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## Integrated Decision Support System – iDSS for Library Holistic Evaluation

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# DESIGN OF AN INTEGRATED DECISION SUPPORT SYSTEM FOR LIBRARY HOLISTIC EVALUATION

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## Abstract

The decision-making process in academic libraries is paramount; however highly complicated due to the large number of data sources, processes and high volumes of data to be analyzed. Academic libraries are accustomed to producing and gathering a vast amount of statistics about their collection and services. Typical data sources include integrated library systems, library portals and online catalogues, systems of consortiums, quality surveys and university management. Unfortunately, these heterogeneous data sources are only partially used for decision-making processes due to the wide variety of formats, standards and technologies, as well as the lack of efficient methods of integration. This article presents the analysis and design of an integrated decision support system for an academic library. Firstly, a holistic approach documented in a previous study is used for data collection. This holistic approach incorporates key elements including process analysis, quality estimation, information relevance and user interaction that may influence a library's decision. Based on the mentioned approach above, this study defines a set of queries of interest to be issued against the integrated system proposed. Then, relevant data sources, formats and connectivity requirements for a particular example are identified. Next, data warehouse architecture is proposed to integrate, process, and store the collected data transparently. Eventually, the stored data are analyzed through reporting techniques such as on-line analytical processing tools. By doing so, the article provides the design of an integrated solution that assists library managers to make tactical decisions about the optimal use and leverage of their resources and services.

**Keywords:** Integrated decision support system, academic libraries, data warehouse

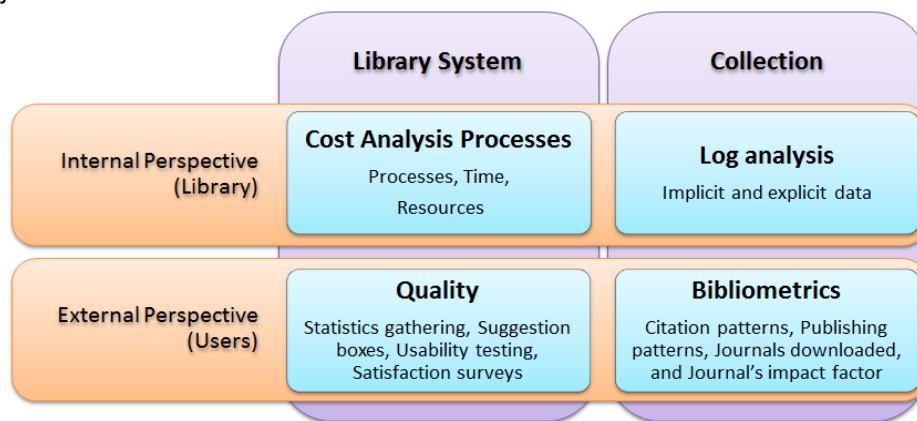
## 1 Introduction

In a rapidly changing information environment characterized by the growing presence of e-content, emergence of new technologies, large amounts of data and continuous diversification in user needs, knowledge management (KM) has become a powerful tool to promote innovation, and to enable reengineering for library processes and services (ACRL Research Planning and Review Committee, 2010; Shanhong, 2002). At present, libraries can use KM as a way to expand their role in areas where they have had little impact such as financial decisions and strategic decision-making (Townley, 2001). Although, the role of KM as a decision-making support tool has been well-documented in private sector organizations (Holsapple, 2001; Nicolas, 2004), its application in public sector institutions including universities, hospitals and libraries remains immature (Tofan, Galster, & Avgeriou, 2013).

Knowledge-based Decision Support Systems (DSS) provide important information to analyze situations or conditions that impact operations, and to make better and faster decisions (Poe, Brobst, & Klauer, 1997). In the case of libraries, several DSS have been documented; however, most of them mainly focus on specific areas such as budget allocation for physical and digital collections. Nevertheless, only a few studies are known to integrate other aspects such as: human resources, technological infrastructure, services and library usage. The purpose of this article is to present the analysis and design of an integrated DSS (iDSS), which includes the aforementioned aspects based on Data Warehouse (DW) techniques for libraries. The remainder of the article is organized as follows. First, a description of the utilized holistic library analysis is briefly described. Then, the research methodology is outlined. Next, the design of an integrated DSS based on DW techniques is presented through a case study, and examples of the final result are reported. Finally, conclusions and future research directions are given in the last section.

## 2 Data collection through a holistic perspective

Implementing iDSS in libraries faces multiple challenges due to the high number of data sources, formats and large volumes of data to be processed. In this context, Nicholson (2004) proposes a theoretical framework that supports libraries gaining a thorough and holistic understanding of their users and services. Nicholson proposes a two-dimension matrix that evaluates libraries based on their library system and collection from internal and external perspectives. Due to the ease of understanding, completeness, as well as applicability to both physical and digital library resources, Siguenza-Guzman et al. (2015) adopted the framework as its basis to propose an architecture and an integrated set of tools to holistically assess libraries (see Figure 1). An example of this framework implementation is presented in a previous case study (Siguenza-Guzman et al., 2013). By describing initial implementation stages, the authors probe the practical validity of the proposed holistic approach; however, the need of an iDSS to collect strategic information is strongly recommended.



**Figure 1: Methodologies proposed for the economic evaluation of libraries through a holistic approach (Siguenza-Guzman et al., 2015)**

The main characteristics of each quadrant and the methodologies proposed by Nicholson (2004) and Siguenza-Guzman et al. (2015) are the following.

1. *Internal perspective of the library system – Cost analysis processes*: costs and resources of library processes and services are analyzed. The authors describe three available methodologies: traditional costing system, activity-based costing system and time-driven activity-based costing, recommending the last.
2. *External perspective of the library system – Quality*: quality of library processes and services are assessed by users. Siguenza-Guzman et al. recommend the use

of at least one of the following methods: statistics gathering, suggestion boxes, Web usability testing, user interface usability, and satisfaction surveys.

3. *External perspective of the library collection – Bibliometrics*: the impact of the current library collection on its users is evaluated. The authors propose combining three methods: citation analysis, vendor-supplied statistics and citation databases.
4. *Internal perspective of the library collection – Log analysis*: this quadrant analyzes usage patterns followed to manipulate the library system. Siguenza-Guzman et al. suggest the use of log analysis methods such as transaction and deep log analysis.

### 3 Research methodology

A successful approach for creating an iDSS based on DW techniques includes much more than the design process. Several decisions must be made such as the DW data architecture to be used, data sources to be consulted and the data integration scheme to be utilized. Thus, an adequate selection of methodology and technological tools for the construction of a DW will be instrumental in ensuring a successful implementation.

There are reasonably well-established approaches for implementing a DW; however two classical methods are predominant: Inmon and Kimball. The Inmon methodology, or top-down approach, transfers the information from various Online Transactions Processing (OLTP) systems to a centralized DW, given that the DW has the following classic features: subject-oriented, integrated, time-variant and nonvolatile (Inmon, 2005). On the other hand, the Kimball methodology, or bottom-up approach, is the union of smaller data marts, where every data mart represents a business process or dimensional mode (Kimball, 2006). A data mart is a subset of the DW based on the same principles, but with a more limited scope. After analyzing the Inmon and Kimball methodologies, a hybrid approach that integrates the best of both methodologies is adopted for this study. The DW methodology chosen for the case study implementation is Hefesto. The Hefesto methodology, created by Bernabeu in 2007, starts by collecting information requirements and needs of the user, followed by the extraction of raw data, the transformation into standard formats, and the loading of the data into the DW database. The Hefesto methodology is characterized by the following features: it is easy, realistic and simple to understand; it is based on user requirements gathering; it reduces the resistance to change; it uses conceptual and logical models, it can be applied to DW and data marts approaches, and it is independent of technologies, physical structure and life cycle type (Bernabeu, 2010).

Regarding the selection of technologies, the market offers a wide range of software development products known as DW Business Intelligence (BI) tools. In this project, the Pentaho Community BI is selected to construct the DW based on the Hefesto methodology. The Pentaho BI<sup>1</sup> is an integrated platform that includes: data integration, ETL (Extraction, Transformation and Load) capabilities, data mining, reporting, OLAP (on-line analytical processing) services and dashboard visualization.

### 4 Designing an integrated decision support system: Case Study

A case study to demonstrate the applicability of the holistic approach proposed to implement an iDSS based on DW was performed at the University of Cuenca (UC) library<sup>2</sup>. The UC library, or Regional Documentation Centre “Juan Bautista Vazquez”, is considered one of the most modern and biggest libraries in Ecuador. Its collection consists of about 250,000 books (i.e. 18 titles per student which is far above the national ratio), digital databases, and multimedia contents. The UC library, visited by an average of 1,200 students, is operated by 20 full time staff members distributed in the main library and two branches.

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<sup>1</sup> Pentaho: <http://www.pentaho.com>

<sup>2</sup> <http://biblioteca.ucuenca.edu.ec/>

#### 4.1 Decision support system architecture

Based on the holistic approach proposed by Siguenza-Guzman et al. (2015), and the methodology and technologies selected to implement the DW, this article presents the resulting iDSS architecture implemented at the UC library as shown in Figure 2. The iDSS architecture of the UC library is structured in three layers: 1) *data sources* contains all sources used as data suppliers to the DW; 2) *data extraction, cleansing and storage* in charge of the design and implementation of ETL processes to maintain the DW; and 3) *data presentation* provides the appropriate reports for supporting information management and decision-making.

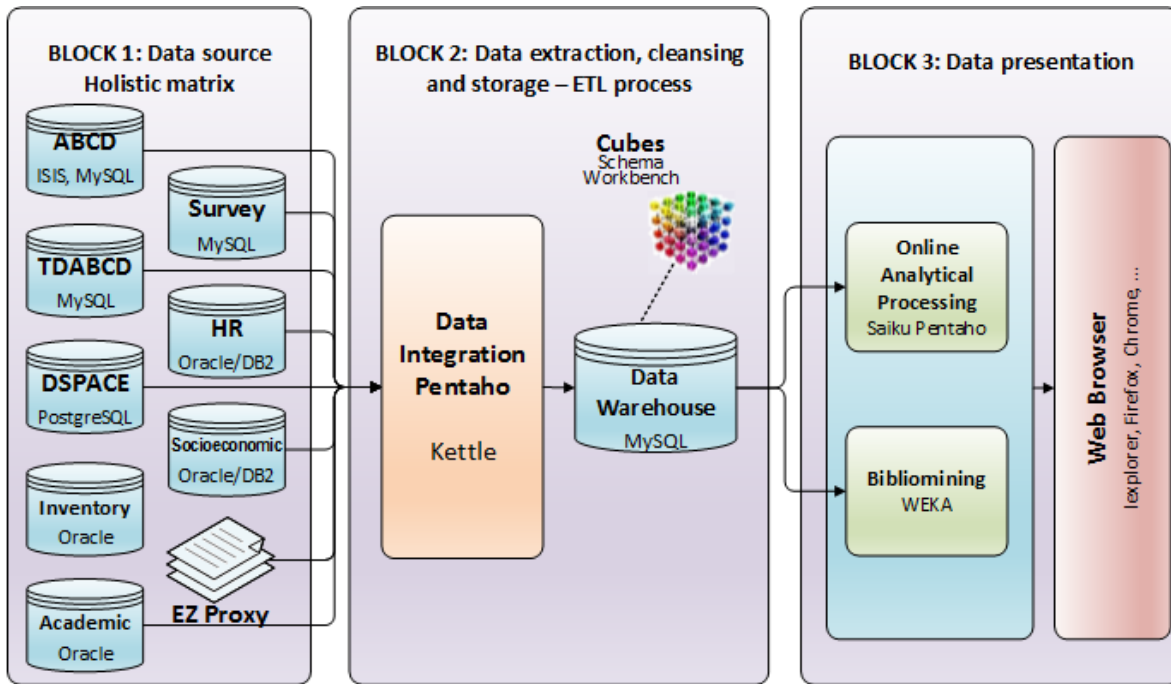


Figure 2: iDSS architecture of the UC library

#### 4.2 Hefesto methodology

This section describes the steps used to create the UC library DW based on the Hefesto methodology. This approach allows tackling the design of the DW from different detail levels, and reducing risks of failure and dissatisfaction by involving end-users early in the design process. The Hefesto methodology consists of the following four steps: 1) *Requirement Analysis* identifies the user information needs to define all queries of interest. 2) *OLTP analysis* is in charge of the data source analysis, determines how the indicators are built, defines correspondences and granularity, and builds the extended conceptual model. 3) *Logical Model* represents the structure of the DW; defines the type of implementation schema, the dimension and fact tables in order to create their respective unions. Facts are the core data elements being analyzed, while dimensions are attributes about facts. 4) *Data Integration* makes use of diverse tools such as cleansing techniques, data quality control, and ETL processes in order to integrate the data of different data sources; policies and strategies for the initial loading of the DW are also defined, as well as for its updating process. The DW creation according to the Hefesto structure is explained in more detail in the following subsections by way of examples.

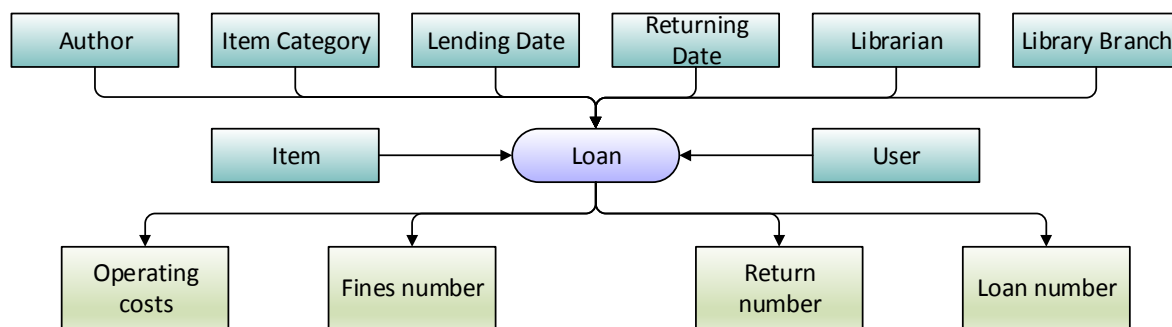
##### 4.2.1 BLOCK 1: Requirement Analysis

The requirements are analyzed through the four perspectives of the holistic evaluation framework proposed by Siguenza-Guzman et al. (2015) (Figure 1). Based on this structure, a list of queries

(i.e. set of queries) of interest to be issued against the iDSS is defined. This list of requirements is collected through questions involving library needs. An example of the lending process requirements serves to exemplify how the questions are approached.

1. What is the number of loans of a particular item, of a given author and title, of a specific item category of a particular librarian in a time unit?
2. What is the number of loans of a particular librarian of a specific library branch in a time unit?
3. What are the operating costs of lending services of a particular campus in a time unit?
4. What is the number of returns of a particular librarian of a specific library branch at a given user type in a time unit?
5. What is the number of fines and its corresponding value in a time unit?

Once all questions are posed, the corresponding indicators and perspectives are identified. The resultant indicators and perspectives of the lending process example are shown in Figure 3.



**Figure 3: Indicators and perspectives of the lending process example**

#### 4.2.2 OLTP Analysis

The following step in the study is to identify the different data sources of the UC library based on the requirement analysis of the holistic evaluation approach. The holistic approach incorporates several key elements including process analysis, quality estimation, information relevance, and user interaction; thus, data have to be collected from internal and external sources. Internal data sources refer to the databases that are managed at the library level. On the contrary, external sources are not managed by the internal processes of the library. Collecting data from these heterogeneous sources presents a big challenge since generally different data sources use dissimilar formats and access methods including both structured (e.g. relational and documental databases) and unstructured data (e.g. word processing documents, spreadsheets and log files).

After several meetings with the library manager, all the different OLTPs were documented. A total of ten data sources were identified and analyzed. These data are generated at library, university and external levels. Library data sources are the following: ABCD, LibQUAL+®, DSPACE, and EZproxy. ABCD<sup>3</sup>, free and open-source integrated library automation software, offers the main functionalities of a library system such as acquisition, cataloguing, circulation, online public access catalog (OPAC) and serials control. ABCD at the UC library uses MySQL and ISIS as its relational and documental database respectively, and MARC21 as its pre-existing cataloguing structure. LibQUAL+®<sup>4</sup> is a proprietary set of services based on Web surveys that allows requesting, tracking, understanding and acting upon users' perception of the quality of services offered by libraries. The LibQUAL+® survey consists of 22 questions, which are grouped into three quality dimensions: services provided, physical space and information resources. DSPACE<sup>5</sup> is an

<sup>3</sup> <http://reddes.bvsaude.org/projects/abcd>

<sup>4</sup> <http://www.libqual.org>

<sup>5</sup> <http://www.dspace.org/>

open-source repository developed to provide access to digital resources. DSpace is implemented in Java and uses PostgreSQL as its database. EZproxy<sup>6</sup> is proprietary software that allows libraries to offer their users remote access to the library e-sources. By default, events are recorded in standard web server log file format; however, EZproxy also includes the ability to add or remove fields to meet particular needs.

In addition, the UC library, as part of the university system, is linked with other university departments, implying information flows within the university. Data sources at the university level are the following: Olympo, GSocioeconomic, Academic and HRM. Olympo is a commercial inventory manager software that uses Oracle as its relational database. GSocioeconomic is an in-house software tool responsible for the management of the socioeconomic data of university students. This software uses the Oracle database where all the student data are loaded. Academic is an in-house software tool that handles academic and enrollment process. This Web software uses Oracle as its relational database. HRM is an intranet-based application that manages data related to human resources. This in-house system uses Oracle as its database. Eventually, at external level, other data are collected from sources such as Scopus reports and Ebsco statistics on online resources utilization. A summary of data sources, utilized to implement the DW at the UC library, are presented in Table 1.

#### UC library data sources

| Application                  | Modules                       | Database               | Type of database | Main attributes  |
|------------------------------|-------------------------------|------------------------|------------------|--|
| <b>Internal data sources</b> |                               |                        |                  |  |
| ABCD                         | Cataloguing                   | ISIS MARC21            | Documental       | Item ID, Author(s), Title, ..., Cataloguer   |
|                              | Circulation                   | MySQL                  | Relational       | Lending, Returning, Fines, Reserves, Interlibrary loan   |
|                              | TD-ABC-D                      | MySQL                  | Relational       | Activities, Resources, Responsible, Processes, Times, Costs  |
|                              | Reference Satisfaction Survey | MySQL                  | Relational       | Librarian, Inquiry, Solution, Satisfaction level, PC Terminal, Survey                                  |
| LibQUAL+®                    | Quality survey                | MySQL                  | Relational       | Campus, Questions, User, Time  |
| DSpace                       | Institutional Repository      | PostgreSQL Dublin Core | Relational       | Community, Collection, Item, Bundle, Bitstream, Bitstream Format                                       |
| EZproxy                      | Remote Access                 | Logs                   | LogFile          | IP address host accessing, Date/time of request, URL Requested, Method of request, # bytes transferred |

#### University data sources

|                |                    |        |            |   |
|----------------|--------------------|--------|------------|---|
| Olympo         | Inventory          | Oracle | Relational | Fixed assets, Class, Section, Area, Address, Provider, Fixed asset document                           |
| GSocioeconomic | Socioeconomic Data | Oracle | Relational | Entry/Exit students, Family members, Academic period, Student information, Faculties, Academic status |
| Academic       | Enrollment         | Oracle | Relational | Enrollment, Career, Academic period, Subject  |
| HRM            | Human Resources    | Oracle | Relational | Personal information, User type, Department   |

#### External data sources

|                  |                            |       |             |  |
|------------------|----------------------------|-------|-------------|--|
| Scopus reports   | Citation database          | Excel | Spreadsheet | Title, Publisher, 5-year Impact Factor, Topic  |
| EBSCO statistics | Vendor-supplied statistics | Excel | Spreadsheet | Year, Month, Searches, Total full text, PDF full text, HTML full text, Image/Video, Abstract |

**Table 1: Summary of data sources of the UC library**

<sup>6</sup> [www.ezproxy.com/](http://www.ezproxy.com/)

Following the data source analysis (Table 1), a conceptual data model was constructed as shown in Figure 4, based on the four quadrants of the holistic analysis (Figure 1).

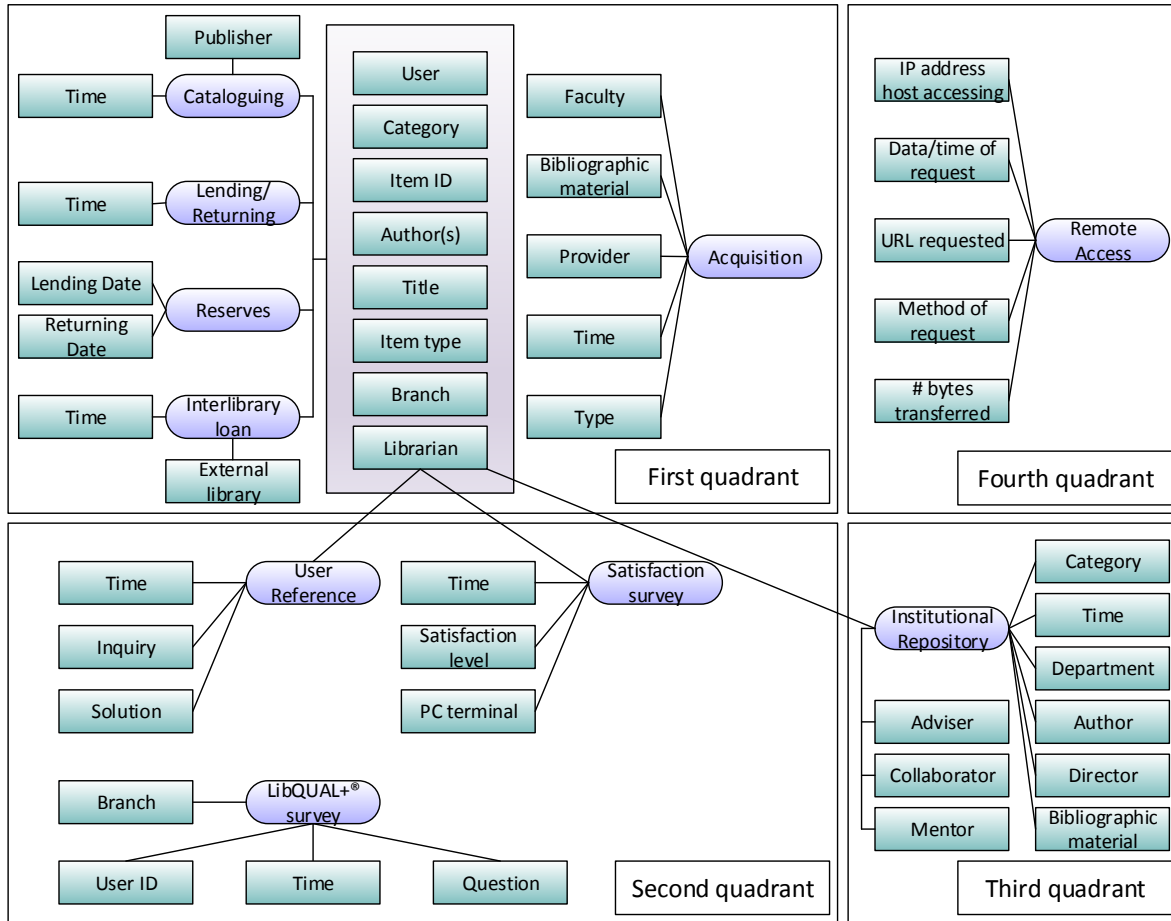


Figure 4: Conceptual data model of the UC library data warehouse

#### 4.2.3 Logic Model

Based on the conceptual data model (Figure 4), a data mapping from the OLTP sources to the logical model is performed. The logical model of the lending process is presented in Figure 5.

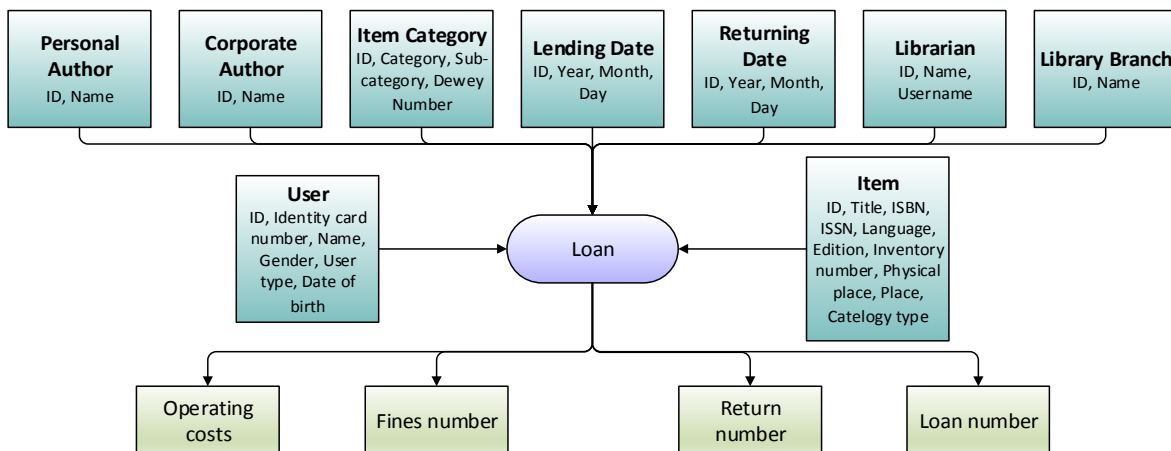


Figure 5: Logical model of the lending process example



In addition, the type of schema is defined. Due to its simplicity and compatibility with the selected tools, the data schema that best fits the study is the “star” schema. In the star schema, facts are represented as a table in the center of the schema with multiple joins connecting it to the dimension tables. Thus, the dimension and fact tables are built to create their respective unions. As a result, multidimensional models are obtained. Figure 6 shows the multidimensional model of the lending process analysis, and consists of a central fact table and its respective dimensions.

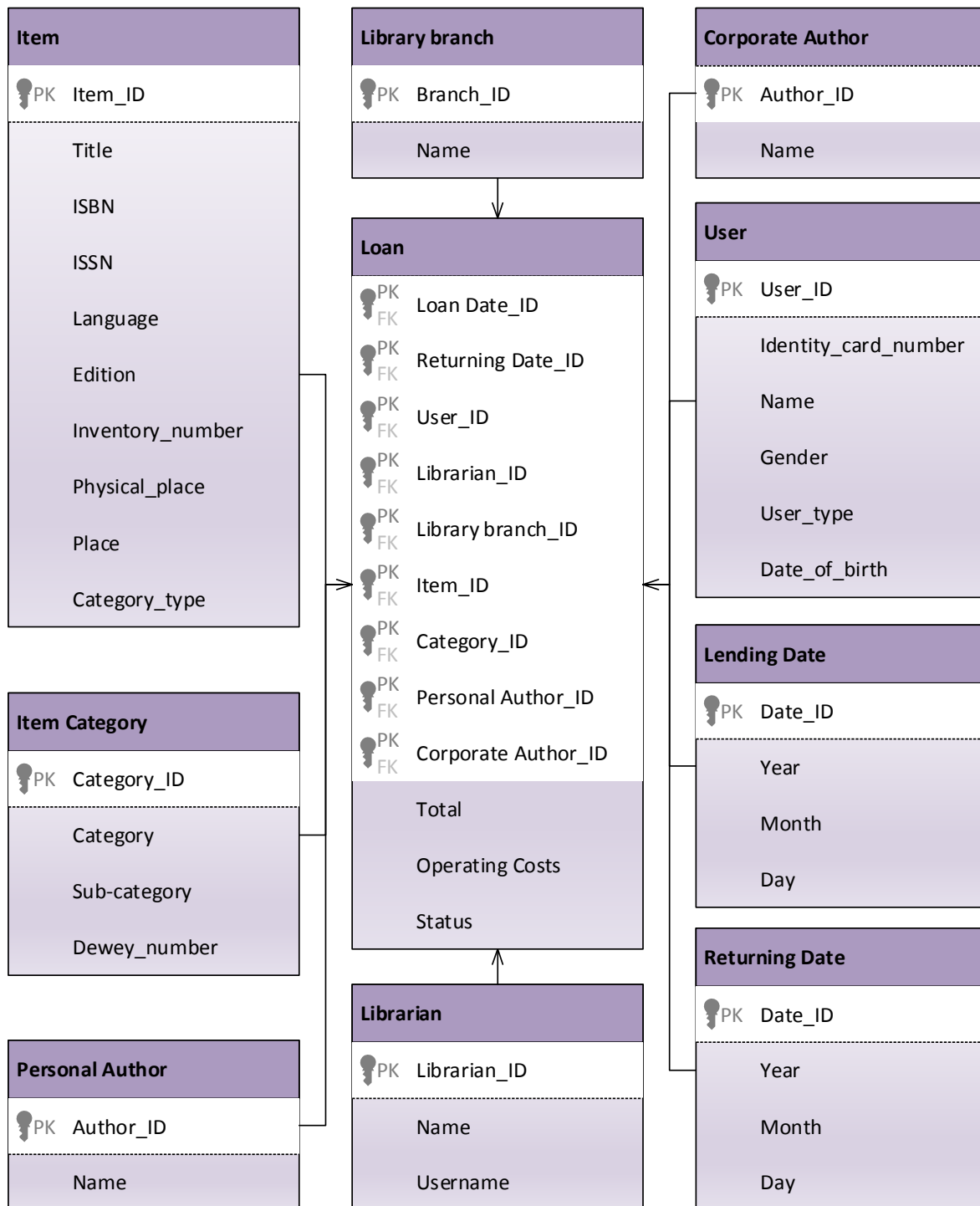


Figure 6: Multidimensional model of the lending process

#### 4.2.4 BLOCK 2: Data Integration

After building the logical model, the relevant data generated by multiple sources are integrated by means of cleansing techniques, data quality control, and ETL processes. This allows having a clean and homogeneous version of the library data. Because this process is the most tedious and time-consuming part, literature recommends starting with a narrowly specific query and working through the entire process, and then, iteratively continuing developing the DW.

- **Extracting data**

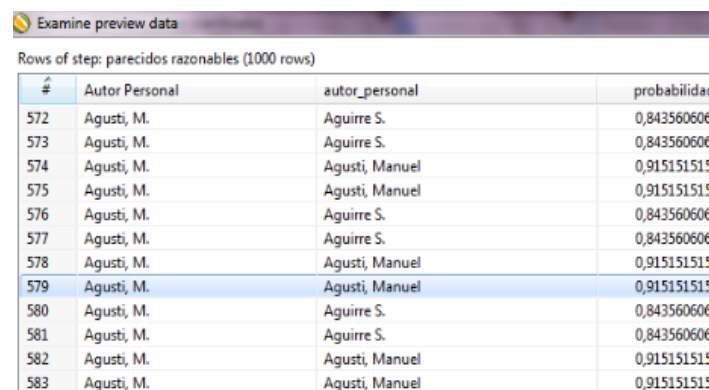
Once the logical model is built, the following step is to extract the relevant data through ETL processes. In order to do so, the Kettle Pentaho suite is used. This tool includes a wide variety of components to access data sources such as relational databases, structured text files and web services, but lacks components to access metadata from documental databases as required in this case study. To solve this problem, a new component was developed in order to retrieve data from the ISIS database and to generate a structured text file with .mrc extension.

- **Cleansing and transforming data**

Before loading data into the DW, these extracted data must go through a series of transformations in order to be cleaned. A particular example is the case of the data recorded through the ABCD system. Since the authority control module to establish uniform data entry, is not used in the UC library, users easily make typing errors without any validation; for example, cataloguers record data in the personal author field through different formats such as:

- *First surname, Names*
- *First surname Second surname, Names*
- *First surname Second surname, First name*
- *First surname, First name initial*

As shown in Figure 7, to solve the aforementioned problem, string similarity measures, such as the Jaro-Winkler metric were used to indicate the percentage of similarity between fields. Finally, data according to the logic model are loaded in the different dimensions and fact tables.



Examine preview data

Rows of step: parecidos razonables (1000 rows)

| #   | Autor Personal | autor_personal | probabilidad |
|-----|----------------|----------------|--------------|
| 572 | Agusti, M.     | Aguirre S.     | 0,843560606  |
| 573 | Agusti, M.     | Aguirre S.     | 0,843560606  |
| 574 | Agusti, M.     | Agusti, Manuel | 0,915151515  |
| 575 | Agusti, M.     | Agusti, Manuel | 0,915151515  |
| 576 | Agusti, M.     | Aguirre S.     | 0,843560606  |
| 577 | Agusti, M.     | Aguirre S.     | 0,843560606  |
| 578 | Agusti, M.     | Agusti, Manuel | 0,915151515  |
| 579 | Agusti, M.     | Agusti, Manuel | 0,915151515  |
| 580 | Agusti, M.     | Aguirre S.     | 0,843560606  |
| 581 | Agusti, M.     | Aguirre S.     | 0,843560606  |
| 582 | Agusti, M.     | Agusti, Manuel | 0,915151515  |
| 583 | Agusti, M.     | Agusti, Manuel | 0,915151515  |

Figure 7: Evaluation of string similarity in the personal author field

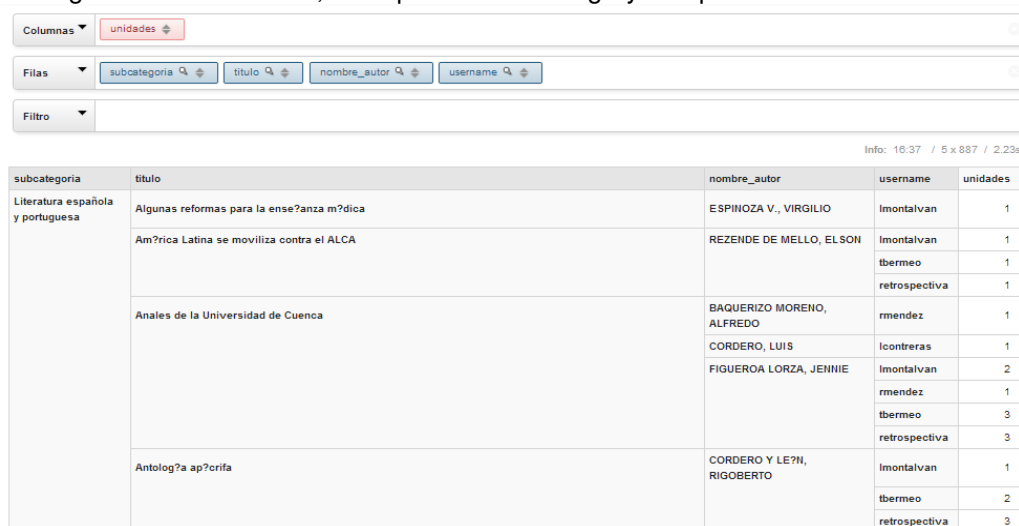
- **Loading data**

After extracting, cleansing and transforming, data must be loaded into the warehouse. To do so, the Pentaho tool is used to create the multidimensional model in a relational database (MySQL). To optimize the model, indexes in the basic and commonly used searching fields are created.

### 4.3 BLOCK 3: Data presentation

Eventually, the stored data can be visualized and analyzed through reporting techniques located in the data presentation layer such as: data reporting, OLAP and bibliomining tools. The tools utilized depend on the needs of the library manager to make decisions. In this study, OLAP tools, also called multidimensional analysis, are selected to produce reports and to be used by decision makers. OLAP tools can be used to prepare regular and unplanned reports, ensure quality, check data integrity, monitor the development of science, and evaluate or benchmark disciplines, fields or research groups (Hudomalj & Vidmar, 2003). According to the questions posed in the requirements analysis (Section 4.2.1), the results of the exploitation are:

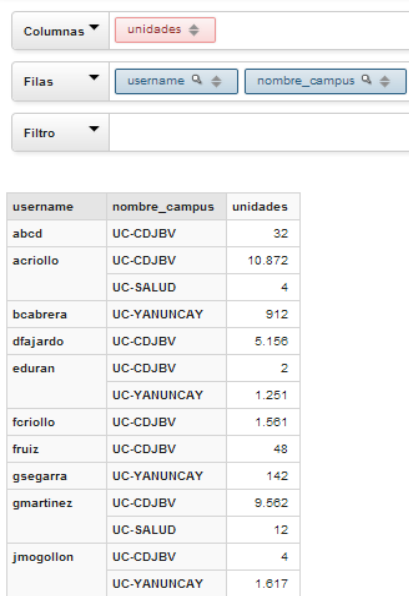
1. Figure 8 answers the first question posed: What is the number of loans of a particular item, of a given author and title, of a specific item category of a particular librarian in a time unit?



| subcategoria                     | titulo                                    | nombre_autor              | username      | unidades |
|----------------------------------|---|---------------------------|---------------|----------|
| Literatura española y portuguesa | Algunas reformas para la enseñanza médica | ESPIÑOZA V., VIRGILIO     | lmontalvan    | 1        |
|                                  | América Latina se moviliza contra el ALCA | REZENDE DE MELLO, ELSON   | lmontalvan    | 1        |
|                                  |   |                           | tbermeo       | 1        |
|                                  |   |                           | retrospectiva | 1        |
|                                  | Anales de la Universidad de Cuenca        | BAQUERIZO MORENO, ALFREDO | rmendez       | 1        |
|                                  |   |                           | lcontreras    | 1        |
|                                  |   |                           | lmontalvan    | 2        |
|                                  |   |                           | rmendez       | 1        |
|                                  |   |                           | tbermeo       | 3        |
|                                  |   |                           | retrospectiva | 3        |
|                                  | Antología de la poesía                    | CORDERO Y LEÓN, RIGOBERTO | lmontalvan    | 1        |
|                                  |   |                           | tbermeo       | 2        |
|                                  |   |                           | retrospectiva | 3        |

Figure 8: Number of loans of a particular item, of a given author and title, of a specific item category of a particular librarian

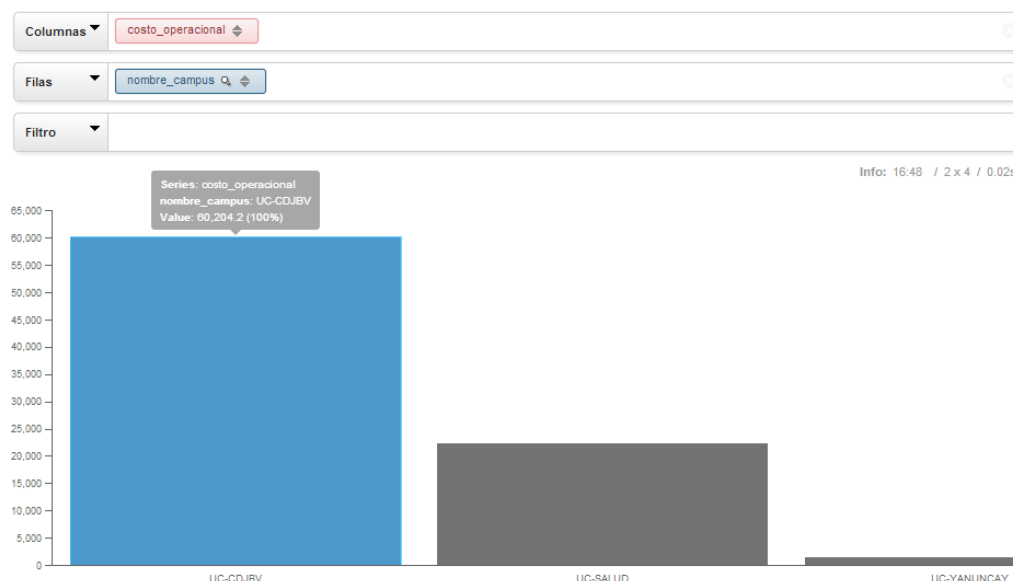
2. Figure 9 answers the second question posed: What is the number of loans of a particular librarian of a specific library branch in a time unit?



| username  | nombre_campus | unidades |
|-----------|---------------|----------|
| abcd      | UC-CDJBV      | 32       |
| acriollo  | UC-CDJBV      | 10.872   |
|           | UC-SALUD      | 4        |
| bcabrera  | UC-YANUNCAY   | 912      |
| dfajardo  | UC-CDJBV      | 5.156    |
| eduran    | UC-CDJBV      | 2        |
|           | UC-YANUNCAY   | 1.251    |
| fcriollo  | UC-CDJBV      | 1.561    |
| fruíz     | UC-CDJBV      | 48       |
| gsegarra  | UC-YANUNCAY   | 142      |
| gmartinez | UC-CDJBV      | 9.562    |
|           | UC-SALUD      | 12       |
| jmogollon | UC-CDJBV      | 4        |
|           | UC-YANUNCAY   | 1.617    |

Figure 9: Number of loans of a particular librarian of a specific library branch

- Figure 10 answers the third question posed: What are the operating costs of lending services of a particular library branch in a time unit?



**Figure 10: Operating costs of lending services of a particular campus**

## 5 Conclusion and Future Work

The main contribution of this work is the analysis and design of an iDSS for a university library through the case study analyzed. The distinguishing feature of the proposed architecture is the emphasis on the use of a holistic conceptual matrix to select the corresponding data sources. This decision implied integrating data from multiple and heterogeneous sources from the library, university, consortiums and suppliers, all of which use dissimilar formats and access methods including both structured and unstructured data. Consequently, an adequate selection of methodology and technological tools for constructing the DW was necessary to ensure the data warehousing success. Important to note is that, thanks to the use of the Hefesto methodology at early deployment time, library managers and stakeholders were able to realize the potential of implementing an iDSS solution in order to make tactical decisions about the optimal use and leverage of their resources and services. Library managers can use this iDSS tool to ensure that different perspectives are taken into account in a decision-making process. In addition, the iDSS provides the data-based justifications for managerial and economic decisions library managers must make.

Work in progress includes the further refinement of the existing reports, and the incorporation of additional sources to the integrated DSS such as the syllabus management system, citation analysis, and Web portal statistics, so as to collect a wider range of information. Future work will focus on the analysis of information using bibliomining techniques such as prediction and classification in order to track patterns of behavior-based artifacts from library systems and thus, predict future library requirements. Furthermore, the plan to use semantic technologies to extend the multidimensional model is also proposed to enable the proper integration of knowledge in a way that is reusable by several applications across libraries.

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