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Advancing University Management Decision - Making Through Data Warehousing and OLAP - Driven Decision Support Systems

Hakan Ergun[1], Dr. Giorgi Ghlonti[2], Dr. Irakli Rodonaia[3]

[1]International Black Sea University, PhDc
Email: *hergun[at]ibsu.edu.ge*

[2]Professor, International Black Sea University
Email: gghlonti[at]ibsu.edu.ge

[3]Professor, International Black Sea University
Email: *irakli.rodonaia[at]ibsu.edu.ge*

Abstract: ***In optimizing the university's business processes, there is also a mix of operational, academic, and administrative 'ingredients', which often requires the decision - maker to mediate between the insights protruded by data and those based on people and the institution. The major challenge is associated with the disintegration of the data concerning processes, which is collected from various sources and needs to be integrated into a unified system to support decision - making. To this end, the current study attempts to advance the concept of a Decision Support System (DSS), which is designed to aggregate data from many sources and analyze it to make sense to university managers. This paper aims to review the basic concepts of the DSS, the role of the DSS in simplifying and improving the business processes of the universities, and the design of the interactive DSS model with operational and strategic perspectives. Moreover, the research identifies the core disciplines that enhance the functionality of DSS, including decision analysis, data warehousing, and OLAP systems. The primary focus of this work is to strengthen university operations by introducing a solid structure in the form of a data - driven DSS that will allow the various stakeholders to use the system to make informed decisions.***

Keywords: OLAP, Multidimensional Data Analysis, Business Process Management, Bus Matrix, University Management

1. Introduction

However, strategic decision - making in the university's business processes comes with significant challenges, primarily acceptable in the vast and unstructured nature of the data involved. University management and directors often rely on database specialists to operate with such data and cannot harvest such data into actionable insights. To make matters worse, longitudinal studies over multiple years must be done to establish trends toward student enrollment, budgetary control, and resource allocation, among other elements, to enhance the institution's performance. Unfortunately, typical database systems do not function in an ideal fashion to complement the nature of complexities involved in such processes or provide the required type and level of analysis. In response to these challenges, the integration of a new Decision Support System (DSS) that utilizes data warehousing technology emerges as an effective and unique strategy by combining and analyzing diverse data sources through the decision support system, data availability, and levels of analysis needed increases in a way that empowers the university management to make thorough and appropriate decisions in an organization on the vital aspects of the institution including academic, financial and operational elements.

Universities are venues for fairs and creative and profitable data generation and delivery about financial, administrative, and social matters. Senior heads such as Rectors, Deans, experts, and different teammates help them achieve their pressing objectives. Data/information on the subject should be treated as part of possible decisions for actions and methodologies for review. It is likewise crucial to include in an implementation evaluation the activities and skilled organization of educational institutions with instruments and tools, parts in state - of - the - art technological advancement [1]

According to recent research [2], a problem arises when a system fails or does not perform as expected. However, problem - solving is more than addressing failures; it also involves identifying new opportunities. Problem - solving is one of the most critical functions within an organization. The process begins with decision - making, which serves as the foundation for resolving issues.

Everything starts with the research phase, which marks the beginning of the entire process. The goals, urgent issues, and needs are addressed and defined in this case. At this stage, for example, different options are being sought, and, for instance, different options are being sought and devised. Such progress paves the way for the selection phase. This is the phase whereby an organization chooses a particular strategic course of action. After that comes the implementation phase, in which the decision is acted upon. Finally, the implementation is appraised in the last monitoring phase to establish if the stated objectives have been achieved. Should there be the need for such modifications, this is done to ensure the set goals have been attained. Management information systems that depict institute business processes, such as the e - learning, study fee, and student record processing systems, may be welcomed but do not help management regarding decision - making.

Managers within university administration need state - of - the - art technology - based systems to aid decision - making. Such systems should provide tools for forecasting and analysis, relevant information, and a business analytics perspective on the organization. This research used comparative analysis and information gathering to highlight the characteristics of DSSs and their impact on university administration and provide guidelines for selecting a development environment. Applications that offer prediction, optimization, and charting based on OLAP and data mining tools are significant components of decision support systems. The technologies used for data processing and storage can be classified into three main categories. Data warehousing is an essential tool that is useful for centrally storing data from a variety of diverse sources. Data mining, which applies easily accessible data sources to discover previously unknown yet helpful information. Online analytical processing, or OLAP, transforms data into multidimensional structures called hypercubes and provides various functions suitable for performing advanced analysis on large datasets.

Transforming Transactional Data into Valuable Insights for Decision - Makers

Most companies today have realized the importance of knowing how to turn their transactional data into a tool that fosters positive decision - making. In our day - to - day functions, we often use our judgment to make choices. Businesses, which are mainly run through computer systems, are grappling with unmeasurable amounts of unstructured data. However, converting knowledge to information, which drives decisions, is always complicated. There are three major processes: data warehouses in the operational database, OLAP technology, and data mining, all of which are tightly linked. These processes serve the purpose of information generation from the available data and thus impact both strategic and operational planning.

As the staff developing information systems that support ground - level activities do not have the models of the overall enterprise at their disposal, information systems supporting operational - level activities designed to serve the needs of particular facets do not consider the possible need for data exchange between different organizational units. Hence, the data arising in different subsystems could be more consistent and relevant to the decision - maker, and data collection for managerial decision - making takes considerable time and expense [3]. The predominant method for data representation within data warehouses is the multidimensional model. This model organizes key business events, or facts, within a multidimensional "cube, " aligning them along various hierarchically structured dimensions to offer varying levels of detail. Multidimensional data models enable users to view data from different perspectives. They leverage online analytical processing (OLAP) to generate analytical queries on these cubes. Existing OLAP systems provide BI users with various tools for constructing such queries. The relationship between enterprise architecture and organizational ontology is established through the so - called Bus matrix. The Bus matrix is a structure that allows each instance from organizational ontology to denote the business process that provides data for its facts and dimensions.

An example of a bus matrix for educational institutions is given in Table 1 below:

Mapping University Business Processes to Ontological Entities for Organizational Analysis

Table 1: Relationship between university business processes and ontologies, highlighting key connections (marked 'C') that support various operational and academic functions.

University Business Processes	Ontologies													
	Degree Program	Courses	Student	(Student?) Service	Qualified Examination	Library	Teaching Staff	Non - teaching Staff	Management Staff	Laboratory	Placement	Examination Branch	Classes	Donors
Admission			C								C			
Registration		C	C	C	C									
Financial Aid			C											
Academic Advising		C	C				C							
Graduation	C	C	C											
Student Services			C	C										
Research						C	C	C	C					
Faculty Management		C	C	C		C	C	C?	C?	C				
Facilities Management										C?	C?			
Fundrising														C
Financial Aid			C	C										
Financial Office														

This table maps university business processes (e. g., Admission, Registration, Research) and ontological entities (e. g., Degree Program, Courses, Student, Staff). The entries marked with "C" indicate a connection or dependency between a process and an entity, signifying its relevance or involvement in that process. This framework aids in understanding how various organizational components interact to support the university's operations, facilitating process analysis and optimization.

While describing relationships between business processes and instances that make ontology, the Bus matrix does not provide information about the content of data aggregates; acquiring this information requires further enterprise architecture analysis at the level of particular business processes (and applications that support them). For this reason, we use so - called SIPOC diagrams, where each process is represented as a supplier of information, the information input itself, the output, and consumers. An example of a SIPOC diagram for the business process “Admission, ” which is one of the primary sources of information about students applying to university, is given in Table 2 below:

DB File Name: NAEC - Georgia (National Assessment and Examinations Center)

Supplier	Input	Process	Output	Customer
NAEC	• NAEC Result	Admission	Record of student in Student Information System	
IRO	• Application Form* • NAEC Recognition			
External Mobility	• Application Form* • Requested Document Package			
Student	Admission Form (Application Form?)			
Payment System	Tuition Fee			
* Some more processes involved before final record. (language proficiency)				

Table 2 Admission Process Flowchart: Depicting the Inputs, Processes, and Outputs Involved in Student Admission, Highlighting Key Stakeholders Such as NAEC, IRO, External Mobility, Students, and Payment Systems

The "NAEC Result" file structure is in the bus matrix above. The "Students" table has been highlighted when organizing and evaluating student data for university management, as it contains several essential characteristics. The table details each attribute, stating the data source, constraints, and type. This matrix was critical in determining data's completeness, accuracy, and reliability in any database. The "Students" table contains a wide variety of personal and school - related information on each student in the "NAEC Result File" database. This can be sourced from NAEC. With the structure of NAEC, it will be used effectively for business operations like registration, admissions, and many more. The table layout is also designed to aid in strategic planning and data - driven decisions in the future beyond the immediate needs imposed.

Bus Matrix for Student Table Based on Admission and Registration Criteria

Table 3: Mapping of University Business Processes to Student Data Attributes: Admission and Registration Phases

University Business Processes	Student Table Attributes	Source
Admission	*s_id*	System
	s_start_year	The year the student started their studies.
	s_fac_id	F (s_dir_id)
	s_dir_id	NAEC Result. Higher Educational Institution Info. Educational program code | IRO NAEC Recognition. Educational program
	s_name_eng	Online form. Name En | IRO NAEC Recognition. Name En
	s_surname_eng	Online form. Surname En | IRO NAEC Recognition. Surname En
	s_name_ge	NAEC Result. Personal Information. Name | IRO NAEC Recognition. Name Ka
	s_surname_ge	NAEC Result. Personal Information. Surname | IRO NAEC Recognition. Surname Ka
	s_citizenship	default Georgia | Online form. Country | IRO NAEC Recognition. Country
	s_gender	Online form. Gender | IRO NAEC Recognition. Gender
	s_passport_number	NAEC Result. Personal Information. Personal ID (PID) | IRO NAEC Recognition. Personal ID (PID)
	s_email	Online form. Email | IRO NAEC Recognition. Email
	s_mobile_phone	NAEC Result. Personal Information. Phone number (mobile) | IRO NAEC Recognition. Phone number (mobile)
Registration	*s_student_id*	F (s_fac_id, current_year)
	s_major	
	s_status	default 1
	s_sector	F (s_dir_id)
	s_type	default 1
	s_level	F (s_dir_id)

Bus Matrix for "NAEC Result" Output DB File

DB File Name: NAEC - Georgia (National Assessment and Examinations Center)

The "NAEC Result" file structure is in the bus matrix below. The "Students" table has been highlighted when organizing and evaluating student data for university management because it contains several essential characteristics. The "Students" table contains a wide variety of personal and school - related information on each student in the "NAEC Result File" database. This information can be sourced from NAEC. NAEC's structure will be used effectively for business operations like registration, admissions, etc. The table's layout is also designed to aid in strategic planning and data - driven decisions in the future beyond the immediate needs imposed.

To build the university business process matrix for the student registration process based on the given structure, I will first identify the key components related to student registration, using the provided table attributes to determine their roles and sources.

In the case of applicant tracking, prospective students progress through a standard set of admissions hurdles or milestones. You may be interested in tracking activities around key dates, such as initial inquiry, campus visit, application submitted, application file completed, admissions decision notification, and enrollment or withdrawal. At any point, admissions and enrollment management analysts are interested in how many applicants are at each stage in the pipeline. The process is much like a funnel, where many inquiries enter the pipeline, but more progress is needed through the final stage. Admission personnel would also like to analyze the applicant pool using a variety of characteristics.

University Business Process Matrix for the Student Registration Process

Process Step	Data Used	Source	Purpose/Outcome
Student Pre - Registration	- s_name_eng - s_surname_eng - s_name_ge - s_surname_ge - s_citizenship - s_gender - s_email - s_mobile_phone	Student Online Form NAEC Results IRO NAEC Recognition	Collect basic personal and contact information from students for records.
Student Identification	- s_id - s_passport_number	System NAEC Results	Assign unique IDs and verify students' identities for system integration.
Program Enrollment	- s_fac_id - s_dir_id - s_major - s_level	NAEC Results Educational Program Database	Match students to appropriate faculties and academic programs based on their credentials and choices.
Student Unique ID Creation	- s_student_id - s_fac_id - s_start_year	System (Derived: Faculty ID + Current Year)	Generate a unique student ID for tracking and system processing.
Academic Tracking	- s_sector - s_level - s_status - s_type	Directorate ID System NAEC Results	Categorize students for academic analysis and sector - based resource planning.
Post – Registration Updates	- s_status	System	Update the status (e. g., active, graduated) to reflect students' academic progress.
Communication	- s_email - s_mobile_phone	System Student Online Form	Ensure smooth communication for administrative and academic purposes.

Table 4 University Business Process Matrix for Student Registration Process: A detailed representation of key steps, data attributes, sources, and their respective purposes in managing the registration and lifecycle of university students.

Each step in the process corresponds to a phase of student registration and lifecycle management. Attributes like ***s_sector, s_type***, and ***s_level*** play roles in classifying and categorizing students post - registration, while ***s_id*** and ***s_student_id*** are critical for tracking and database consistency.

Sources such as NAEC Results and IRO NAEC Recognition emphasize the integration of external data to validate student qualifications and credentials.

Olap Diagram

The work of [4] highlights the use of online analytical processing (OLAP) in business intelligence (BI) systems, enabling users to analyze multidimensional data from various perspectives. OLAP facilitates the examination of complex datasets through techniques such as querying with languages such as SQL or MDX, which offer flexibility in data retrieval. However, these queries can be time - consuming and cognitively demanding for many users. Alternative tools such as graphical OLAP clients, parameterized reports, and dashboards can overcome this challenge. These tools provide more user - friendly and comprehensive solutions for accessing and analyzing data in BI systems.

Data warehousing remains a fundamental component of modern business intelligence (BI) and analytics. It provides a platform for integrated, clean, and consistent data appropriately structured for analysis. The predominant method for representing data within data warehouses is the multidimensional model. This model organizes key business events or facts within a multidimensional "cube, " aligning them along various hierarchically structured dimensions to offer varying levels of detail.

Multidimensional data models enable users to view data from different perspectives, leveraging online analytical processing (OLAP) to generate analytical queries on these cubes. Existing OLAP systems provide BI users with various tools for constructing such queries. While query languages like SQL or MDX offer a flexible and customizable means to query data warehouses, they are often time - intensive and cognitively demanding, as noted by [5]. To mitigate these challenges, alternative tools and interfaces are available to streamline the querying process.

It needs to define the fact table and dimension tables that will be part of this OLAP schema. In this case, since the data revolves around students, their attributes, and their educational details, we can structure it as follows:

An OLAP cube typically includes the following:
Facts: The factual information that can be analyzed, such as the number of students or specific population subgroups.
Dimensions: Here are attributes considered as slicing and dicing the facts.

Fact Table (Students): This table provides quantitative information about students, including their unique number, year of enrollment, faculty ID, directorate ID, primary specialization, student status, sector, category, and level of education obtained.

Dimension Table (Personal Information): This table contains descriptive information about the students, such as their first names and family names in English and Georgian scripts, country of citizenship, month of birth and sex, and the types and numbers of their international passports.

Dimension Table (Contact Information): This table contains the students' mailboxes and unique telecom numbers, including mobile ones.
This structure allows for the performance of a broad range of analyses and the reporting of student data, using OLAP technology to utilize multi - dimensional queries.

Development of a Multidimensional Data Model for Student Admissions Analytics: Integration of Fact and Dimension Tables

Fact Table: Students
The fact table will contain measurable data about students. For this example, the key attributes from the provided list will be included in the fact table, and other related attributes will be organized into dimension tables.

Facts

Student Fact Table:
- s_student_id (Primary Key, Fact identifier)
- s_status (Fact attribute: status of the student)
- s_type (Fact attribute: student type)
- s_sector (Fact attribute: student sector)
- s_level (Fact attribute: academic level)

Dimension Tables
The dimension tables will contain descriptive attributes that provide context to the data in the fact table.

Dimensions

1) **Faculty Dimension**:
- s_fac_id (Primary Key)
- s_dir_id (Link to directorate)
- s_sector (Derived from s_dir_id)
- s_level (Derived from s_dir_id)

2) **Major Dimension**:
- s_major (Field of study)

3) **Personal Information Dimension**:
- s_student_id (Link to fact table)
- s_name_eng, s_surname_eng
- s_name_ge, s_surname_ge
- s_citizenship
- s_gender
- s_passport_number
- s_email, s_mobile_phone

4) **Educational Program Dimension**:
- s_dir_id (Primary Key)
- Related programs from NAEC data

5) **Time Dimension**
- (Optional, based on year tracking in s_student_id):
- current_year

The OLAP diagram will have the "Students" fact table at the center, with links to the dimension tables "Personal Information" and "Contact Information. "

OLAP Schema for Student Data Analysis: This diagram illustrates the multidimensional data model designed for student - related analytics. The central fact table, the Student Fact Table, aggregates the key. The OLAP diagram will feature the "Students" fact table at the center, connected to the dimension tables "Personal Information" and "Contact Information. "

OLAP Schema for Student Data Analysis: This diagram represents the multidimensional data model created for student analytics.

The primary data table, the Student Fact Table, consists of consolidated measurable values and has five linked dimensions: Faculty, Major, Personal Info, Educational Program, and Time. Each dimension is helpful for more complex queries and reporting, enabling an in - depth understanding of the academic, social, and institutional metrics. It is linked to five dimensions: Faculty, Major, Personal Info, Educational Program, and Time. Each dimension provides granular details for advanced querying and reporting, enabling comprehensive insights into academic, demographic, and institutional data.

OLAP Schema Diagram

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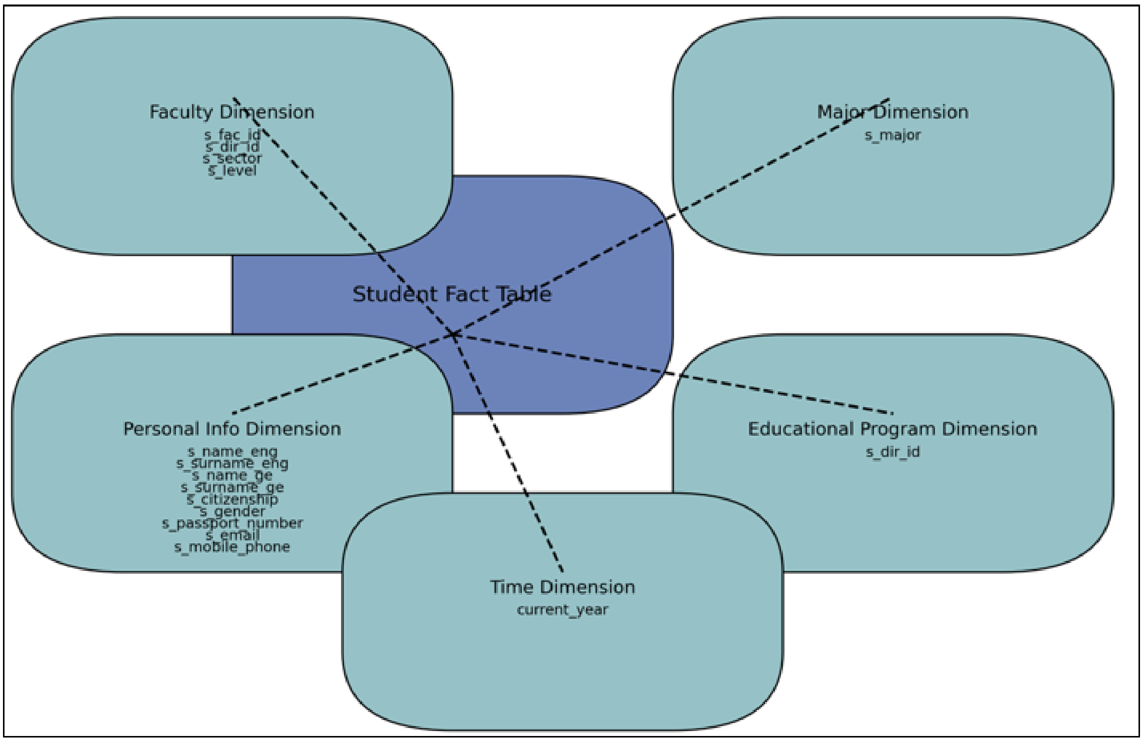

Figure 1: OLAP schema for student data analysis, showing a central fact table linked to dimensions—Faculty, Major, Personal Info, Educational Program, and Time—to enable multidimensional querying and reporting.

A Focus on the "NAEC Result" Output DB File

The bus matrix for the output database file "NAEC Result" includes the "Students" table, representing a comprehensive and elaborate structure such that all necessary attributes are captured and sourced accurately. In this regard, it would be appropriate for data management and the facilitation of several university business processes such as admissions, registration, and advising. The matrix brings out the significance of each attribute, its type, and its source to ensure that the clarity and consistency of the data are handled and used. The sources, however, need to be further elucidated for accuracy and reliability.

2. Conclusion

Applying Decision Support Systems (DSS), a combination of sophisticated OLAP capabilities and data warehousing technology, offers a new perspective on university management and decision - making processes. It is worth noting how critical the role of the DSS is in facilitating the transformation of unprocessed data structures and bringing them as an executive in favor of both tactical and strategic management decisions. University managers can resolve data integration and its complexity issues through the use of a very sophisticated data framework, hence achieving a better and more robust description of the analysis models.

The paper highlights the importance of multidimensional data sets in making good decisions. OLAP analysis aims to sort and analyze vast arrays of information on many parameters so that the administrator can determine the direction of activity, control the distribution of resources, and improve student performance. Creating specific structures like bus matrices and multidimensional schema also aids in turning operational data into meaningful business intelligence.

This study has outstanding implications. It indicates that using such advanced DSS tools reduces the complexities of institutions' decision - making processes and enhances data management within university organizations.

Universities have the potential to implement an efficient decision - making environment by integrating data warehousing, OLAP, and predictive analysis, which would, in turn, meet the changing trends in academic and administrative activities.

Considering the above, this research recommends the tactical promotion of DSS technology for better university performance. Future studies may investigate the extent of systems such as these and their applicability in other areas of academia and the general world outside the university prism. Moreover, developing intuitively designed and user - friendly interfaces and relevant training courses for users of decision - making systems would increase the chances of these systems being adopted and used effectively. The deployment of DSS in university administration is not only a state - of - the - art technology but rather a building block to the institution's standards and innovations.

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