Solutions for decision support in university management

Soluţii pentru asistarea deciziei în managementul universitar

Andrei STANCIU, Ph.D.
The Bucharest Academy of Economic Studies, Romania
e-mail: andrei75@gmail.com
Mihai FLORIN, Ph.D.
The Bucharest Academy of Economic Studies, Romania
e-mail: fmihai@gmail.com
Cristina RĂDULESCU
The Bucharest Academy of Economic Studies, Romania
e-mail: mcrisrad@yahoo.com
Ofelia ALECA
The Bucharest Academy of Economic Studies, Romania
e-mail: ofemasec@gmail.com

Abstract

The paper proposes an overview of decision support systems in order to define the role of a system to assist decision in university management. The authors present new technologies and the basic concepts of multidimensional data analysis using models of business processes within the universities. Based on information provided by scientific literature and on the authors' experience, the study aims to define selection criteria in choosing a development environment for designing a support system dedicated to university management. The contributions consist in designing a data warehouse model and models of OLAP analysis to assist decision in university management.

Keywords: *university management, decision support, multidimensional analysis, data warehouse, OLAP*

Rezumat

Articolul propune o viziune de ansamblu asupra domeniului sistemelor informatice de asistare a deciziei şi încearcă să delimiteze rolul unui sistem de asistare a deciziei în managementul universitar. Sunt prezentate succint noile tehnologii în domeniu şi concepte de bază privind analiza multidimensională a datelor utilizând modele de analiză bazate pe activităţi din cadrul activităţii universitare. Pe baza informaţiilor furnizate de literatura de specialitate, dar si pe baza experienţei autorilor, se incearcă definirea unor criterii de selecţie în alegerea unui instrument pentru proiectarea unui sistem dedicat managementului universitar. Contribuţia adusă de acest articol constă şi în *proiectarea modelului unui depozit de date şi elaborarea cuburi OLAP dedicate asistarii deciziei în managementul universitar.*

Cuvinte-cheie: *management universitar, support de decizie, analiza multidimensională, depozit de date, OLAP*

JEL Classification: M15

Introduction

Instirutions in higher education around the world are facing with a wide range of problems such as the need of implementing required standards for quality in education, attracting valuable candidates and, of course, financial problems.

In order to solve such problems, decision makers must implement various reforms imposed by national and European legislations while maintaining organization's funds appropriately balanced.

Information systems, ranging from e-learning platforms to applications dealing with student records and study fees, though successful in supporting business process in universities, is not useful in assisting management in the decision-making process.

Managers need systems based on advanced technologies, which offers forecasting and analysis tools, being capable of providing valuable information and an analytical overview of the organization and, as such, capable of assisting decision in university management.

The research methods employed in this study required the information gathering in order to highlight the characteristics of decision support systems and their impact on university management, and comparative analysis to define criteria for selecting a development environment. Information was collected from recent scientific papers and technical specifications of systems designed to assist decision making.

Decision support systems and university management

A cardinal problem of the development strategy in European universities is to diversify the offer of study programs in order to fulfil the market requirements and to adapt to candidates' needs. In fact, preserving old educational structures is a condemnation to stagnation.

The researchers involved in the EU-funded project "Benchmarking in European Higher Education" (www.education-benchmarking.org/) reveal that "the quality is the key to support developments and in this context, enhancing university performance and modernising university management must be on the agenda of all university leaders and decision-makers in Europe."

Quality and efficiency in the university environment involves, first of all, quality decisions. Further, this paper focuses on developing IT technologies in order to support decision-making processes.

In recent years, decision support systems have grown increasingly sophisticated, incorporating multiple functionalities and components, in order to cater for various and complex business needs. Increase in volume of data stored in operational databases, legal constraints and technological progress are merely few of the challenges faced by this type of systems, aimed at assisting the decision-making process, in all its stages.

Power (2007) presents the evolution of decision support systems, starting from the 60's, the period of their emergence, when computerized models were used for assisting the decision-making process; cited sources include Raymond (1966), Turban (1967), Urban (1967), Holt and Huber(1969). Researches on decision support systems boomed in the 70's, leading to identification of various business fields in which decision support systems can be successfully used.

From the very beginning, decision support systems have been regarded as one of the most active components of information systems (Reix, 1990). Gorry and Scott Morton (1971) argue that "Information systems should exist only to support decisions".

Because of the immense popularity of decision support systems, they are regarded as extremely useful in various business areas, such as industrial processes, human resources, urban planning, education, healthcare, government or defence; in fact, irrespective of the field, decision support systems are key enablers of process optimization adding value to all business activities.

After analysing 217 papers, Eom SB, Lee SM, Kim EB and Somarajan C (1997) came up with a classification of papers on decision support systems, published by 19 prestigious publications in America and Europe over a period spanning 7 years (1988-1994). The largest number of papers concerns the field of "Corporate Functional Management", followed by far, by those on "Government" and "Education" (Figure 1).

However, in spite of this statistics, decision support systems are extremely useful in various areas within higher education, such as university admission (Elimam, 1991) (Mar Molinero, Qing, 1990), funds management (Tyagi, et al. 1988), course scheduling (Dinkel et al. 1989) and strategic management (Hornby et al. 1994).

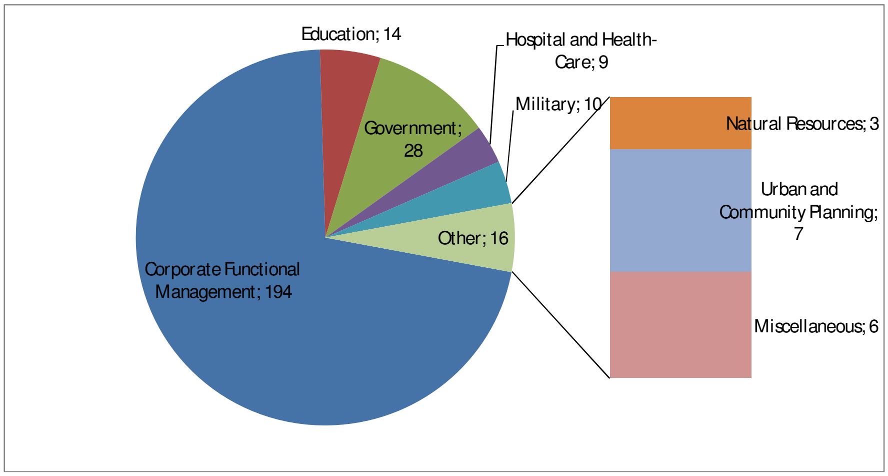

Figure 1 Structure on business fields of articles on decision support systems
Source: Eom SB, Lee SM, Kim EB and Somarajan C (1997)

In fact, management of universities is similar to that of organizations in any business field, as it is responsible for the efficiency of business processes within organization. The business environment universities are part of can be considered highly competitive, but unlike other organizations, universities cannot rely on market surveys in order to forecast the number and structure of potential students. In care of the university entry process, decision support systems can provide valuable data on the faculties and educational paths which are particularly appealing to potential candidates, alternatives solutions considered by candidates, analysis of geographical distribution of students relative to university location and various forecasts. However, due to multiple influences, many of them unpredictable, such as economic crisis, forecasting number of candidates in years to come may be impeded by some uncertainty.

Eom et al. (1998) thinks that decision support systems are interactive information systems defined by the following:

- They support the decision making process rather than replace it,
- They resort to data and models,
- They solve structured as well as poorly structured (Bonczek, 1981), semi-structured (Bennett 1983) or unstructured (Thierauf 1982) problems,
- Their main focus is the efficacy rather than the efficiency of the decision-making process.

The most important components of decision support systems are represented by applications offering forecast, optimization and chart functionalities; reports and dashboards generators, OLAP, as well as data mining tools. Technologies used for data storage and processing (Zaharie et al. 2001) may be grouped in three main categories:

- Data warehousing, which provides central storage for data from multiple and heterogeneous sources;
- OLAP (On-line Analytical Processing), which reorganizes data in multidimensional structures referred to as hypercubes, providing various analyses capacities adapted to large volumes of data;
- Data mining, which enables the discovery of new and valuable information in available data sources.

From transactional data to valuable information for decision-makers

Regardless of the business field, the decision-making process and its outcomes are hugely dependant on the quantity and the quality of the underlying information. As in case of most organizations business activities are supported by software systems which are meant to capture everyday business operations, it is obvious that these systems are significant sources of valuable information. Although the conversion of raw data which feeds such systems into information supporting business decisions is entirely transparent to decision-makers, the actual process is actually far from being trivial or straight-forward. We will briefly outline this process, emphasising what may be regarded as key constituents of the decision-making technical infrastructure: data warehouses built on top of data stores used by operational information systems, OLAP technologies and data mining.

Data warehousing

Operational information systems deal with business transaction data and they are meant to capture, as accurately as possible, the logic of a particular business process or functionality. As a consequence, data processed by such systems is extremely detailed and volatile, as it can be subject to frequent changes. It is also kept in data stores which are usually represented by relational databases, organized in multiple tables, according to E.F. Codd's rules. Trough a process called normalization, these rules enforce a specific structuring of data, usually fragmented into a large number of tables, which is directed at optimizing data inserts, updates, and deletions. However, though perfectly justified from a transactional perspective, this approach to data structuring has proven to be inadequate from a analytical perspective. That means that due to data fragmentation, sometimes even simple statistics may be difficult to perform, as they may require correlation of data stored in multiple tables.

As opposed to operational data stores, a data warehouse is a different kind of data store, as it is not designed according to the logic of business transactions and processes, but as a key enabler of business analysis and decision-making at all levels, within different areas of an organization. As operational data stores amass detailed data on business transactions, it is obvious that raw data needed for such analyses is already available, but it should be organized differently, according to major subjects of interest within a business or organization. In case of universities, for example, faculties, academic staff, departments, disciplines, students, date / time (which is a universal analysis criterion, irrespective of the business field) etc. are common element for conducting various analysis and, as such, for reorganizing data on grades, study fees, scholarships or other activity indicators in a manner which is dictated by analysis purposes, not by the logic of business processes.

A data warehouse may be regarded as a central repository which integrates data from multiple, even heterogeneous data stores (databases with various formats, spreadsheets or other files), used by operational systems. Though an organization might use a single database for recording daily business operations, it is still not recommended to adjust it to serve for analytical purposes as well, given that database optimization for analytical processing will deteriorate its performance in transactional processing, and vice versa. Given the differences in structuring and organization, migrating data from various operational data stores to a data warehouse, requires a process of reconciliation and data transformation. At the same time, it is worth mentioning that is common for data warehouses to exclude data items which, although relevant for various business processes, are not essential from a decision-making perspective; for instance, phone numbers and e-mails recorded in a student database may be left out of the data warehouse used as a decision support for university management.

As opposed to operational data, data stored in data warehouses is non-volatile, which means that once stored, it is not expected to be subject to updates or deletions. One consequence of this fact is that a data warehouse enables a historical perspective of the business. Another consequence is that it stores huge amounts of data collected over several years which may hinder performance of specific queries, which actually need a smaller set of data. In such cases, data marts solutions may be considered. Data marts and warehouses have similar features, except for the volume; in fact, a data mart is a smaller version of a data warehouse, which is partitioned according to specific criteria such as geographical region, period of time etc.

Dimensional modeling and OLAP

Although data warehouses amass huge volumes of data, collected over extended periods of time and organize it in order to facilitate fast responses to queries, they still store raw data. The role of converting this data into information which is useful to the decision-making process is performed by specific tools and applications, which enable various processing techniques ranging from simple browsing of the data to complex analysis. Such technologies, which are complementary to data warehousing, are commonly known as On-Line Analytical Processing – OLAP, a concept coined by E.F. Codd (Codd et al., 1993). In 1995, Nigel Pendse, of The OLAP Report, produced a set of basic requirements for OLAP systems, which should enable *Fast Analysis of Shared Multidimensional Information* (FASMI):

Fast: satisfactory query responses, in matter of seconds, even to ad-hoc queries

Analysis: various numerical and statistical data analysis, which may be predefined, as well as specified through ad-hoc queries

Shared: sharing of data across a large user base, within different areas of a business and granting access to OLAP reports from various locations, as in case of web applications

Multidimensional: multidimensional perspective (view) on business data

Information: enabling access to all the data that must be processed, in order to produce required information.

The multidimensional data views are commonly referred to as data cubes, expanding the usual, three-dimensioned and perception of cubes. In OLAP systems, data cubes integrate multiple perspectives on business data, so they may have as many dimensions as the business model allows. This approach to business data is achieved as a direct result of dimensional modeling, which basically aims at representing quantitative business data and statistical indicators, in direct relation to the corresponding business context. The main concepts in dimensional data modeling are measures, dimensions and facts and they are briefly described in what follows.

Measures represent numeric data, used to evaluate the business, from a quantitative perspective. In case of a university, examples of such measures may be the student marks for various examinations, incomes from study fees or examination fees, or scholarship payments.

Dimensions correspond to parameters which describe the business context associated with measures. For instance, a specific amount representing a study fee may be viewed in terms of period of time, student, faculty, or form of study (day or distance learning), each element corresponding to a distinct perspective, or dimension, along which business data can be analysed. For better serving analyses purposes, the values belonging to each dimension, commonly known as dimension members, may be organized on several levels, forming dimension hierarchies.

For instance, in case of time dimension, each year consists of two semesters, each semester includes six months, each month consists of a certain number of days etc.

Facts are collections of measures and context data. They typically refer specific business activities, associated with one and only one member from each dimension. For instance, recording a scholarship payment involves recording the actual amount plus the data required to identify the student, faculty, date etc.

However, apart from defining the context of business facts, dimensions may be perceived as collections of properties along which various analyses of numerical data may be performed. As direct consequence of the hierarchical structure of dimensions, measures may be aggregated above their initial granularity, at a lower or higher level, depending on the actual business needs, in order to calculate various indicators. For example, calculation of the full amount of examination fees corresponding to a specific day, month, semester etc. or, summarizing marks of students in the form of general averages per student, per year, or per faculty. In fact, in order to improve query performance, multidimensional applications need to pre-compute some of the summary data and explicitly store such aggregates.

Data mining

Apart from OLAP calculations, another type of analysis to be performed on data stored in data warehouses is represented by data mining. This concept covers a range of techniques and associated software instruments, which make use of certain algorithms in order to discover various patterns within business data, as well as relationships that may not be obvious otherwise. There are two common approaches to data mining. The first one, known as *exploratory* or *undirected* data mining, explores data in order to find anything that might be of interest (for example, such analysis may point to a certain relationship between curriculum structuring and average grades of students). The second, *directed* data mining, is usually performed on a regular basis, in order to solve a specific problem (for instance, poor student performance in exams), or to capitalize on a certain opportunity (such as the need for particular skills required on the labour market and reflected in the number of students demanding certain optional courses).

As a detailed description of data mining techniques and algorithms (decision trees, clustering, neural networks etc.) is beyond the scope of this paper, in a brief review of the main usages of data mining techniques, we enumerate the following: discovering unknown data associations (for instance the relationship between geographical regions where students live and the degree to which they pay their study fees), identifying patterns which lead to new organization of data (for example, by taking into account the optional disciplines chosen by students, specific student profiles may be defined), discovering patterns which may be used for making predictions about the future (for instance, if a correlation can be established between marks scored in certain disciplines, it can be used to make assumptions about future exams).

Criteria used in selection of tools for developing decision support systems for university management

As decision support systems transform data stored in databases in valuable information, a growing trend on the software market is integration of data analysis capacities in database management systems. The most prominent software producers to follow this trend are Microsoft, Oracle, IBM and SAP.

In 1998, Microsoft made an important step forward as a provider of OLAP technologies, by launching OLAP Services, an OLAP server distributed together with SQL Server 7.0. Analyses Sevices is a server application packaged with later versions of SQL Server, which can also be used with non-Microsoft products, such as databases implemented with IBM DB2 or Oracle RDBMS. The latest version, SQL Server Analysis Services (SSAS) 2008 provides OLAP functionalities, as well as data mining capacities which capitalise on a large number of algorithms (MSDN, 2009)

Among the most important functionalities in Microsoft SQL Server 2008 Analysis Services (SSAS) (Microsoft, 2009) we enumerate the following:

- *MDX scripts.* Multidimensional Expressions (MDX) are a new mechanism used for defining calculated members.
- *Business Intelligence Wizards*. It is an application that can be easily used by any user in order to solve complex Business Intelligence problems.
- *Data Mining*. Analysis Services offers data mining tools in order to produce a series of rules and models valuable for various purposes such as forecasting.
- *Integration* with other Microsoft applications (such as Office).

Although Microsoft achieved great success with Analysis Services, Oracle was the first provider of database management systems to acknowledge the importance of OLAP technology, by acquiring IRI's Express back in 1995. This product was later integrated with Oracle 9i, characterized by Oracle as the first engine for relational-mutidimensional databases (Rittman 2006), which offered OLAP as a separate option ("OLAP Option").

Unlike Microsoft, which uses its own query language, MDX, Oracle resorts to SQL (Structured Query Language). Oracle systems are able to process data coming from multiple sources, or produced by various applications, including Oracle E-Business Suite, PeopleSoft (part of Oracle Corporation), Siebel (Solution for customer relationship management), as well as SAP systems.

According to the producer (Oracle 2006), the benefits of Oracle solutions are the following:

• Business intelligence functionalities built on an integrated infrastructure which includes interactive dashboards, financial reporting tools, OLAP tools, real-time intelligent predictions and integration with Microsoft Office

• Universal perspective available for everyone, everywhere. That means that a relevant perspective on the business is offered not only to analysts, but to all interested professionals, on various levels within an organization, depending on services and access rights associated with user roles.

• Unified business model built on a business model which integrates metadata within Oracle business intelligence and analysis tools, in order to reduce TCO (Total Cost of Ownership).

• Integrated business intelligence infrastructure supporting any data source or ETL (Extraction, Transformation, Loading) tool, major business applications, analysis tools or database systems, including IBM DB /2, Teradata, Microsoft SQL Server, SAP Business Information Warehouse (BW), Microsoft Analysis Services, as well as XML(a model for storing unstructured and semi-structured data in databases) data and unstructured data.

In recent years there has been a strong trend of market consolidation, as successful products and brands of small software companies have been acquired by major players on the software market, which are interested in developing sophisticated application suites by integrating outsourced components, complementary to their own products.

Given the number of benefits, the cost of decision support systems is understandably high and as such, the decision of purchasing a system of this type is a major management decision in any organization. Referring to an *InformationWeek Research* survey on 230 professionals in business technologies, Whiting (2006) shows that, in the future, 44% of organizations will increase funds for business intelligence tools, 46% will allocate funds that are equal to those used at present and only 10% will diminish the respective funds.

Using another survey by *InformationWeek Research* with participation of 500 IT specialists, focused on expenditures on decision support applications (**Error! Reference source not found.**2), Hayes and Smith (2007) reveal that 40% of customers favour an Oracle solution, 38% a Microsoft solution, while 20 % of votes went to SAP. The small difference between these figures suggests that, because of the strong competition on software market, major producers offer similar services and tools directed at decision support. As a consequence, when choosing a particular solution, multiple factors must be considered, among the most important being user skills and preference for certain platforms and technologies, databases used for storing business data, as well as software systems and technologies that the organization owns, that interact with the decision-support system.

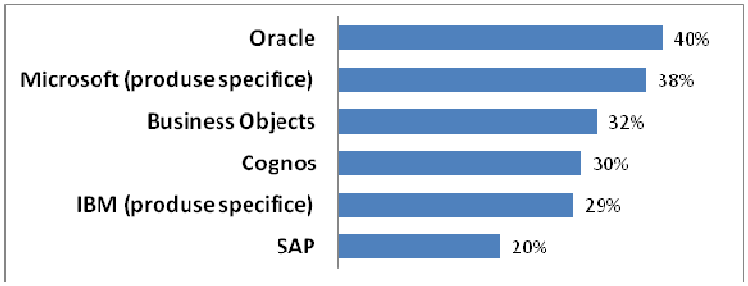

Figure 2 Most widely-used decision support systems
Source Hayes and Smith (2007)
Note: Multiple responses were accepted

Rittman (2006) believes that the most important factor to be taken into account when choosing an OLAP tool is the experience with a particular technology and operating system. As such, facile administration and configuration, as well as standardization on Windows platform lead to Microsoft Analysis Services. On the other hand, when concurrent access must be ensured for a large number of users, on a non-Windows platform, Oracle is the recommended solution.

A simplified data warehouse model for decision support in university management

Figure 3 captures a simplified version of data warehouse schema that can serve the purpose of multidimensional analysis in a university, as it concerns student performance and collection of various fees. The model employs a special type of schema, commonly known as constellation, which typically contains several fact tables (in this case, *Result* and *Receipt*) which share several dimension tables.

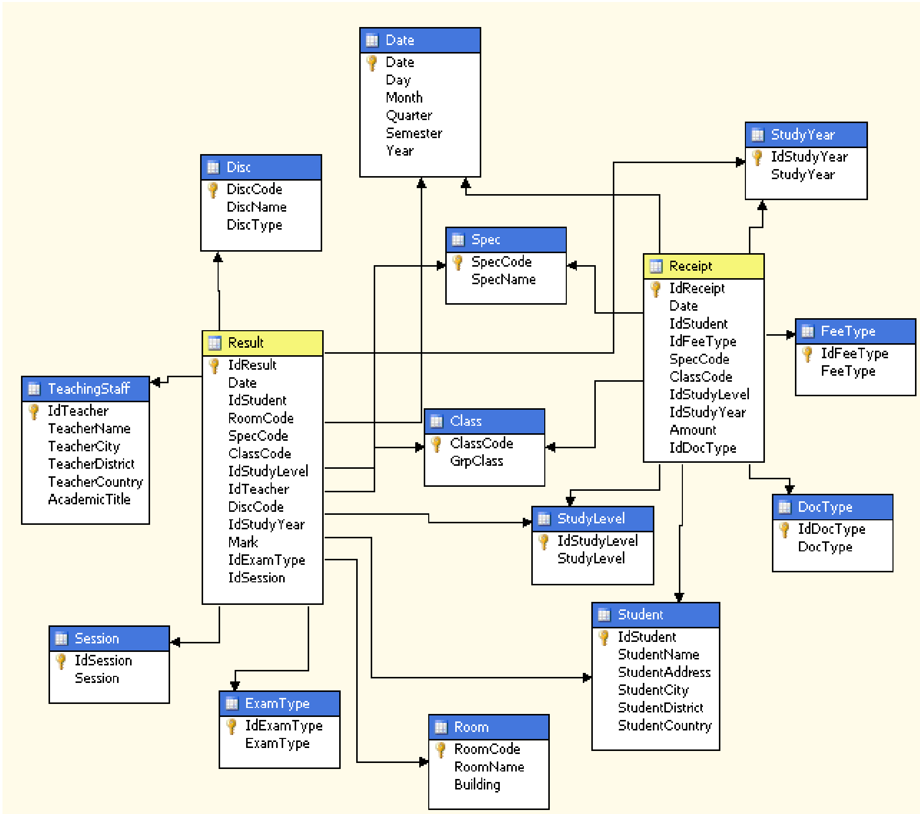

Figure 3 Simplified model data warehouse that stores student results and university fees

Employing this data warehouse as a source, several OLAP cubes have been developed in order to benefit from the flexibility and advantages of multidimensional analysis of business data managed by any university.

Figure 4 illustrates average grades scored by students in Finance and Management specializations, in exams concerning several core disciplines, over a three-year period (2007-2009).

Results presented in Figure 4 may be used by university management in order to evaluate the actual knowledge level and student achievement for both specializations and identify various trends in learning behaviour.

Study Level				
All				
		Spec Name		
		Finance	Management	Grand Total *
Disc Name	Year	AVGOfMark	AVGOfMark	AVGOfMark
⊟ Databases	2007	5.5		5.5
	2008	6.5		6.5
	2009			
	Total *	5.83333333333333		5.83333333333333
⊞ Expert Systems		8	7	7.33333333333333
⊟ Finance	2007	8.5	7	8
	2008	7.5		7.5
	2009	5		5
	Total *	7.4	7	7.33333333333333
⊞ Financial Accounting		6	6.5	6.4
⊞ General Accounting			6.5	6.5
⊟ History	2007	5.5	8.5	7
	2008	6.5		6.5
	2009		4	4
	Total *	6	7	6.42857142857143
⊞ International Accounting		4	6.25	5.8
⊞ Management		5	5.5	5.4
⊞ Programming Languages		7	6.33333333333333	6.6
⊞ SIAD		7.5		7.5

Figure 4 OLAP data for student performance analysis

Figure 5 presents students' attendance at exams, recorded over the same period (2007-2009) and analysed by examination type. The user may opt for selective display of data, restricted to specific study cycles (Graduate, Postgraduate, etc.).

Study Level						
All						
		Exam Type				
		Credit	Enlarge	Normal	Reprogramming	Grand Total *
Year	Student Name	CountOfMark	CountOfMark	CountOfMark	CountOfMark	CountOfMark
⊞ 2007				17	5	22
⊟ 2008	Coco MONTANA			2		2
	Florin ION			2		2
	Gelu MIHAI			2	1	3
	Gigi TUDOR	1		1		2
	Gina IANCU			2		2
	Izabella AGLIANI			2		2
	Michael TONY			2		2
	Pepe MARIO				2	2
	Robert YANG			2	2	4
	Titi FRANCU		1	1		2
	Total *	1	1	16	5	23
⊟ 2009	Coco MONTANA					
	Florin ION					
	Gelu MIHAI				1	1
	Gigi TUDOR					
	Gina IANCU					
	Izabella AGLIANI					
	Michael TONY			1		1
	Pepe MARIO				1	1
	Robert YANG			1		1
	Titi FRANCU				1	1
	Total *			2	3	5
Grand Total *		1	1	35	13	50

Figure 5 OLAP data for exam attendance analysis

Figure 6 captures an OLAP analysis of fee revenues that each specialization added to the university budget, over the 2007-2009 period.

	Spec Name		
	Finance	Management	Grand Total *
Year	Amount	Amount	Amount
2007	2448	3612	6060
2008	1300	2615	3915
2009	1360	1300	2660
Grand Total *	5108	7527	12635

Figure 6 OLAP data for annual revenue analysis, by specialization

Figure 7 illustrates an OLAP analysis conducted by the financial department, concerning annual university revenues per student and mean of payment, during the period 2007-2009. Such statistics may trigger various tests to determine why students are reluctant to use certain means of payment, or strategies for encouraging use of certain payment instruments issued by agreed financial institutions.

		Year			
		2007	2008	2009	Grand Total *
Doc Type	Student Name	Amount	Amount	Amount	Amount
⊟ Payment order	Coco MONTANA	1200	1300		2500
	Florin ION				
	Gelu MIHAI	12			12
	Gigi TUDOR				
	Gina IANCU	1200		1300	2500
	Izabella AGLIANI			15	15
	Michael TONY	1200			1200
	Pepe MARIO	12			12
	Robert YANG	12			12
	Titi FRANCU		15		15
	Total *	3636	1315	1315	6266
⊟ Receipt	Coco MONTANA				
	Florin ION	1200	1300		2500
	Gelu MIHAI			15	15
	Gigi TUDOR	1200		1300	2500
	Gina IANCU				
	Izabella AGLIANI	12			12
	Michael TONY		1300		1300
	Pepe MARIO			15	15
	Robert YANG			15	15
	Titi FRANCU	12			12
	Total *	2424	2600	1345	6369
Grand Total *		6060	3915	2660	12635

Figure 7 OLAP data for annual revenue analysis,
per student and payment instrument

Figures above show how data warehousing and OLAP technologies, implemented as easy-to-use software packages, may be used by university managerial staff for effective visualization and analysis of relevant information, aggregated on various levels, depending on actual business needs.

Conclusions

The transactional systems implemented in universities, such those for student records, are useful in supporting daily activities, but are not designed to support decision-making process.

The managers need support systems, based on advanced technology, which offers tools for analysis and forecasting, systems capable of providing valuable information and an accurate overview of the organization.

In recent years, decision support systems have a strong development and software companies invested in new technologies. Strong competition, led to the emergence of complex solutions, which provide tools oriented to decision support.
As a consequence, the choice of a particular solution must take into account several factors, among which the most important are users skills, their preferences for certain technologies and platforms and databases used to store data in organizations.

OLAP and data warehouse technologies are efficient solutions for data analysis and can provide the necessary support to assist decision in university management.

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