data coming from the data stream is mapped to specific fields in the output table.

C. OLAP CUBES

OLAP cubes are the fundamental elements that enable subsequent analysis and influence the information model defined in the data marts. In order to define an OLAP cube it is common to define the consolidated data on which it is based, the measures to be obtained from those consolidated data, and the possible graphic controls that will be supported by OLAP cubes.

An OLAP cube is defined through its logical scheme. In the case of Pentaho, the *Pentaho Schema Workbench* tool is used, where the fact tables (that define the real state of the educational system) and dimension tables (specific view of the data to be analyzed) are specified.

In the Community of Madrid educational system, it is possible to define various logical schemes given their complexity. For the pilot plan presented, two logical schemes were defined: teachers and students/school. For the sake of clarity of this paper, just the students/school scheme is presented. The teachers scheme follows a similar approach. In the students/scholar scheme, the fact tables are focused on the real state of students and schools. These tables included data specific to the student (special needs, sex, school year, educational modality, etc.) and the school (available place offering, total center capacity, area of influence, etc.).

Associated with this table, several dimensions of analysis were defined: educational modality, food services, capacities to attend to special needs, territories of implantation, internationalization, etc. Figure 7 shows a subset (the complete diagram includes 20 variables in the fact table and 15 dimensions) of the star diagram defined with significant information to understand the approach.

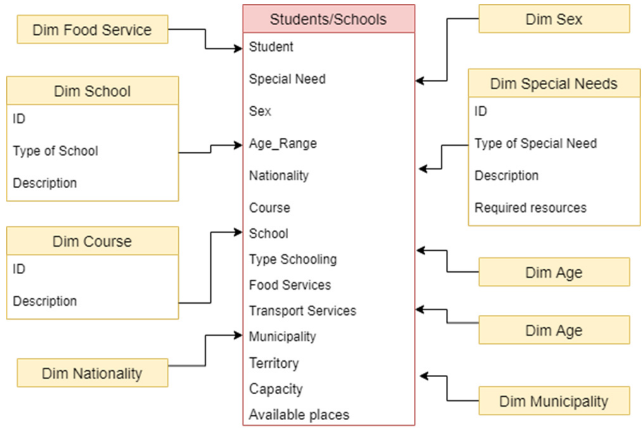

FIGURE 7. Star Schema defined for the pilot plan (simplified view).

Figure 8 shows how the creation of the OLAP cube is done with this tool:

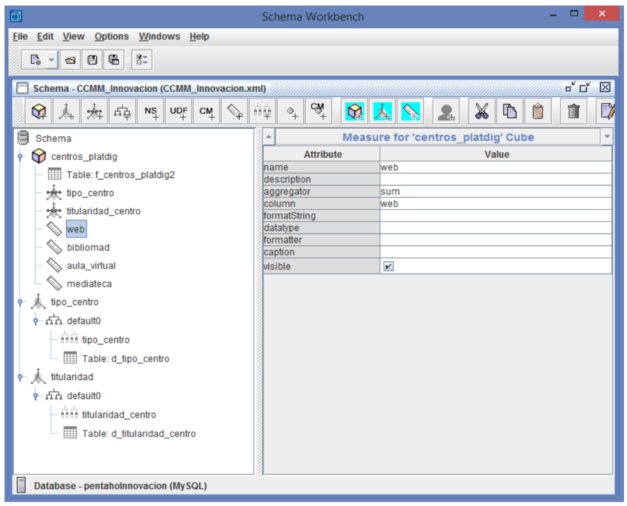

FIGURE 8. Creation of OLAP Cubes.

Once the OLAP cube is created, it must be registered in the OLAP server. The server will oversee the transformation of the OLAP client requests to the data marts language (SQL language).

D. ANALYSIS TOOLS

The platform provides three types of analysis. The implementation of the three systems is shown below.

1) DASHBOARDS

Dashboards allow creation of standard sets of displays for previously selected indicators. In the implemented platform, a dashboard must be associated to a specific OLAP cube and must follow one of the previously configured templates. Figure 9 shows an example of a dashboard with three visualizations.

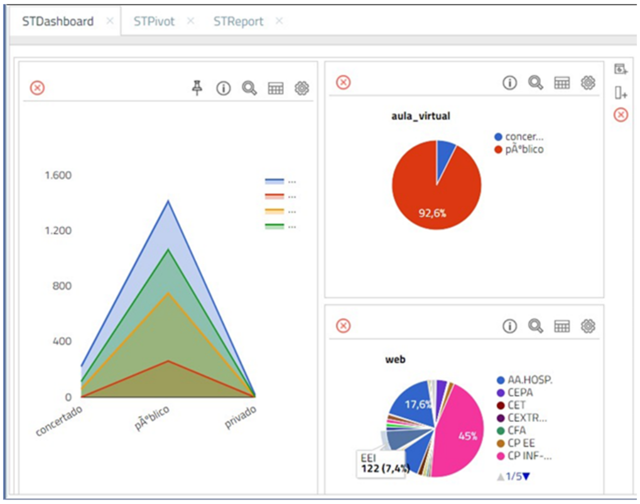

FIGURE 9. Dashboard graphically describing information from an OLAP Cube.

2) PIVOT TABLES

Pivot tables are analysis systems widely used in decision support systems based on OLAP cubes [14]. The analysis system is based on a table, but in which the user can define the variables (dimensions) that compose it, including the operations between them. In this way, users can get a view that is adapted to their own requirements.

The pivot table is again associated to an OLAP cube. Once associated with the cube, no administrator intervention is needed, unless one needs to modify an existing cube (add or remove dimensions) or create new cubes. Figure 10 shows the configuration of a pivot table by end users.

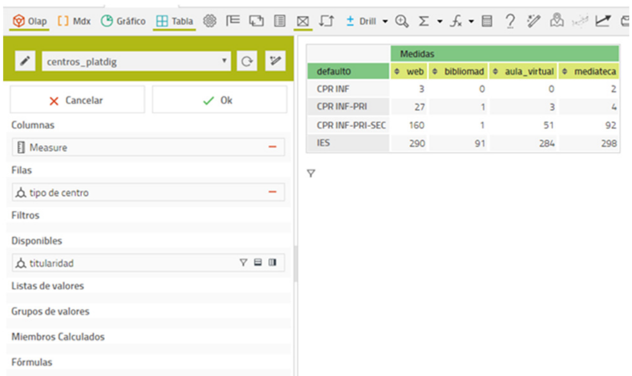

FIGURE 10. Configuration of a Pivot Table.

The implementation carried out elsewhere allows graphics to be included associated with the tables created, as shown in Figure 11.

3) REPORTING

Managers or technicians can create reports from the consolidated data in the data mart. However, this approach is less usable and requires more technical training from users.

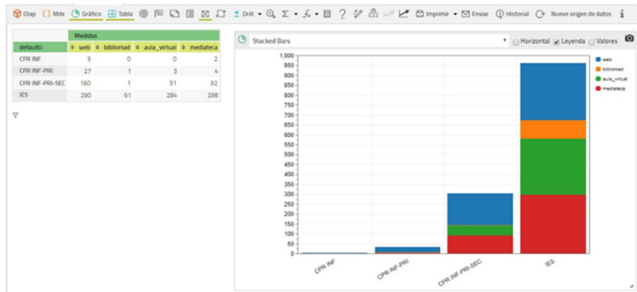

FIGURE 11. Visualization of a pivot table.

Figure 12 shows a screenshot of the reporting interface. As we can see, it is necessary to indicate specifically both the report parameters and the filter to be applied.

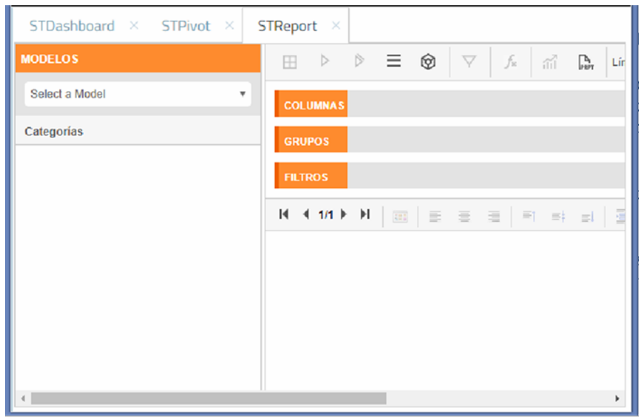

FIGURE 12. Configuration screen to create new reports.

VII. PREDICTIVE ANALYSIS

Although the platform itself does not implement predictive tools, it does allow access to its data marts in order to perform predictive analysis through process mining projects.

In the project presented, only the type of methodology to be used in these projects has been restricted: CRISP-DM. This methodology facilitates, in addition to a systematic development of predictive analysis, a system of documentation aligned with the organizational process of the Community of Madrid education system.

Since there are several tools available, no additional framework has been specified to carry out this type of project. Each analysis may use the technologies it considers most appropriate provided they have tools for integration with the educational management platform under the established security conditions.

VIII. VALIDATION

A validation of the two types of analysis enabled after the implementation of the framework has been carried out: dynamic analysis and predictive analysis.

A. DYNAMIC ANALYSIS

In order to check the platform's viability, a validation was carried out. The implementation assumes incorporation of operating and maintenance personnel for the platform (computer technicians and data managers). Therefore, the validation has been focused on the accuracy of the analysis carried out for a specific case of use. Figure 13 shows the design of the implemented pilot plan.

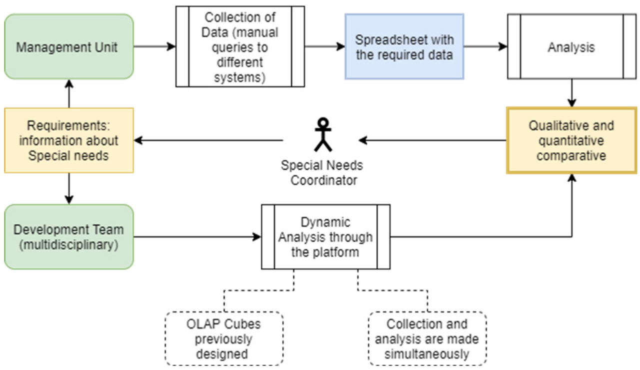

FIGURE 13. Pilot design.

As can be seen in the figure above, a resource analysis was chosen based on the region's special educational needs. For this purpose, the coordinator of the management unit in charge of this aspect carried out a requirements capture process with the needs from the requested analysis. The requirements were delivered to the management unit in charge in the Community of Madrid and to the development team with the technicians from the previous unit. In both cases, which did not coincide exactly in time, the standard procedure for carrying out the required analysis was followed. After this procedure, the unit coordinator verified the conclusions of the two analyses at both the qualitative and quantitative level.

For the dynamic analysis done through the platform, two OLAP cubes were generated with information of interest for this unit. The managers in this team carried out checks on the consistency of the results, as well as the tool's usability.

After these initial checks, a new iteration was done with the requirements document as the basic check element. In this iteration, some adjustments had to be made and a new version of the OLAP cubes was created. After this process, the generation of credentials was approved so that the analysts participating in the pilot could carry out their analysis with this tool.

After the entire process, the management unit coordinator concluded that there were some variations linked to the imprecise definition of some concepts at the qualitative level. An example is the date from which a student's enrollment is considered as not active in the current course. These concepts were considered easy to refine in the tool itself, even after only one iteration of analysis.

At a quantitative level, except for some discordance related to the imprecision of concepts referred to above, greater precision was observed in the platform. This higher degree of accuracy may be due to less exposure to human error in data collection and to the fact that the platform data are updated in quasi-real time. In the traditional process, from the beginning of the data request to the consolidation into final spreadsheets, weeks may pass which, in turn, may imply changes in the measured values.

B. PREDICTIVE ANALYSIS

Independently of the dynamic analysis, which was able to be contrasted with the normal operation of the management services of the Community of Madrid, the predictive analysis was validated.

For this purpose, a data-mining project was defined to estimate the number of groups that would be required for the next academic year based on a ten-year history and 27 possible variables. We should highlight that this study without the management platform proposed is not efficient because it is not possible to gather the 27 variables selected (they depend on different information systems) and it is not usual to take into account a ten-year history (normally only the current year is considered to define actions for the coming year).

The data-mining project was carried out using the programming language R as an analysis tool with the Caret package (Classification And REgression Training package for R).

The analysis mechanism chosen was regression models. These models allow a quantifiable answer to be obtained so that they can be applied to each one of the courses in the different Community of Madrid educational institutions, as well as obtaining the number of groups that should be offered.

Before starting, an exploratory data analysis was carried out where the 27 initial variables were reduced to eleven variables. These variables were then lowered to the five most significant ones.

After completing the analysis process, it was determined that for the following year modification of groups would be required in 52 schools out of 4,436. During the two previous years, the number of centers planned was in the range of 51-52. This range of modification were established after several years of using an essay-error method to establish the most optimal value. Although the effectiveness of the results could not yet be verified, they are consistent with the previously established ranges and by only using the information stored in the OLAP cube. Any communication with the current team deciding the number of schools was avoided to check the accuracy of the results.

The data mining project was carried out by a team specialized in these techniques in a time and cost-efficient manner. The number of necessary interactions with the different functional units was kept at a minimum, significantly facilitating their execution.

IX. CONCLUSION

This paper has presented the analysis and developments made during the implementation of a framework for strategic intelligence systems for educational management support in a pilot project run in the Community of Madrid. Beyond the improvement in data organization, the deployment has made it possible to minimize the number of interactions necessary to conduct the analyses presented in the pilot, improving agility in decision-making with adequate levels of precision and broad acceptance by end-users.

The educational context is increasingly complex, which together with the limitation of resources, makes planning and managing actions difficult. Innovation management systems, and more specifically strategic intelligence systems, face similar problems: a changing context, a large number of variables and limited resources to carry out necessary actions. To deal with this complexity, they assume data-based decisions as the main support for the success in meeting their objectives. These data-based decisions require organizational change, as well as generation of data management and analysis platforms that facilitate both the interpretation and the discovery of hidden but useful relationships to meet objectives.

In the case of the Community of Madrid, the strategic intelligence platform applied to education management is based on the creation of a data warehouse and associated analysis technique: dashboards, OLAP cubes and automatic report creation.

This platform, designed according to creation standards for intelligence systems, represents greater agility in the flow of information within the system itself. Managers do not have to go through the process of requesting information from technicians, which can take days and can be error-prone. In this scenario, they themselves can access the information in a straightforward way and manipulate the associations between variables according to their needs. As such, in addition to obtaining the data in real time, it is possible to conduct exploratory data tasks that were previously more complicated to execute.

Besides this enhanced performance, there has been improvement in the analysis capacity, which is due to three fundamental aspects:

- Consideration of a greater number of variables. Thanks to OLAP cubes, the association of variables inside the same cube is a simple task. This allows managers to perform a process of exploring relationships that can lead to new information.
- Use of data history. Since the complete information on the region's educational system was segregated into several different information systems, using data from several different years was complex. With the consolidation of data from the platform, this becomes trivial.
- Possibility to carry out predictive analysis. Data mining projects often require many resources to obtain curated data that is usable. In the case of systems such as the one in the Community of Madrid, it would also involve requesting information from several different information systems. This is not a very agile process that also does not assure that one is working with all the available information due to the complexity of obtaining a general vision of the entire information system. With the creation of the platform, this type of project can be carried out without altering the normal functioning of the rest of the system.

OLAP cube structures, which are the basis of subsequent analyses, are expensive to develop. However, once performed, they are stable in time as well as flexible. In addition, refinements made during the pilot plan are designed in a fluid way and guided by the people who will later carry out the analyses.

As suggested by the strategic intelligence standards, those who are part of the organization have been involved from the beginning, so that the platform has been adapted to existing needs and has not caused new unnecessary workflows. This has improved its acceptance, and the realization of a more ambitious pilot that includes several different management units and a stable development and maintenance team has been positively evaluated.

The strategic intelligence approach provides more accurate knowledge of the needs and current state of the educational system of the Community of Madrid. The changes in the state are automatically reflected and in addition, the structures created are stable since they respond to strategic criteria. This reduces the need for constant refinement, but at the same time provides technicians with flexibility of analysis. This flexibility cannot be achieved with the procedure that had been used until now.

Despite the satisfactory results obtained in the validations, its implementation as a support tool for decision-making for the entire system of the Community of Madrid is subject to the necessary political and organizational changes. Besides updating the definition of the collaboration processes between workers and between functional units, it is necessary to define new processes that guarantee the correct consolidation of data within the platform, as well as data lifecycle management. This last aspect is fundamental and requires the creation of specific roles for that task, which in this project has been carried out by analysts and developers.

Once the technological platform has demonstrated its validity at a technical level and end-users acceptance, it is necessary to integrate it into the real planning processes of the educational management system. The following pilot plans should be oriented towards validation of complete decision processes including the platform. For this purpose, in an education organization such as that of the Community of Madrid, it is necessary to assume full integration of the platform in a specific management unit. In this case, the selected management unit would be resource planning for special educational needs, since part of the validation analyzes carried out in the first pilot project involved this unit.

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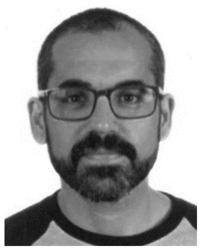

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