7-12-2014

Designing and Implementing a Data Warehouse using Dimensional Modeling

VINAYA GANAPAVARAPU

VINAYA BHARADWAJ GANAPAVARAPU

Candidate

COMPUTER ENGINEERING (ECE)

Department

This thesis is approved, and it is acceptable in quality and form for publication:

Approved by the Thesis Committee:

GREGORY L. HEILEMAN, Chairperson

TERRY J. TURNER

CHRISTOPHER C. LAMB

Designing and Implementing a Data Warehouse using Dimensional Modeling

by

Vinaya Bharadwaj Ganapavarapu

B.Tech., Jawaharlal Nehru Technological University, 2008

THESIS

Submitted in Partial Fulfillment of the
Requirements for the Degree of

Master of Science
Computer Engineering

The University of New Mexico

Albuquerque, New Mexico

May, 2014

Dedication

To my family.

Acknowledgements

I would like to thank my advisor, Professor Gregory Heileman and committee members Terry Turner and Christopher Lamb for their patience, help and support. I would also like to thank Rita Abeyta from the Office of Institutional Analytics, UNM for helping me in understanding higher education data.

Designing and Implementing a Data Warehouse using Dimensional Modeling

by

Vinaya Bharadwaj Ganapavarapu

B.Tech., Jawaharlal Nehru Technological University, 2008

M.S., Computer Engineering, University of New Mexico, 2014

Abstract

As a part of the business intelligence activities initiated at the University of New Mexico (UNM) in the Office of Institutional Analytics, a need for a data warehouse was established. The goal of the data warehouse is to host data related to students, faculty, staff, finance data and research and make it readily available for the purposes of university analytics. In addition, this data warehouse will be used to generate required reports and help the university better analyze student success activities.

In order to build real-time reports, it is essential that the massive amounts of transactional data related to university activities be structured in a way that is optimal for querying and reporting. This transactional data is stored in relational databases in an Operational Data Store (ODS) at UNM. But for reporting purposes, this design currently requires scores of database join operations between relational database views in order to answer even simple questions. Apart from affecting performance, i.e., the time taken to run these reports, development time is also a factor,

as it is very difficult to comprehend the complex data models associated with the ODS in order to generate the appropriate queries.

Dimensional modeling was employed to address this issue. Dimensional modeling was developed by two pioneers in the field, Bill Inmon and Ralph Kimball. This thesis explores both methods and implements Kimball's method of dimensional modeling leading to a dimensional data mart based on a star schema design that was implemented using a high performance commercial database. In addition, a data integration tool was used for performing extract-transform-load (ETL) operations necessary to develop jobs and design work flows and to automate the loading of data into the data mart.

HTML reports were developed from the data mart using a reporting tool and performance was evaluated relative to reports generated directly from the ODS. On average, the reports developed on top of the data mart were at least 65% faster than those generated from directly from the ODS. One of the reason for this is because the number of joins between tables were drastically reduced. Another reason is that in the ODS, reports were built against views which when queried are slower to perform as compared to reports developed against tables.

Contents

List of Figures

Chapter 1

Introduction

1.1 Overview

The University of New Mexico (UNM) had nearly 30,000 students enrolled in 2011 and enrollment has steadily increased by 24% as compared to the year 2001. With a wide range of programs and courses, increase in enrollment each year and sometimes more than one instructor per course, one can imagine the complexity and volume of data that would have been accumulated over the years.

To ensure success of students, it is important to track their progress each semester, i.e., to track if a student has reached a certain achievement level or not, meeting the academic needs of students, establishing and accomplishing short-term and long-term goals. Currently, only quantitative questions like number of students served or number of students receiving a passing grade in a course and so on determine measures taken to ensure progress of students. Such reports however do not enable deeper understanding, for instance, growth of a student in a given time period, comparing growth over years and factors contributing to this.

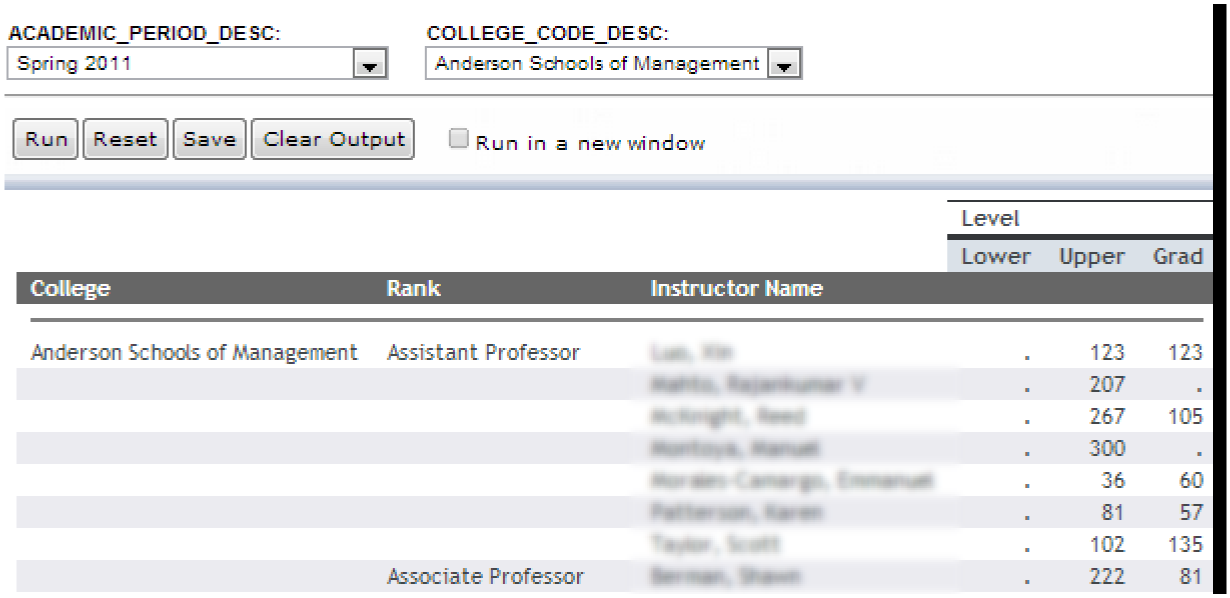
With sufficient historical data, it is now the time to make proper use of it. It is very important to make data-based decisions. With a proper understanding of the needs of business users, decision makers and policy makers, the historical data and also the new data can be logically modeled to support decision-making or business intelligence.

There are two steps to the business intelligence process. One, is to build a data model to support the reporting requirements of users which will help them track progress and success and the second is to build a predictive data model that will help the policy and decision makers by providing a better vision for the purpose of decision making.

The University of New Mexico currently has an operational data store (ODS) which is being used to serve as the back-end to generate many reports or to cater to many applications that were developed for the academic or the executive offices. But with changing needs, the database design of ODS is not efficient enough to support analytics that need to be developed.

Finally, the difficulty associated with generating the reports necessary to answer specific questions needs to be addressed. This is very difficult to comprehend the ODS table structure given the way it is defined and many users utilize the views in ODS to build their reports; a very time consuming process. Reports built on top of ODS views take a long time to run as views are not physically populated in the database, rather they are just a logical representation of data in tables.

Consider an example as in Figure 1.1 where a report is generated for student credit hours (sch) generated by faculty filtered by college in a given academic period. This report requires a drop down on the academic period and when one of them is selected, the ODS view needs to be queried and calculations need to performed on the fly. This process of querying an un-indexed view with hundreds of columns and



College	Rank	Instructor Name	Level: Lower	Upper	Grad
Anderson Schools of Management	Assistant Professor	[illegible]	.	123	123
		[illegible]	.	207	.
		[illegible]	.	267	105
		[illegible]	.	300	.
		[illegible]	.	36	60
		[illegible]	.	81	57
		[illegible]	.	102	135
	Associate Professor	[illegible]	.	222	81

Figure 1.1: Student credit hours generated by faculty.

performing calculations while generating the report consumes an undesirable amount of time.

1.2 Proposed Solution

A current need, therefore involves the need to design a database that supports reporting, analytical and decision-making capabilities for executive offices at UNM. An efficient way to solve the problem mentioned in the previous section, is to use one of the industry standard methods in order to design a data warehouse that will provide a platform for running reports and to develop analytics. Bill Inmon and Ralph Kimball are the two pioneers in the theory of building data warehouses. Kimball's method of approach to developing data warehouse was chosen over Inmon's method. The design and implementation of the data warehouse using Kimball's approach as described in [1] will be the main focus of this thesis. The data warehouse will contain

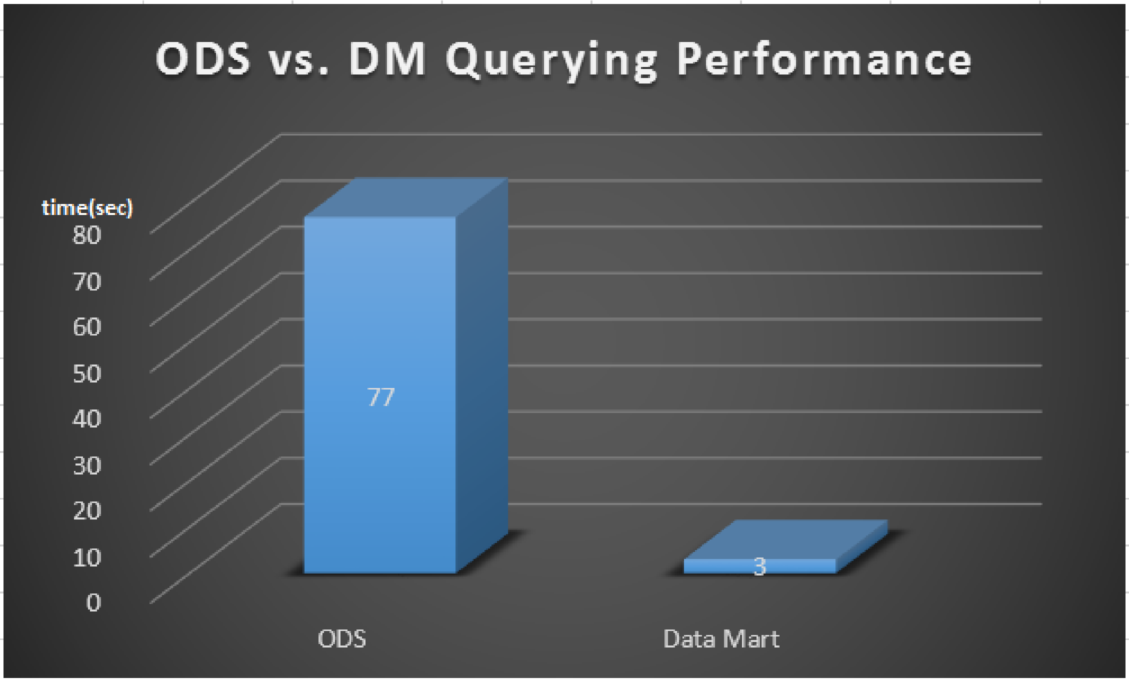


Figure 1.2: ODS versus data mart performance.

data related to students, faculty, staff, finance, research, space, academic outcomes to list a few.

It is evident from the example shown in Figure 1.2 which demonstrates the performance of the data mart against ODS. When a SQL query involving joins between two tables and group by and order by clauses, the data mart returns the results in 3 seconds where as the ODS takes around 77 seconds to return the same results.

Chapter 2

Background

2.1 Existing philosophies on data warehouses

With exponential growth in data and with increasing interest to analyze and understand it to derive some knowledge out of it, it is absolutely necessary that the historical data be stored in a manner that can be easily analyzed. It is also important to derive some important statistics and various performance metrics. But this cannot be effectively implemented using the ODS. The data needs to be reorganized into a dimensional model.

A third normal form (3NF) is an entity relationship (ER) model where the tables are normalized to a state where there is no data redundancy, attributes in an entity are solely dependent on whole of the primary key of the entity. A primary key can be just one attribute or a composite key consisting of two or more attributes.

The 3NF was initially defined by E.F.Codd and was later expressed differently by Carlo Zaniolo. According to [5], it is defined as follows.

> A table is in third normal form (3NF)if and only if for every nontrivial

> functional dependency X → A, where X and A are either simple or composite attributes, one of two conditions must hold. Either attribute X is a superkey, or attribute A is a member of a candidate key. If attribute A is a member of a candidate key, A is called a prime attribute. Note: a trivial FD is of the form YZ → Z.

A 3NF ER model is good design to handle transactional data. Examples for transactional data are courses taken by students in each term, proposals filed by each principal investigator each year and so on. This type of design is good for performing quick inserts, updates and deletes because the tables usually have a small number of fields with foreign keys to other tables.The reason behind this is that, to generate a simple report one would end up joining scores of tables in a 3NF environment which ends up being very time and resource (hardware) intensive. Apart from this, the model becomes very complex very quickly as a result of which it becomes very difficult to understand and navigate the model even for a developer let alone a business user.

To address this problem, Bill Inmon in Figure 2.1 proposed an idea with a top-down approach and named the system as corporate information factory (CIF) defined in [2]. The components of a CIF include a data warehouse which is built in 3NF and individual de-normalized data marts which are populated from the data warehouse. These data marts cater to individual business process needs. Reporting cubes are built as required on top of the data marts. The data warehouse as defined by Bill Inmon, contains enterprise data without any redundancy at the lowest level of detail i.e., transactional data in 3NF.

According to Inmon, a data warehouse is subject-oriented, non-volatile, integrated, time-variant and has no virtualization.

Another pioneer, Ralph Kimball proposed his own version of a data warehouse

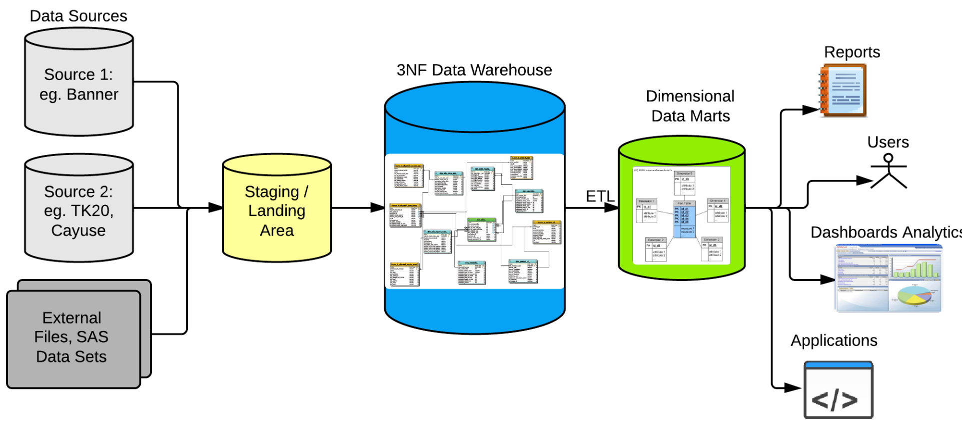


Figure 2.1: Inmon data warehouse Architecture [2].

Figure 2.2 which is termed as a bottom-up approach. A data warehouse as defined by Kimball in [1] is the conglomeration of all individual data marts. These data marts are built using dimensional modeling. Each data mart contains data specific to a business process. This method was chosen as part of business intelligence architecture that has been implemented at UNM.

The benefits of dimensional modeling technique are:

Better data navigation and presentation: The logical data model is designed in a way that is easy to understand and navigate even for business users. This enables them to build their own reports.

Easy and low-cost maintenance: The data is stored in the same way as it is presented unlike in the case of relational databases where in most cases views are built in order to build any reports. This increases the maintenance cost in the case of relational databases or ODS.

Better performance: Most reports require summarized data which results

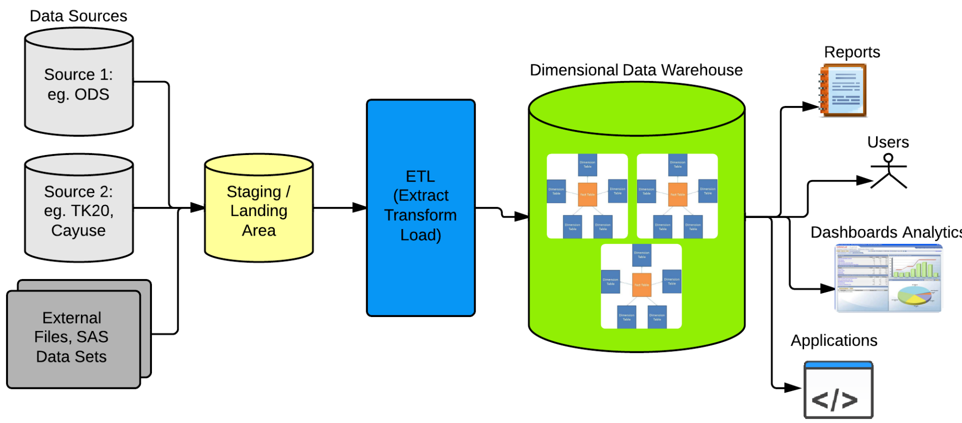


Figure 2.2: Kimball data warehouse Architecture [1].

in a slower performance due to on-the-fly calculations in the case of non-indexed views in ODS. In the case of dimensional modeling, summarized tables are built as required. It also allows the ability to store data history in a manner that is easy to query and build reports on. Such a design delivers faster query performance and to drill down and drill across hierarchies.

2.2 Differences between Inmon and Kimball methods of approach to data warehousing

Data warehousing is the process of building a data warehouse. Reports are currently being built on top of the views in ODS. The ODS is not actually optimized for reporting or analytics.

Now in the case of Inmon's approach of data warehousing, the architecture suggests that a 3NF data warehouse be built as the next step, which would contain all the data in the organization, and then build a data marts layer to support the reporting layer. In our case, with ODS and a staging layer in place, it is not optimal in terms of time and money to build another layer of 3NF data warehouse which can be seen as nothing but another staging layer for the data. This data warehouse has no independent deliverable of its own.

In the case of Kimball's approach however, the idea is to build the data marts layer right after the staging layer. These data marts cater to individual business processes identified. All the data marts together then form the data warehouse as defined by Kimball. The common dimensions between the business processes are however shared between them, without building a separate version of it, to maintain a single version of truth and make it simple to update. These are called conformed dimensions. Using this approach, we do not need a second staging layer and since the data marts are specific to a business process, reports can be generated out of it, without waiting for rest of data marts to be designed and implemented.

Therefore, considering reasons like cost-effectiveness and the ability to deliver reports quickly, it has been decided that the Kimball methodology would be used for designing a data warehouse to address our problem.

2.3 Definitions

A few of the common terms of data warehousing used in this thesis are explained below as defined by Kimball in [1], [4] and [6].

A **Fact table** consists of the foreign keys to all the dimension tables in the schema and facts that are numerical business measurements. It is a transaction based table.

A **Dimension table** is an explicitly defined subject area in a business. it is a non-transaction based table.

Conformed dimensions are standardized tables modeled once and shared across multiple fact tables in the same schema or even a different data mart. This is determined by the Bus Matrix. These tables support the ability to drill across and integrate data from multiple business processes. The main advantage of using conformed dimensions is to save storage space. It is also easier to maintain and refresh one table versus multiple versions of the same table.

An **enterprise data warehouse bus matrix** is the architectural blueprint providing the top-down strategic perspective to ensure that data can be integrated across the enterprise.

The **grain** is defined as the lowest level of detail in a table. The grain of a fact/dimension table is the definition of what constitutes a unique fact/dimension table record.

A **factless fact table** is a fact table that contains no facts but captures certain many-to-many relationships between the dimension keys. Most often it is used to represent events or provide coverage information that does not appear in other fact tables. Some examples include tracking student attendance or registration events, identification numbers of building or facility.

The **business key or natural key** identifies a business entity. Examples include student_id, course_id and program_id.

The **primary key** uniquely identifies a record in a table. A primary key can consist of a single field or multiple fields and cannot be a NULL value.

The **Foreign key** is a single field or multiple fields which uniquely identifies a record in another table.

The **Surrogate Key** uniquely identifies a record in a dimension table. It is usually ETL generated and provides the means to maintain data warehouse information when dimensions change. One simple way improve performance of queries is to use surrogate keys. Surrogate keys can be derived from the existing natural keys or it can be a simple integer. As an example, a surrogate key can be a composite key, being the combination, student_id + academic_period or just an integer value generated by the ETL program while a record is being inserted the table. Using integer surrogate keys means a thinner fact table and the thinner the fact table, the better the performance.

The **star schema** is a dimensional design for a relational database. In a star schema, related dimensions are grouped as columns in dimension tables, and the facts are stored as columns in a fact table. The star schema gets its name from its appearance: when drawn with the fact table in the center, it looks like a star or asterisk.

The **snowflake schema** is a variation on the star schema. When principles of normalization are applied to a dimension table, the result is called a snowflake schema.

A degenerate dimension is present in the fact table. For example this may be a transaction number, invoice number, ticket number, or bill-of-lading number, that has no attributes and hence does not join to an actual dimension table. A junk dimension is present in the fact table. Examples include boolean indicator or flag fields such as enrolled_flag, ethnicity indicators, etl_timestamp and so on.

Chapter 3

Design and Implementation

Kimball's approach was chosen as the base architecture for supporting business intelligence at UNM. The conceptual model and logical model were designed based on the requirements analysis and source data analysis.

3.1 Process of building a Kimball data warehouse

Various steps involved building a Kimball data warehouse include business/user requirements gathering, requirements analysis, source data analysis, target database logical model design, target database physical design, source data cleansing, extract transform load (ETL) process design, data validation, report development and performance analysis. All design principles are based on Kimball's approach to data warehousing as defined in [1].

Different approaches were used for gathering requirements including phone interviews, personal interviews with individual end users and stake holders and also group meetings. A requirements document was prepared in agreement with the business.

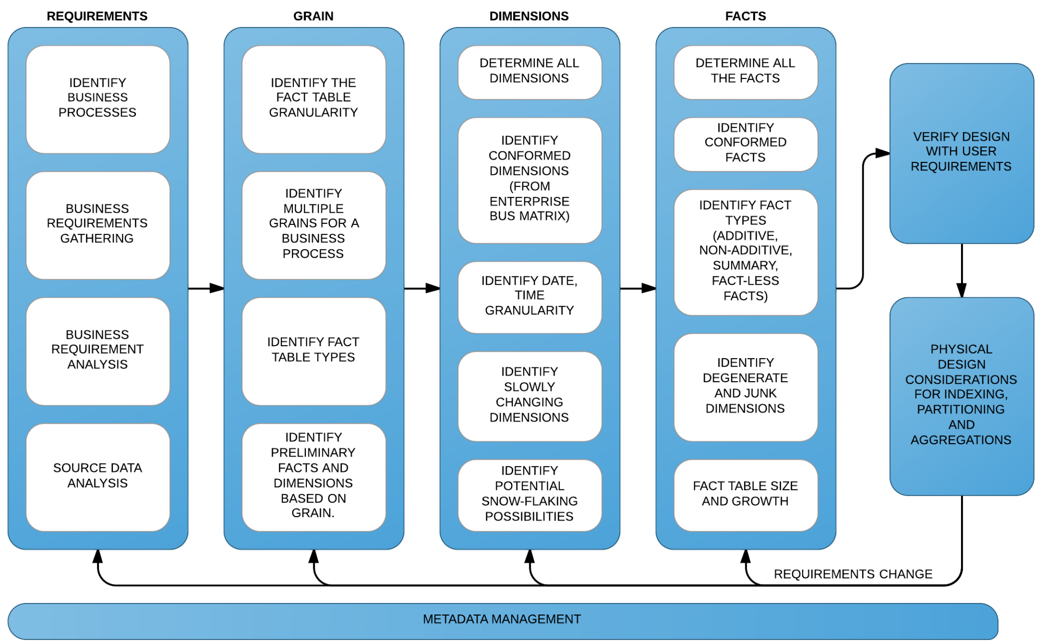


Figure 3.1: Kimball data warehouse life cycle [1].

Requirements analysis was done keeping the structure of the source data in mind. A conceptual data model was prepared which laid out a high level structure of the entities and the relationships between them after identifying separate business needs. Facts and dimensions were identified. Grain of the tables was determined. Conformed dimensions are identified using the business matrix. A data mart may have multiple star schemas but dimensions can be shared between different fact tables or business processes. For example, the student data mart has multiple star schemas. One star schema is dedicated to the academic progress of the student, student detail, program, department, courses, instructors and person data. The second schema captures financial aid. Another star schema is dedicated to applications and admissions.

Next, the logical data model and the physical data model (for Oracle 11g environment) were designed using licensed software, Toad data modeler. There were some design issues which needed special handling including many-to-many relationships and slowly changing dimensions which are explained later in this thesis.

A document was prepared which contained the source table fields mapped to the target table fields. This is called the source-to-target mapping document. Preparing this mapping document is very essential as it is the base for the extract transform and load (ETL) development process.

The next step in the data warehousing process is the ETL design. SAS® data integration software was used to perform the ETL tasks.

Using the data mart as the back end, HTML reports as required by various business units were designed using Web Focus which is the primary reporting tool currently being used at UNM.

3.2 Business Matrix

The business matrix Figure 3.2 is tabular representation of the business process versus the dimension tables. This is an agile modeling method and is done so as to identify the Conformed dimensions. In the figure, we can see that the dimensions academic calendar, course, department and person are shared between multiple business processes. These are called conformed dimensions.

3.3 Grain

The grain of a table is defined as its lowest level of detail. The tables in Figure 3.3 and Figure 3.4 show the grain of the fact and dimension tables in the student data mart. For example, the student enrollment fact table has one row per student per

	IDENTIFIED DIMENSIONS							
BUSINESS PROCESSES	Acad Calendar	Course	Department	Student	Program	Instructor	Financial Aid	Person
Student Enrollment	X	X		X				X
Course Enrollment	X	X						
Department Enrollment	X		X					
Program Enrollment	X				X			
Instructional Assignment	X	X	X			X		X
Financial Aid	X						X	

Figure 3.2: Business Matrix.

FACT TABLES	ATOMIC GRANULARITY	FACTS
Student_Enrollment_Fact	1 row per student, per course, per term	Enrollment,Grade
Course_Enrollment_Fact	1 row per course, per term	Enrollment,Grade
Department_Enrollment_Fact	1 row per department, per term	Enrollment,Grade
Program_Enrollment_Fact	1 row per program, per term	Enrollment,Grade
Instructional_Assignment_Fact	1 row per instructor, per course, per term	Primary Indicator, % Responsibility
Financial_Aid_Fact	1 row per student, per term	Amount Awarded

Figure 3.3: Granularity of fact tables.

course per semester which means that this table will have all the records of a student with respect to all the courses the student was ever enrolled in. Also mentioned are the primary facts in that table. Similarly the dimension tables granularity in Figure 3.4 shows a few main fields in that table.

3.4 Logical and physical design

After designing the business matrix and determining the granularity of tables, the next step is logical designing of the data mart. This was done using the Toad data

DIMENSIONS	ATOMIC GRANULARITY	DATA FIELDS
Academic_Calendar_Dim	1 row per academic period	Academic Year and Aid Year Hierarchies
Course_Dim	1 row per course, per academic period	Acad. Period, Course No., Sections, CRN
Department_Dim	1 row per department	Department Hierarchy Information
Student_Dim	1 row per student, per academic period	Student program, campus, college, dept.
Program_Dim	1 row per program	Program Information
Person_Dim	1 row per person	Demographic Information
Financial_Aid_Dim	1 row per fund_code	Fund Information
Instructor_Dim	1 row per instructor	Instructor Department, Rank
Instructor_Group_Dim	1 row per instructor group	Instructor Group Key
Instructor_Group_Bridge	1 row per instructor, per instructor group	Instructor Group Key, Instructor Key

Figure 3.4: Granularity of dimension tables.

modeling tool and most of the business processes or subject areas mentioned in the business matrix diagram were designed using the star schema approach. In a star schema, there is a fact table, which has all the foreign keys to the dimension tables in that subject area and the facts. The dimension tables have data related to different areas like person, course, student, department, program and so on. Figure 3.5 shows the student subject areas within the enterprise university data warehouse. Other subject areas include finance, research and so on. In the student data mart, there are different aspects that have been identified like student enrollment, course enrollment, admissions, financial aid and some summary tables. Each of these aspects have their dimension tables and a fact table. For example, the student enrollment schema has a fact table named student_enrollment_fact and dimension tables academic_calendar_dim, student_dim, course_dim and instructor_dim. The dimension tables have a surrogate key apart from the natural keys. This is done in order to uniquely identify each record in the table. This surrogate key is usually a number and is automatically generated when the table is being loaded. Figure 3.6 shows the student enrollment star schema with the student_enrollment_fact table having all the foreign keys to the surrounding dimension tables and then the actual facts like grades and credit hours. Similarly Figure 3.7 shows the

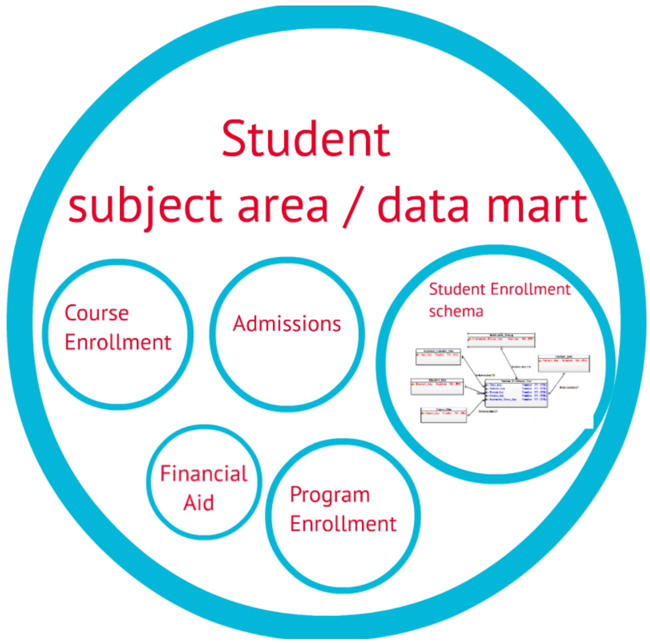


Figure 3.5: Student data mart schema.

course_enrollement. Figure 3.8 shows the instructor course assignment fact schema. This schema captures all the courses assigned to various instructors over years. It shows a instructional_assignment_fact table having facts like percent responsibility of each instructor assigned to a course with multiple instructors. The fact table is connected to the required dimensions. It can also be observed, the table and field names are quite intuitive and are easily understood by anyone.

Indexing the tables appropriately and partitioning the tables if required are part of the physical design. After the physical design, the table definitions are captured into a data definition language (DDL) file and are installed on the database.

3.5 Solutions provided by the data mart design

The following is a non-comprehensive list of solutions offered by this Data Mart:

Student level facts and statistics: The data mart can answer questions at the most transactional level about students like courses registered by a student in a given term, final grades of each student in a course, enrolled date and drop date of a course and bio-demographic information.

Course level facts and statistics: These include total active enrollment in a term in a course, total drop outs out of a course, instructor details of a course including cases multiple instructors per course, total enrollment in each course and enrollment categorized by ethnic groups, average grade of all students in each course and average grade by ethnicity.

Instructor level facts and statistics: These statistics include all courses taught by an instructor in a given term, percentage contribution of each instructor in a course with multiple instructors, bio-demographic information about instructors and HR and departmental information about instructors.

Department level facts and statistics: Examples for department level statistics that are provided by the data mart include courses offered by a department in a given term and their corresponding facts and summarized reports include enrollment in each course offered by a department over many semesters and grade distribution, i.e., number of students in each grade, in each course offered by a department in a semester.

Program level facts and statistics: The data mart provides program level statistics like courses in a program in a given term and their corresponding facts. Some of the summarized level of information includes count of students registered in a program over a period of many semesters.

Financial aid facts and statistics: These are statistics on students who have been awarded financial aid in a given term. The data mart can also be used to see how many students received a Pell grant or submitted the free application for Federal

Student Aid (FAFSA) in a semester. This data can be analyzed together with the grades data resulting in interesting information.

Applications and admissions statistics: These include account of those who have submitted their test scores and prior GPAs to UNM, count of applicants to each program in each academic period versus count of admitted students, average test scores of applicants who were admitted into each department or program, distribution of admitted students with various test scores and so on.

3.6 Further optimization of the data mart for reports

Sometimes, it is required to see reports that need aggregation of the fact tables. Examples include reports needed by some of the executive offices at UNM which require summarized data from the student_enrollment_fact table rolled up to the department, program, degrees awarded or student data summarized by term and level. To generate the appropriate reports according to these requirements, the reporting tool needs to perform aggregation on the fly. This may take a lot of time depending on the complexity.

3.6.1 Building summary fact tables

To overcome this issue, summary fact tables have been designed to readliy address such report requirements. Figure 3.9 shows a few summary fact tables that have been designed as a part of the student data mart. The summary fact tables contain rolled up version of the actual transaction level data. For instance, the program_enrollment_fact table has one record per program per semester which states facts like total enrollment in the program and enrollment distribution by ethnicity. Similarly, the grain of student_level_summary_fact table is one record per student and contains cumulative data of the student until that point of time since inception. The table student_term_summary_fact has one record per student per semester and keeps track of student GPA, credit hours and such for each semester. The degreesawarded_fact table has degrees awarded to all the students at UNM. These tables enable quicker reporting as on-the-fly calculations can be avoided. In spite of it being true that more storage is required, the creation of these summary tables can be justified considering the facts that storage is not very expensive and the tremendous performance benefit the creation of these tables has to offer.

3.7 Design issues

3.7.1 Resolving many-to-many relationships

It is impossible to implement many-to-many relationships between tables, on a physical database except by having another table between them which splits the many-to-many relationship to many-to-one and one-to-many relationships. In Kimball's dimensional modeling, this is called the bridge table [1].

In this design, the student_enrollment_fact table takes care of the many-to-many relationship between student-dimension and course-dimension tables. However, at UNM, we also have multiple instructors for some courses. To implement this, an instructor_group dimension table was introduced which has an instructor_group_key attribute. There is a one-to-many relationship between instructor_group dimension table and student_enrollment_fact table.

An instructor_group_bridge table is introduced which has an instructor_group_key and instructor_key (from the instructor_dimension) having many-to-one relationship to both instructor_group dimension and instructor_dim tables. Thus we are breaking up a many-to-many relationship into two many-to-one relationships.

3.7.2 Implementing slowly changing dimensions (SCD)

The fact tables see frequent insertion of new records in sync with the transactions taking place. Thus, fact table grows quickly over time, but updates to these records are rare. In the case of Dimension tables, the data growth is relatively slow, however updates may be necessary to those records with changes to the business rules, or student data, personal data and so on.

These changes may or may not be tracked based on business requirements. The following are some of the different ways to do so. These methods are based on Kimball's approach to slowly changing dimensions in a data warehouse in [1].

SCD TYPE 1: Overwrite existing record

In slowly changing dimension Type 1 [1], the existing attribute is updated, i.e., it is over-written with the new value. This type of SCD is used when the business requirements state that no history of data is required for any analysis.

In the example Figure 3.11 shown below, the address is replaced with the new value.

SCD TYPE 2: Add a New Record

In this type of slowly changing dimension, a new record is added whenever there is a change, instead of updating the existing record with the new value. This is done with the help of two date fields, effective_start_date and effective_end_date. These dates are manipulated, whenever there is a change [1].

This type of SCD, is the most commonly used and preferred because of its ability to store unlimited history as well as to store the time of that change.

In the example Figure 3.12, The effective_end_date field is initially populated with a random future date value, preferably a few years away, keeping the life cycle of the data warehouse in mind. Now, whenever there is a change to address, the effective_end_date is changed to the when the address effectively ends, and a new record is added with the new address value along with the respective effective_start_date. Also, there is another field called current_flag which is a boolean value indicating whether the record is active or not. This column in included in order to further optimize the query performance on this table when finding active or inactive records.

For example, to pull the active/current records, one may just look for current_flag = 1 instead of looking at (or joining on) the effective_start_date and effective_end_date values.

SCD TYPE 3: Add new column

In slowly changing dimension type 3, a new field is introduced to keep limited track of the changes [1].

This type of SCD is used when the business requirements state that only limited history needs to be stored in the data mart. If there is a pre-determined value for the number of versions of history being tracked, this type of SCD handling is helpful in reducing redundancy and thus save storage space.

In the example Figure 3.13, assuming that we are keeping history of two values for social security number, one field is the current social security number called SSN and the previous or expired value is under the field name Prior SSN. Whenever a change is reported, the prior SSN field is updated with the existing value in SSN field and the SSN field is updated with the new value. We could also have dates to keep track of when the change has occurred.

Hybrid SCD (SCD Type 6): SCD Type 1 + Type 2

There are many types of hybrid slowly changing dimensions, one of which is a combination of SCD types 1 and 2. This is also termed as SCD type 6 [1].

In this type of SCD, as in Figure 3.14, one field in the table can be a Type 2 SCD (field: Address) and another is handled as a type 1 SCD (field: SSN). Initially we have a record with an address and SSN. When there is a change in the address, it is updated according the rules of SCD type 2 i.e., updating the effective_start_date, effective_end_date and current_flag fields. However when there is a change in the SSN, it is updated according to the SCD type 1 rules which is to just replace or over-write the old value.

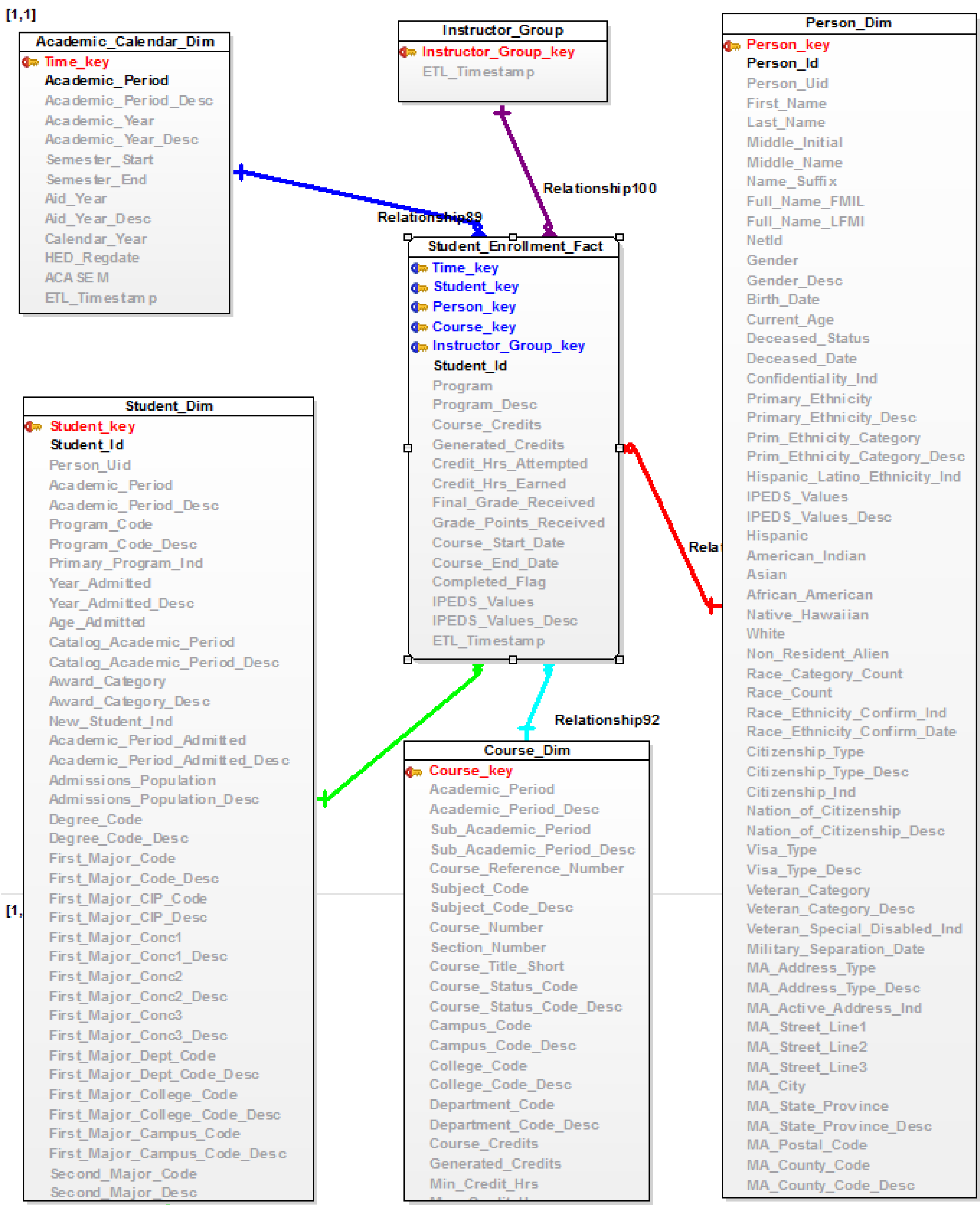


Figure 3.6: Student Enrollment Star Schema.

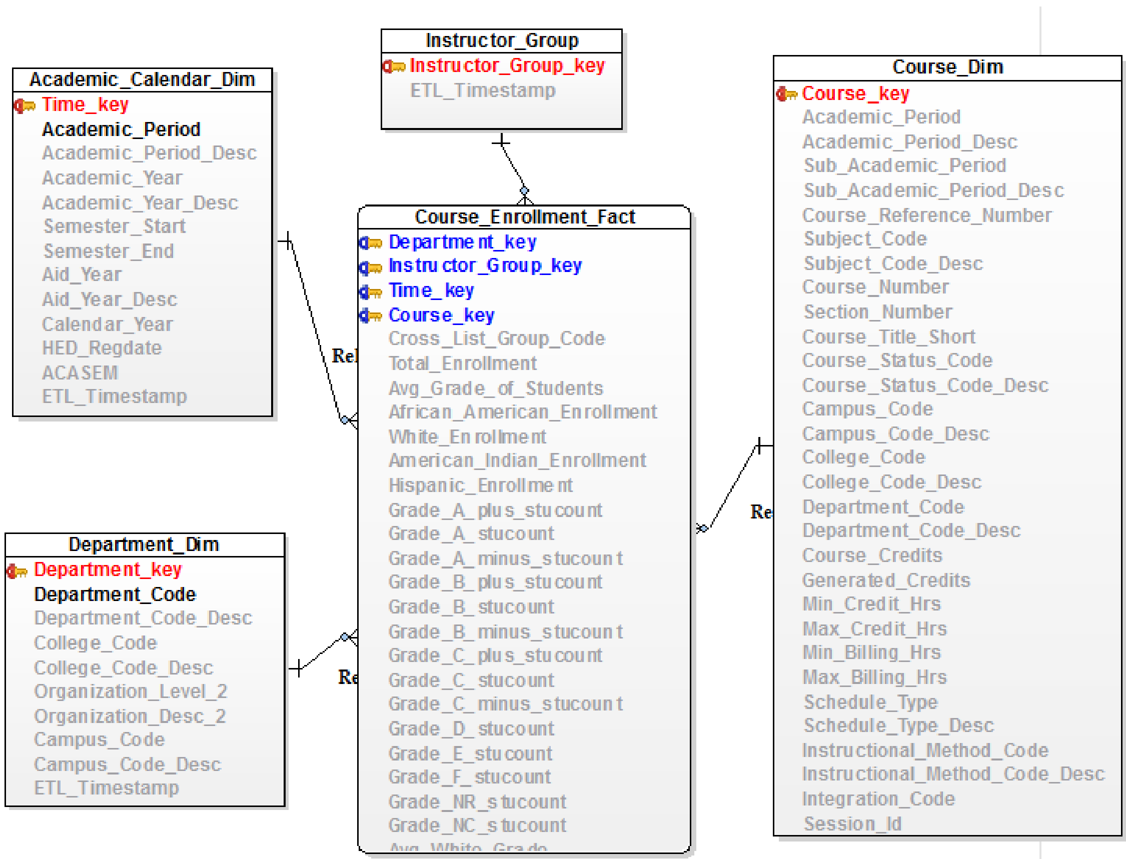


Figure 3.7: Course Enrollment Star Schema.

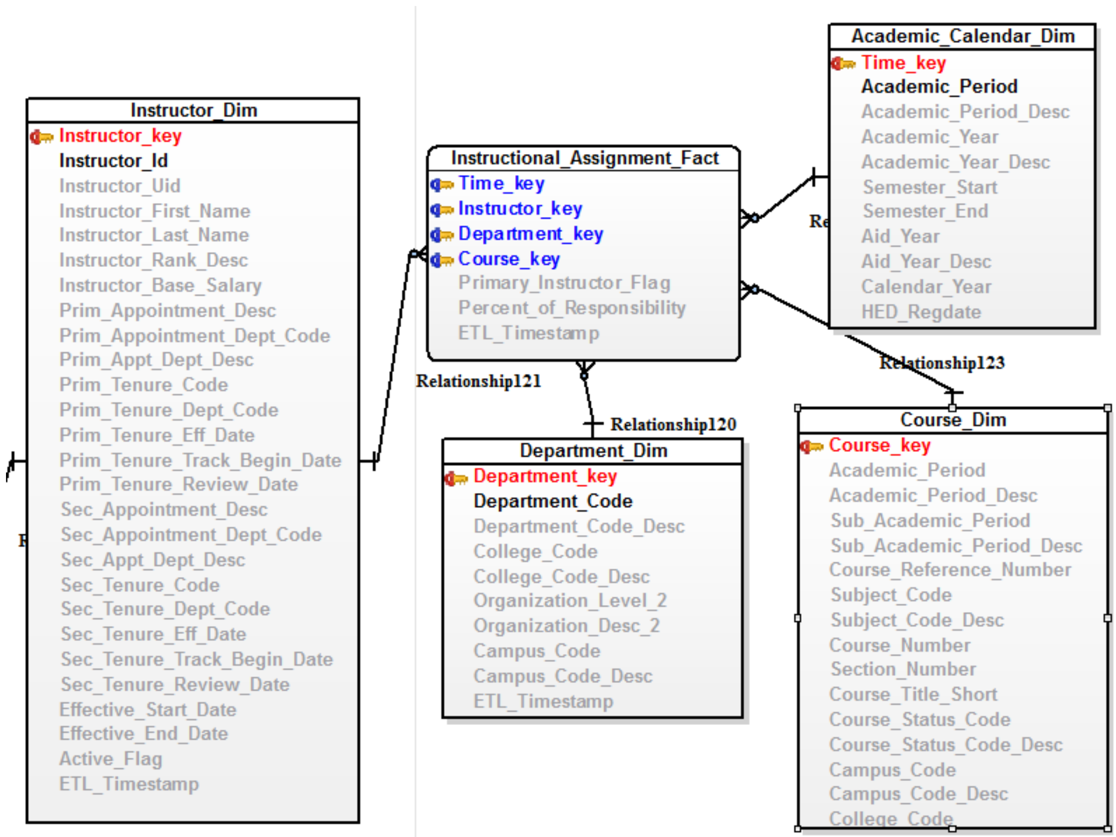


Figure 3.8: Instructor Course Assignment Fact Schema.

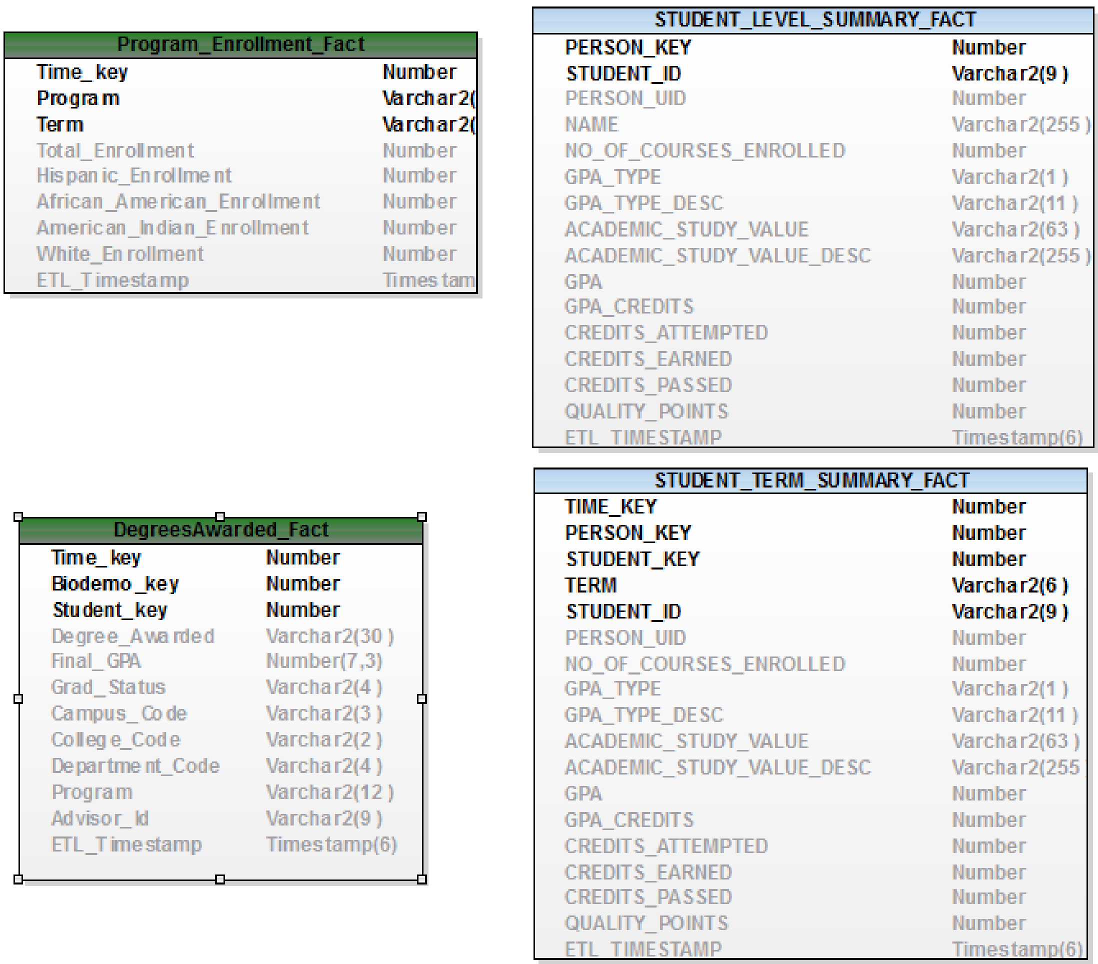


Figure 3.9: Summary Fact Tables.

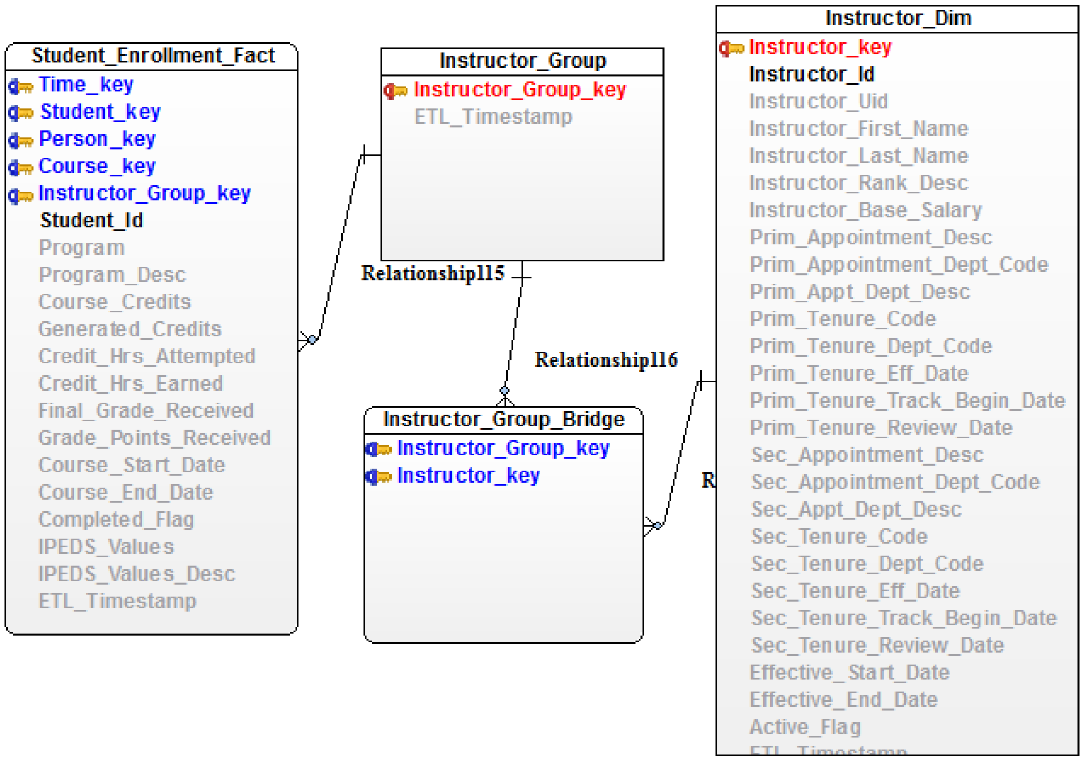


Figure 3.10: Instructor Bridge Table.

ORIGINAL RECORD			
Key	Person_Id	Name	Address
1	101	xyz	1 UNM, ABQ, NM
NEW RECORD			
Key	Person_Id	Name	Address
1	101	xyz	2 Gallup, NM

Figure 3.11: Slowly Changing Dimension Type 1.

ORIGINAL RECORD						
Key	Person_Id	Name	Address	Eff.Start Date	Eff.End Date	Current_Flag
1	101	xyz	1 UNM, ABQ, NM	1/1/2010	9/9/2099	1
NEW RECORDS						
Key	Person_Id	Name	Address	Eff.Start Date	Eff.End Date	Current_Flag
1	101	xyz	1 UNM, ABQ, NM	1/1/2010	1/1/2013	0
2	101	xyz	2 Gallup, NM	1/2/2013	9/9/2099	1

Figure 3.12: Slowly Changing Dimension Type 2.

ORIGINAL RECORD				
Key	Person_Id	Name	SSN	
1	101	xyz	1000001	
NEW RECORD				
Key	Person_Id	Name	SSN	Prior SSN
1	101	xyz	123456789	1000001

Figure 3.13: Slowly Changing Dimension Type 3.

ORIGINAL RECORD							
Key	Person_Id	Name	Address	Eff.Start Date	Eff.End Date	SSN	Current_Flag
1	101	xyz	1 UNM, ABQ, NM	1/1/2010	9/9/2099	1000001	1
NEW RECORDS - Address change - SCD Type 2							
Key	Person_Id	Name	Address	Eff.Start Date	Eff.End Date	SSN	Current_Flag
1	101	xyz	1 UNM, ABQ, NM	1/1/2010	1/1/2013	1000001	0
2	101	xyz	2 Gallup, NM	2/1/2013	9/9/2099	1000001	1
NEW RECORDS - SSN change - SCD Type 1							
Key	Person_Id	Name	Address	Eff.Start Date	Eff.End Date	SSN	Current_Flag
1	101	xyz	1 UNM, ABQ, NM	1/1/2010	1/1/2013	1000001	0
2	101	xyz	2 Gallup, NM	2/1/2013	9/9/2099	123456789	1

Figure 3.14: Hybrid Slowly Changing Dimension.

Chapter 4

Extract Transform Load (ETL)

4.1 Populating the data mart

Extract transform and load (ETL) process is implemented after source tables have been analyzed and target tables have been designed and installed in the database. The SAS® data integration (DI) studio is the ETL software piece of the SAS® suite of products. It has a more complex learning curve compared to some other ETL tools like Pentaho or Talend; however,f it offers more flexibility in scheduling parallel jobs and work flows.

4.2 Logical steps in ETL

The method used for the ETL process is based on the principles from [3] and the technical details of ETL implementation is based on methods defined in [7]. After the data mart has been implemented on the target database, staging tables are designed. Data from various sources including ODS, pre-award research data stored in a database system called cayuse, space data stored in a database system called famis is brought into a staging area using ETL jobs. Here the data is cleansed and validated along with other quality checking and improvement processes as required. From the staging tables, data is brought into the data mart tables using SAS® data integration studio. First, records are inserted into the dimension tables from the respective staging tables along with ETL generated surrogate keys and then fact tables are loaded by capturing numerical columns from the staging tables and the corresponding surrogate keys from the dimension tables as foreign keys.

The first step in ETL is to define libraries in DI studio that contain connection information to back end database servers. After this, metadata or definitions of tables or views from the source and target environments are imported into the DI studio environment. As a next step, the staging tables are populated using simple transformations in DI studio. Further steps include loading the dimension tables and finally loading the fact tables.

The dimension tables are loaded before the fact tables. The reason behind this is that the fact table contains foreign keys to records from the dimension tables and needs to pick it up while being loaded. This helps to maintain referential integrity of the fact table i.e., a record exists in a fact table if and only if all the corresponding key records exist in the respective dimension tables.

Source to target mapping: In the DI studio, within some transformations like ‘table loader‘, and ‘splitter‘, we have an option to select what input columns we need and then map it to the respective output column. This is done automatically if the source and target column names are same, otherwise the columns need to be mapped manually using point-click and drag method. Figure 4.1 shows such an example.

Populating a staging table: Figure 4.2 demonstrates use of simple transformations like ‘extract‘ and ‘insert rows‘ to populate a staging table called

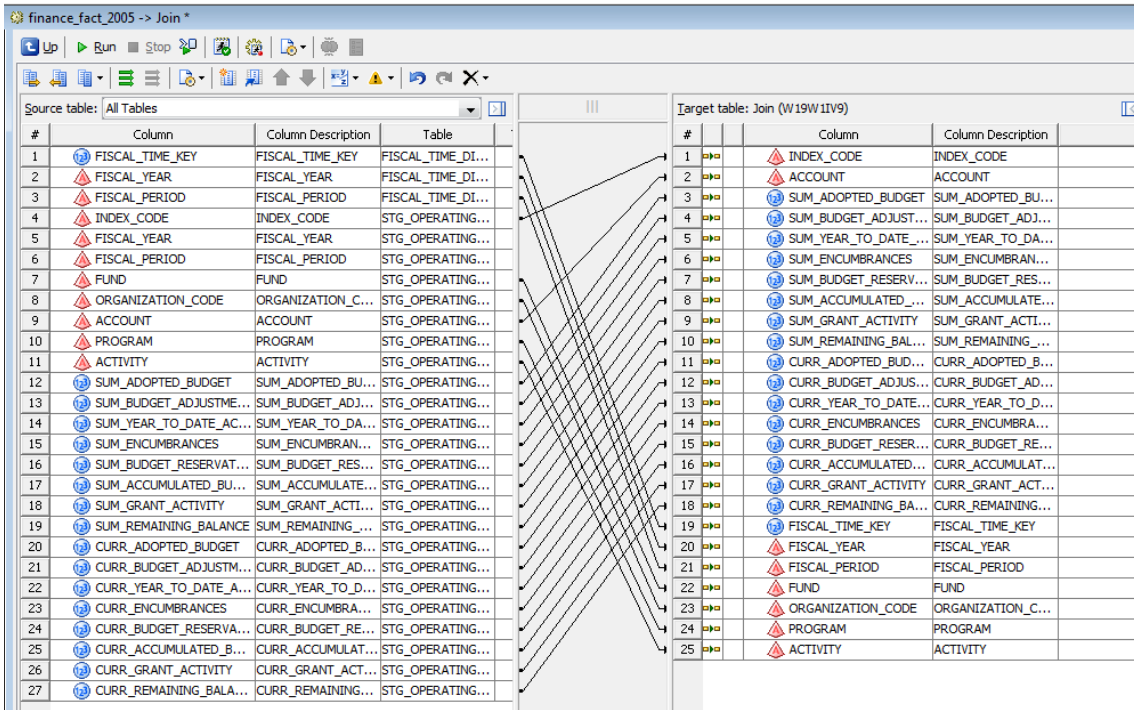


Figure 4.1: Source to Target mapping in SAS® DI Studio.

stg_operating_ledger_cunm using and ODS source table operating_ledger_cunm. Within the extract transformation there is an option to filter the rows extracted according our needs. This operation is similar to 'select' used along with a 'where' condition in plain structured query language (SQL).

Loading a dimension table: Figure 4.3 shows how a dimension table in a data mart is loaded. The source table is year_type_definition from the ODS and the target dimension table is academic_calendar_dim. In the first step, some simple SQL is run which truncates the dimension table, then the next steps show data extraction from the source table based on some filter conditions mentioned in the extract transformation. The SCD type 1 transformation is then used to generate a value for time_key which is the surrogate key for the target table. This generates an integer incremented by 1 for each new record inserted into the table. The consequent

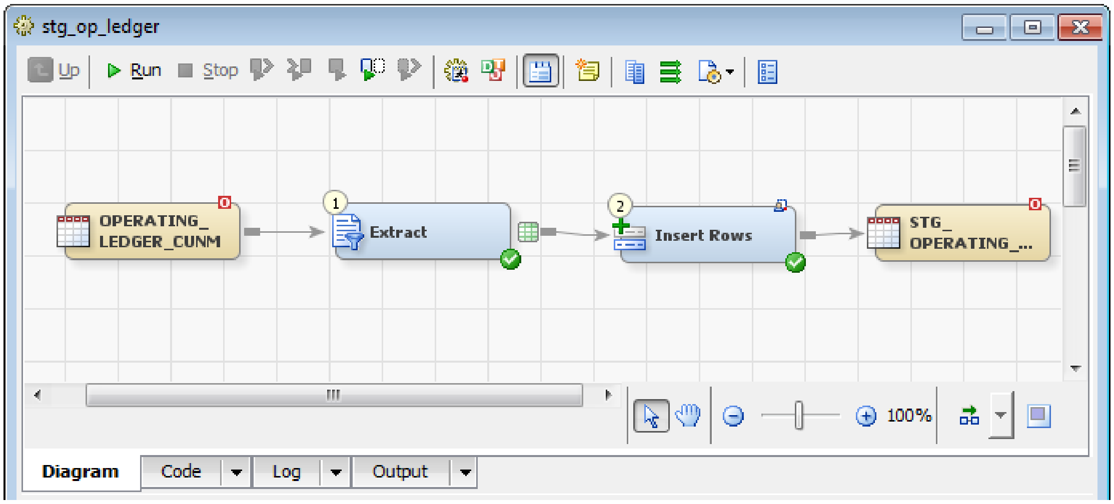


Figure 4.2: Populating a staging table using SQL transformations in SAS® DI Studio.

steps show execution of SQL for some calculated or derived fields in the target table.

Loading a fact table: The fact table contains the foreign keys to the respective

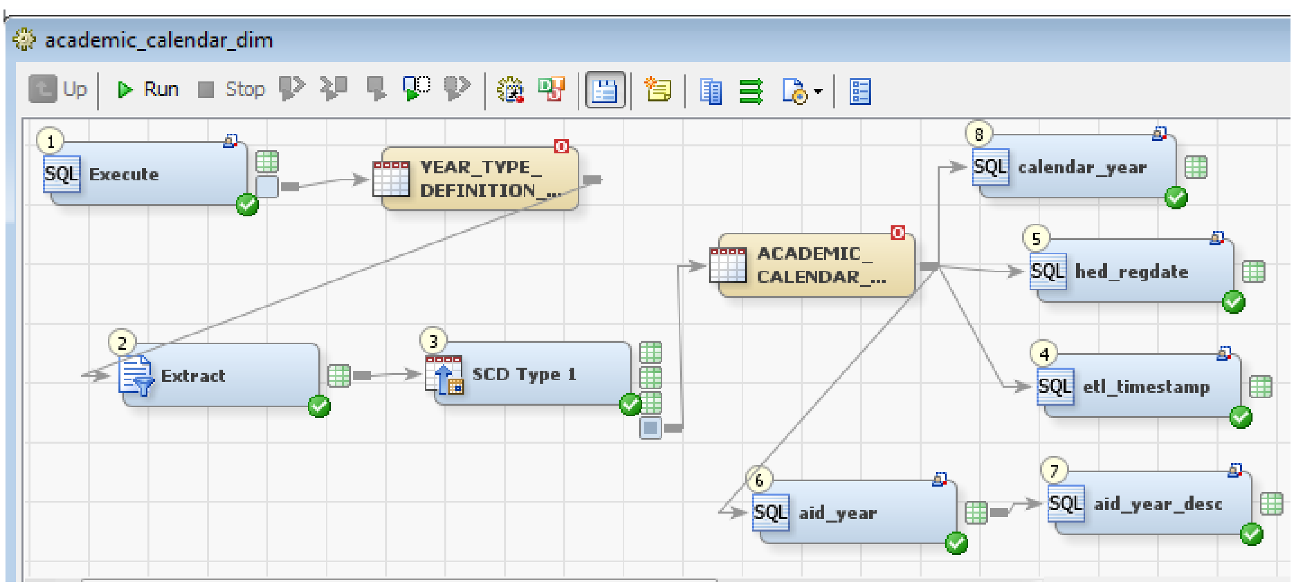


Figure 4.3: Populating a dimension table.

dimensions which is the reason why fact table needs to be loaded after all the dimension tables have been loaded. In Figure 4.4 an ETL job to populate a fact table is demonstrated. The target table is finance_fact. It can be noticed that the facts are coming from the staging table while the keys come from the dimension tables and are pulled using join or lookup transformations.

Joins and where conditions can be specified with in the DI studio, and Figure 4.5 shows such an example. Join types like left, right, full, inner. cross or union can be specified and clauses like where, group by, having, order by and sub-query can be given with in this GUI tool which makes complicated SQL easier to implement.

Generating a work flow in the DI studio is very intuitive. Once jobs are created, they can be run directly from the DI studio interface or can be deployed to a scheduling server. These jobs generate a '.sas' file which is the actual executable program run on the server. Once jobs are created in the DI studio, they are deployed to the scheduling server. Here a work flow is created and jobs are selected to run as part of the flow. In Figure 4.6 a complete flow of loading a star schema tables is shown. First all the staging tables are refreshed. When only all of them are successful, which is represented by the 'and' gate, the work flow moves on to the next jobs, which is to load the dimension tables. These jobs can also be run simultaneously, which can be seen in the comments 'start(index_dim)' which means the next job kicks off as soon as the current one starts. And finally the fact table is loaded after all dimension tables have been loaded seen as 'done(account_dim)' in the comments.

In DI studio, a work flow can be scheduled or run based on many conditions. Figure 4.7 shows the wide range of options available. It can be run manually any time, or it can be scheduled to run multiple times at specified points of time. Triggers can be programmed to run the flow at any time or file event including conditions like arrival of a file and increase in a file size.

The DI studio allows enough flexibility to run custom SAS code. This option is present in many transformations including execute, table-loader, splitter, data-transfer and surrogate-key-generator. Figure 4.8 shows a simple job containing an SQL extract transformation which contains SQL code wrapped around by proc-SQL which is a function used by SAS® to interpret SQL code. Figure 4.9 shows sample proc-SQL code. This code starts with a proc-SQL command. The option nosymbolgen specifies that log messages about macro variable references will not be displayed. Within the connect string, details like database, path which is defined in a SAS® library, user name and password are provided. The password can be encoded by using SAS® function called pwencode. The actual SQL statement is an execute statement. Control flow of transformations in a job in Figure 4.10 shows how order by which transformations are run can be changed by dragging them and placing them where desired. The control flow can then be validated with the press of a button. Job status shows progress of a job can be checked for any errors or warnings or successful completion at each stage or transformation. Figure 4.11 shows the status window in the DI studio GUI for the academic_calendar_dim job. The engine looks for any precode first and runs it if present and then follows through all the steps and checks for any postcode after the final step. Job statistics as shown in Figure 4.12 play an important role in optimization of jobs. It helps in understanding duration of each job, CPU time, memory occupied and threads on the server. Depending on the necessity, parameters in the job or on the server can be changed to allow more threads or more memory.

4.3 Refreshing the data mart

Currently SAS® scheduler within the management console is being used to schedule jobs and work flows depending on the refresh needs. There are two ways of refreshing the data mart tables. Complete reload and incremental load.

The refresh strategy for each table may vary depending on how the source table data is refreshed. For example, in the case of person dimension table, we have one record per person and any change in the detail, is replicated by replacing old data. In such a situation, it is better to opt for a complete reload, instead of tracking and updating changes. Even in the case of a fact table for instance, it is more practical to re-build it each time. This will ensure proper referential integrity of the fact table and that the keys are pointing back to the correct record in the dimension table.

However in the case of student or course dimensions, the data in the respective source tables in the ODS is not manipulated. Only new records are added to them. Therefore an incremental load process may suffice here.

Data mart maintenance is relatively easier and cheaper as compared to a 3NF database because of fewer number of tables involved. A proper naming convention was also followed when naming fact, dimension or staging tables and indexes.

4.4 ETL performance and data validation

The SAS® DI Studio was able to perform row inserts into Oracle tables at a rate of one million records per minute. This was achieved while running multiple jobs in parallel. After the data mart is populated, simple tests are run like record counts. More complex queries are also run to check performance and also data validation. Sample results are sent to business users for validation before moving jobs and data to production environment. After this stage, data is automatically refreshed by the time event or trigger events in the scheduling server.

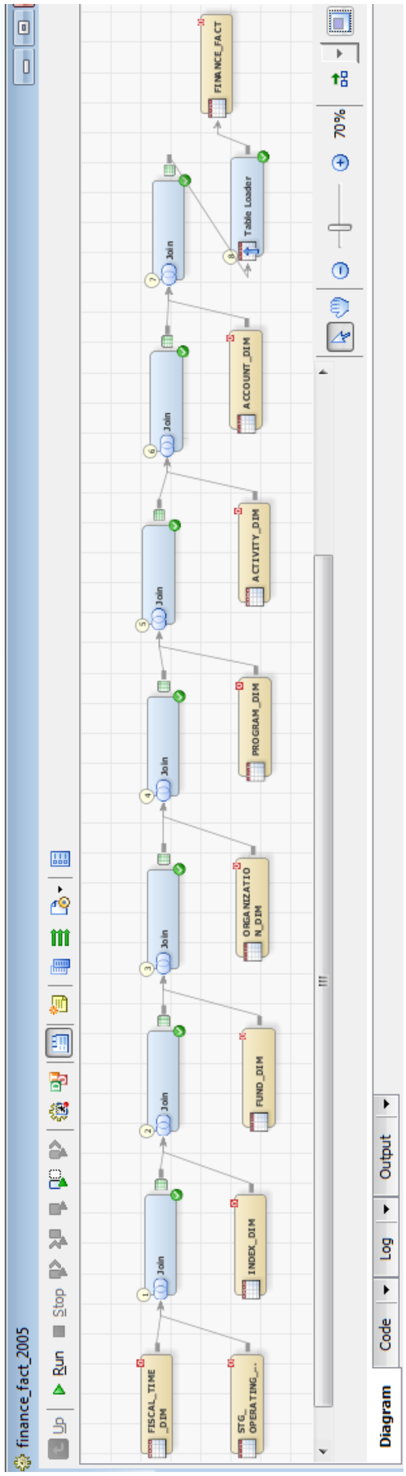


Figure 4.4: Populating a fact table - Finance Fact.

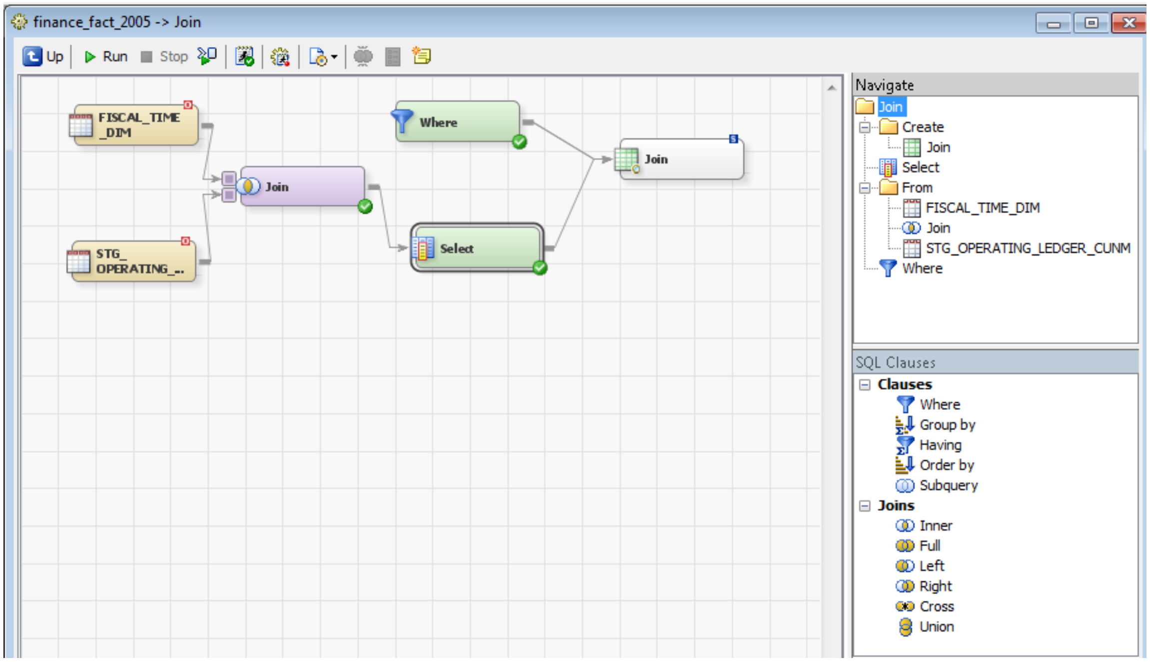


Figure 4.5: Joins and where conditions in SAS® DI Studio.

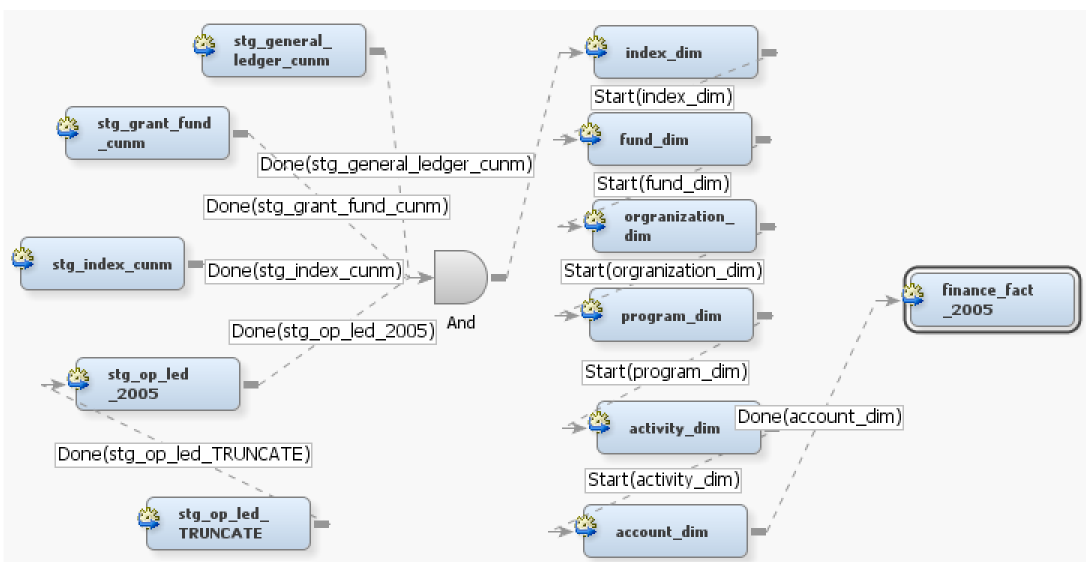


Figure 4.6: Work flow, parallel jobs and scheduling in SAS® DI Studio.

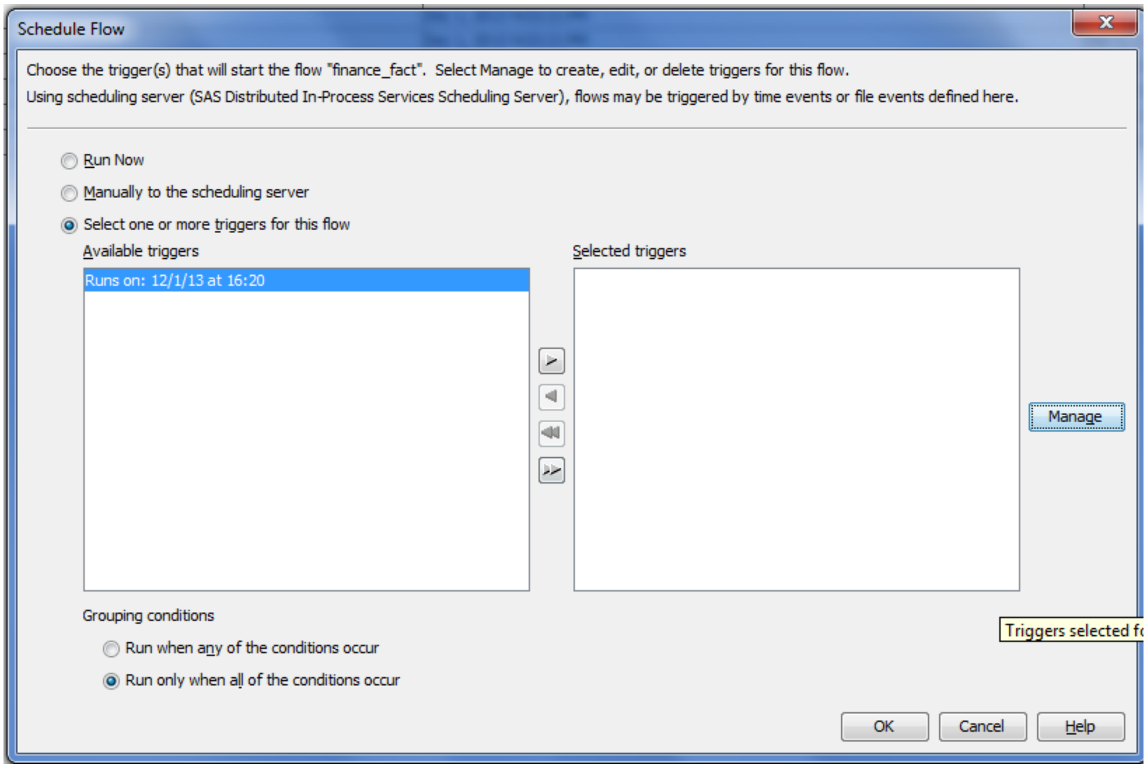


Figure 4.7: Job scheduling triggers in SAS® DI Studio.

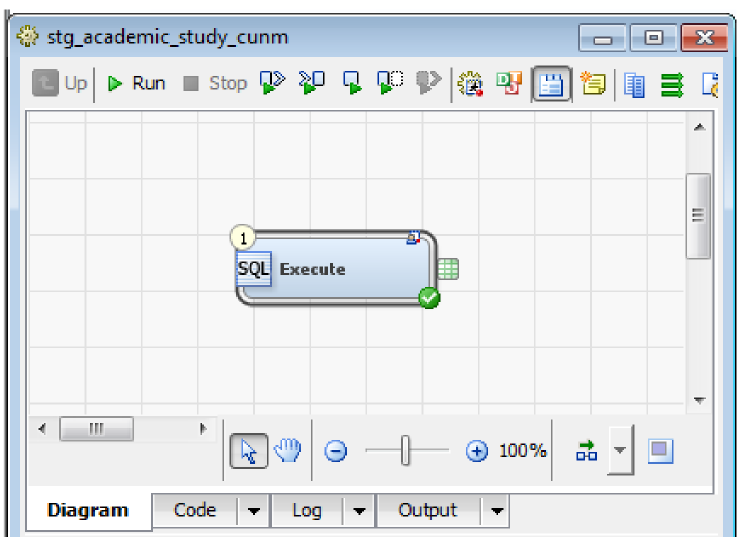
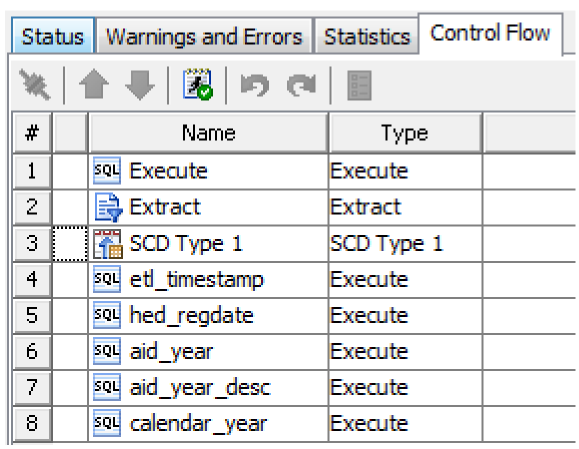


Figure 4.8: SQL Extract transform to run custom SQL.

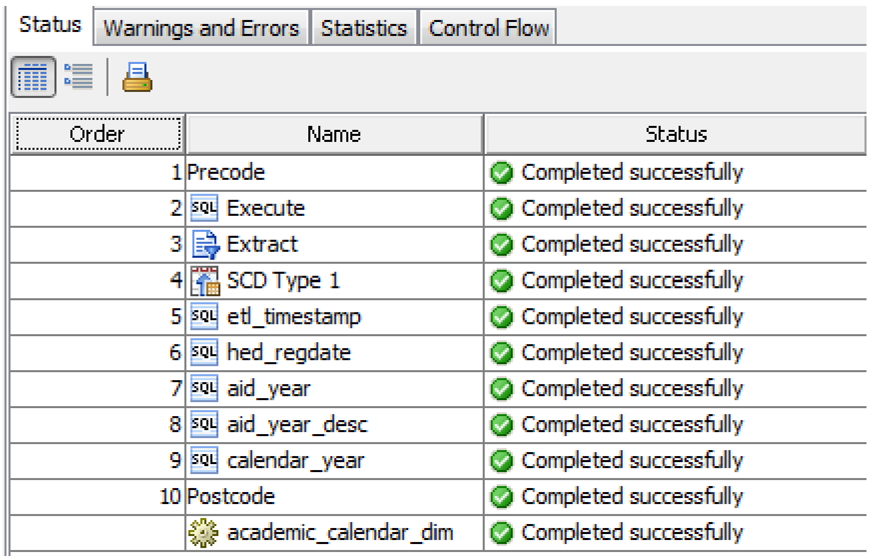
```
proc sql;
options  nosymbolgen;
   connect to oracle (user=unm_oia_staging
    password="{SAS002}B38A003D0E37DB4F3E619F7838AD52CD" PATH=odst);

execute (
   DROP TABLE unm_oia_staging.STG_ACADEMIC_STUDY_CUNM
) by oracle;

execute (
CREATE TABLE unm_oia_staging.STG_ACADEMIC_STUDY_CUNM
(  Student_Id,
   Person_Uid,
   NAME,
   ACADEMIC_YEAR,
   ACADEMIC_PERIOD, , , , . )
AS SELECT id,
          person_uid,
          name,
          academic_year,
          academic_period, , , , .
     FROM ODSMGR.ACADEMIC_STUDY_CUNM@OIA_ODST_ODSP.UNM.EDU
     WHERE ACADEMIC_PERIOD >= '200680'  ) by oracle;

   disconnect from oracle;
quit;
```

Figure 4.9: Proc-SQL example to run custom queries.



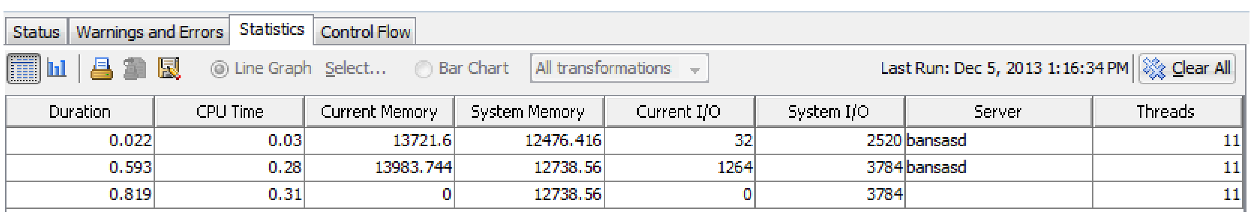
#		Name	Type
1		Execute	Execute
2		Extract	Extract
3		SCD Type 1	SCD Type 1
4		etl_timestamp	Execute
5		hed_regdate	Execute
6		aid_year	Execute
7		aid_year_desc	Execute
8		calendar_year	Execute

Figure 4.10: Control flow of transformations in a job.



Order	Name	Status
1	Precode	Completed successfully
2	Execute	Completed successfully
3	Extract	Completed successfully
4	SCD Type 1	Completed successfully
5	etl_timestamp	Completed successfully
6	hed_regdate	Completed successfully
7	aid_year	Completed successfully
8	aid_year_desc	Completed successfully
9	calendar_year	Completed successfully
10	Postcode	Completed successfully
	academic_calendar_dim	Completed successfully

Figure 4.11: Job status.



Duration	CPU Time	Current Memory	System Memory	Current I/O	System I/O	Server	Threads
0.022	0.03	13721.6	12476.416	32	2520	bansasd	11
0.593	0.28	13983.744	12738.56	1264	3784	bansasd	11
0.819	0.31	0	12738.56	0	3784		11

Figure 4.12: Job statistics.

Chapter 5

Reporting from the data mart

5.1 Data Mart Performance

The data mart was designed and implemented using a dimensional modeling method namely star schema. A star schema is essentially easy to understand, implement and maintain. As seen in the previous chapters, a star schema has a fact table and a few dimension tables. The student data mart has several subject areas like student enrollment, course enrollment, admissions, financial aid and so on. Each subject area has a fact table with dimension tables shared between these multiple subject areas. Such tables are called conformed dimensions. For example the student enrollment star schema has one fact table student_enrollment_fact and dimension tables like academic_calendar_dim, student_dim, course_dim etc.. The naming convention has been chosen in such a way that it is apparent as to what data is present in that table. A dimension table contains comprehensive information about that aspect of the subject area. For example, course_dim table contains all information regarding a course like college, department, course reference number, academic period in which it was offered, section number and so on. The fact table contains transaction level data capturing all events regarding that subject area.

As each subject area is defined and the tables designed, it becomes very clear as to what tables need to be used for a given query to that subject area. Reports can be generated very easily based on a proper understanding of the data mart structure.

A fact table may contain many records, but because it contains a very small number of columns querying the fact table is much faster. This is one of the main reasons why the data mart should be able to perform better than the ODS in response to report generation requests. More reasons are mentioned below.

Logical design: The star schema design requires fewer number of joins to build a report as compared to the number of joins required to build the same report from ODS tables.

Indexing appropriate columns: Columns in the tables of this star schema are indexed optimally according the query or report requirements. Whereas in ODS, the tables if they are indexed it is not done optimally. Also most of the time, views rather than tables in ODS are used to build reports by most users at UNM, which are slower to access.

Using surrogate keys: We use just this one numerical field to join a fact and a dimension table as compared to using multiple fields to join tables in ODS. For instance, when querying course level statistics, the fact table used is course_enrollment_fact which is joined to dimension table academic_calendar_dim on time_key and to course_dim on course_key. Time_key and course_key are numerical fields generated by the ETL job having unique values for each record in a dimension table.

Using summary fact tables: In reports which require the use of aggregate functions, summary fact tables are built with the aggregate fields pre-populated so that the reports can directly read from these tables avoiding calculations on-the-fly

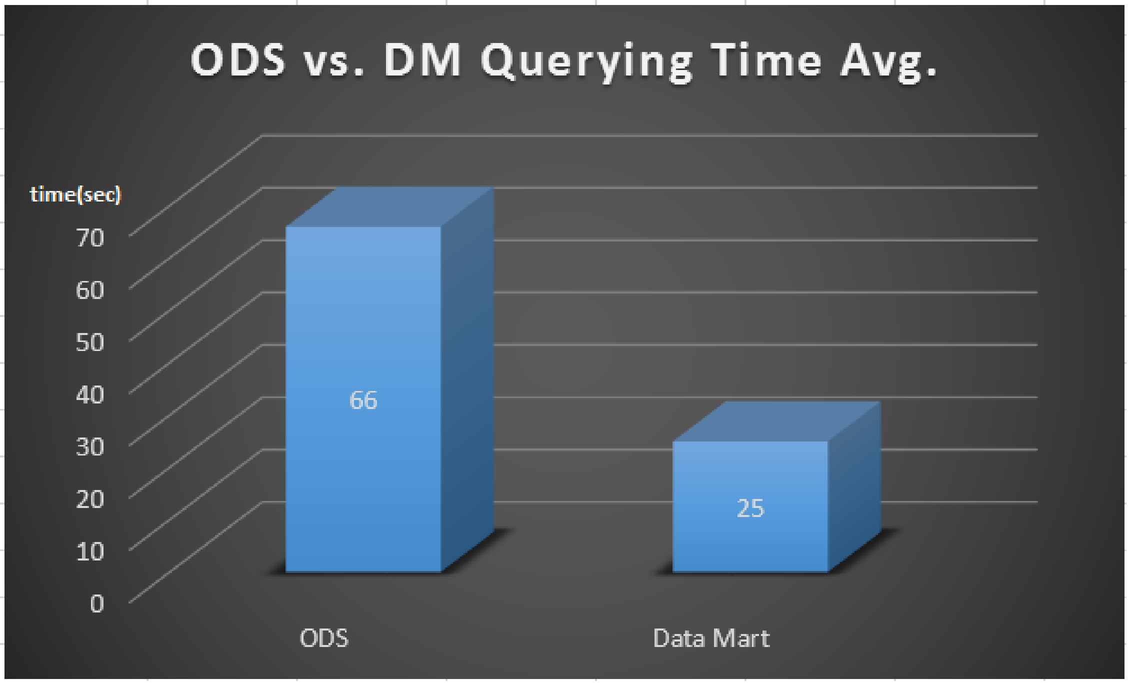


Figure 5.1: Average ODS versus data mart performance.

thus ensuring faster delivery of reports.

I received response the times for the SQL queries against both ODS and the data mart. These queries were based the grade distribution report and also a few other reports which gives grade distributions and pass rates for courses, section, ethnicity. Figure 5.1 shows an averaged performance of data mart versus ODS over different queries. The data mart performed better than the ODS. On an average, the data mart is more than 50% faster than the ODS.

5.2 Reports

The purpose building a data mart using star schema is to enable the development of a wide variety of reports and predictive analytics. This is possible because of the flexible way in which the data is organized. It is the same data as in ODS but organized in a different, more logical way. It is also relatively easy to develop reports out of the data mart as compared to ODS because of the fewer number of tables involved.

Several specific reports were proposed to be generated for a project based on this student mart. Some have been built while others are still in development. Below is a non-exhaustive description of a few of them. The WebFOCUS reporting tool is being used to generate these reports.

General ad-hoc class performance report: For a given semester, this report allows one to get grade distributions, withdrawal rates and pass rates for selected courses and sections. Courses can be selected by instructor, course reference number, or by selecting a series of courses and sections. This report will also need to have the ability to restrict its output to various sub-populations based on ethnicity, financial aid, or other demographic conditions. Inputs can be course reference number, instructor, academic period, subject code, course number, section number, ethnicity, financial aid status, category of financial aid received, status as a first generation college student (if possible) Outputs are grade distribution, withdrawal rate and pass rate. As an example of demonstrating the simplicity of building a report from the data mart, in this report, dimension tables used are course_dim, academic_calendar_dim, student_dim and the fact table used is course_enrollment_fact joined on the surrogate keys time_key, student_key and course_key. Therefore with relatively simple SQL joins and select operations, this complex report was built enabling drill-down and drill-across capabilities which allow dynamic reporting based on selecting academic period, department, course and section.

Two course grade comparison report: This report will compare how students in one course during one semester performed in another course during a subsequent semester (e.g. Physics I during Fall of 2012 and Physics II during Spring of

2013). This report will also be able to look at sub-populations in a similar manner as the previous report.

A few other reports that are supported by the data mart are mentioned below:

- A report that shows the transitions to and the transitions from a given major. For a given time period, it shows the number and majors of students that transferred into a given major. Also for a given time period, it shows the number and majors of students who transferred from a given major.
- A report that gives the percentage of STEM classes taken by STEM majors, broken down by major for a given academic period.
- A report that gives the number of degrees granted, broken down by major and level of degree including average GPA for a given semester.
- A report that gives the number and percentage of non-STEM majors in STEM courses broken down by course.

Figure 5.2 is a report which shows student credit hours (sch) generated by faculty in each academic period by college. The report in Figure 5.3 shows student enrolled hours in an academic period by college and by course level, i.e., lower undergraduate, upper undergraduate or graduate.

ACADEMIC_PERIOD_DESC: Spring 2011
COLLEGE_CODE_DESC: Anderson Schools of Management

Run | Reset | Save | Clear Output | Run in a new window

College	Rank	Instructor Name	Level Lower	Level Upper	Level Grad
Anderson Schools of Management	Assistant Professor	[illegible]	.	123	123
		[illegible]	.	207	.
		[illegible]	.	267	105
		[illegible]	.	300	.
		[illegible]	.	36	60
		[illegible]	.	81	57
		[illegible]	.	102	135
	Associate Professor	[illegible]	.	222	81

Figure 5.2: SCH generated by faculty by academic period, college.

Academic_Period: Spring 2008
Campus: Main
Run

College	Department	Course Level Lower	Course Level Upper	Course Level Graduate
Anderson Schools of Management ASM	Anderson Schools of Management ASM	1,248	12,304	3,814
Subtotal: Anderson Schools of Management ASM		**1,248**	**12,304**	**3,814**
Associate VP Student Services	Air Force ROTC	71	70	.
	Army ROTC	86	151	.
	Naval ROTC	21	81	.
Subtotal: Associate VP Student Services		**178**	**302**	**.**
College of Arts Sciences A S	*Interdisciplinary: A.S.	99	891	47
	African American Studies	99	177	.
	American Studies Department	1,146	954	290

Figure 5.3: Student hours enrolled by academic period, college.

Chapter 6

Future Work

The student data mart being discussed in this thesis currently has a star schema that incorporates fact tables for applications and admissions, student enrollment, course enrollment, semester performance and financial aid. In the near future, we also look to incorporate curriculum data, student assessment data, career services and alumni data. Having this kind of data from high school GPA and admission test scores, academic performance at UNM and how well students are able to move onto a job or higher studies helps us to better understand and measure student success.

A finance data mart is also being built to analyze the flow of money through various organizations for various activities. The finance reports and applications for the president's and the provost's office as well as individual departments will be supported by this data mart.

In the near future, the University of New Mexico plans to build a research space data mart which will have information about the research space allotted to each principal investigator bringing in funding to UNM. This data mart includes the investigator data, research proposal, grant, fund, organization, program, account and activity data. It would also contain the space data which includes what space was allotted to which researcher and how it was used during a certain period of time. This data mart would give UNM scope to do analytics on how efficiently space is being used on campus, improve space allotment and also predict future usage.

The ETL process will be automated further to support nightly updates of the data mart and automatic report generation and publication. There is scope to take leverage of the built-in transformations in the SAS® data integration studio to support dimensional modeling, handle many-to-many relationships and slowly changing dimensions. Apart from that it includes top of the line tools which will help build interesting analytic models including forecasting, what-if analysis and predictive analytic models. Reports will be built using SAS® visual analytics (VA).

Sankey diagrams shown below were developed as a part of another analytics initiative and are currently run on Amazon EC2 cloud with a Postgres database as the back end. The data was loaded into this database using Excel spreadsheets. In future, these Sankey diagrams will be supported by the data marts.

The Sankey diagrams can be viewed at www.provostcloud.unm.edu. The first example shown in Figure 6.1 is the college flow of majors by semester in 2008, Arts and Sciences college, Chemistry department. There are a bunch of filters and statistics provided at the bottom of the page to drill down to the user's needs. The second sankey diagram in Figure 6.2 highlights part of the flow when one of the nodes is hovered upon by the mouse. This uses Data-Driven Documents (D3) Javascript programming. At the bottom of the web page there are some filters and the corresponding statistics displayed. This is shown in Figure 6.3.

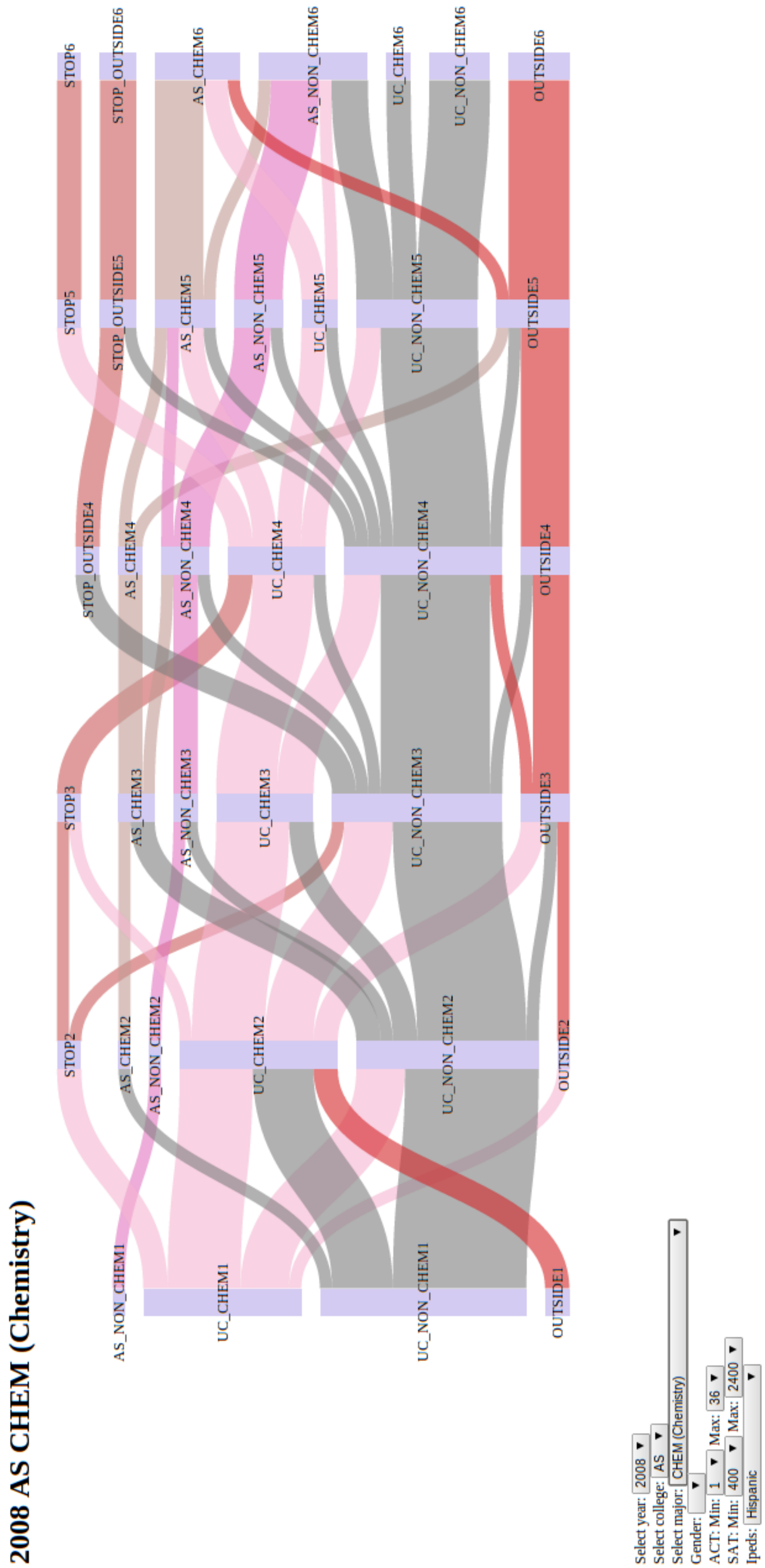


Figure 6.1: Sankey Diagram for 2008 Arts and Sciences Chemistry College Flow.

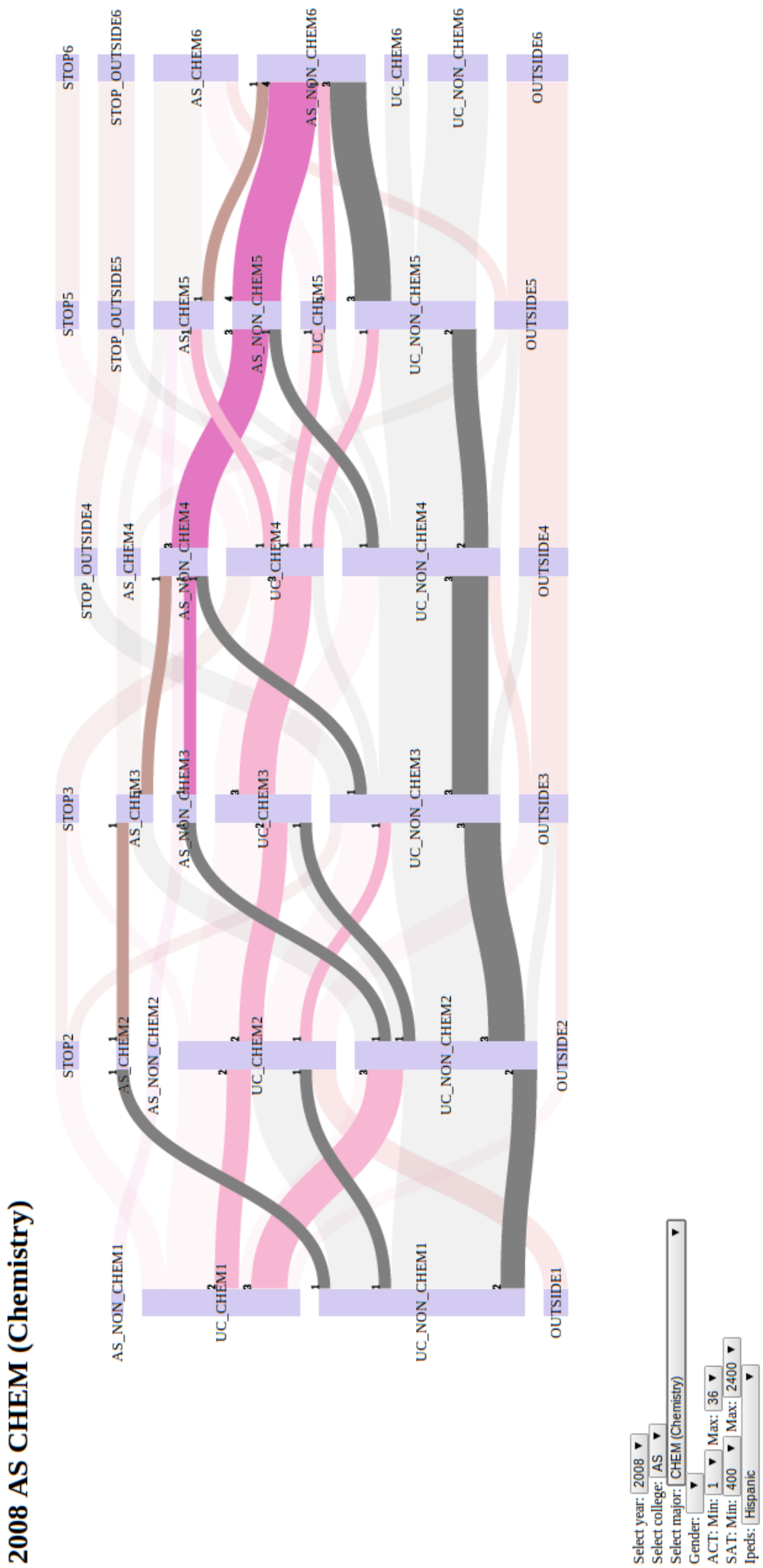


Figure 6.2: Sankey Diagram node highlight example.

Select year: 2008
Select college: AS
Select major: CHEM (Chemistry)
Gender:
ACT: Min: 1 Max: 36
SAT: Min: 400 Max: 2400
Ipeds: Hispanic

	Semester						
Year grad rate							
Type	**semester 1**	**semester 2**	**semester 3**	**semester 4**	**semester 5**	**semester 6**	**total**
STOP	0 (0.0%)	2 (6.1%)	2 (6.1%)	0 (0.0%)	2 (6.1%)	2 (6.1%)	2
STOP_OUTSIDE	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (6.1%)	3 (9.1%)	3 (9.1%)	3
AS_CHEM	0	1	3	2	5	7	7
AS_NON_CHEM	1	1	2	4	4	9	9
UC_CHEM	13	13	8	8	3	2	2
UC_NON_CHEM	17	15	14	13	10	5	5
OUTSIDE	2	1	4	4	6	5	5
GRAD_OUTSIDE	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0
GRAD	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0

Figure 6.3: Sankey diagram statistics display.

Appendices

6.1 Student data mart table structure (DDL)

The table structure of the student data mart designed, implemented and in production environment, is given below.

```
CREATE TABLE ACADEMIC_CALENDAR_DIM
(
  TIME_KEY                NUMBER,
  ACADEMIC_PERIOD         VARCHAR2(63 CHAR),
  ACADEMIC_PERIOD_DESC    VARCHAR2(255 CHAR),
  ACADEMIC_YEAR           VARCHAR2(63 CHAR),
  ACADEMIC_YEAR_DESC      VARCHAR2(255 CHAR),
  SEMESTER_START          DATE,
  SEMESTER_END            DATE,
  AID_YEAR                VARCHAR2(63 CHAR),
  AID_YEAR_DESC           VARCHAR2(255 CHAR),
  CALENDAR_YEAR           NUMBER(4),
  HED_REGDATE             VARCHAR2(5 CHAR),
  ACASEM                  VARCHAR2(30 CHAR),
  ETL_TIMESTAMP           TIMESTAMP(6)
```

```
);

CREATE TABLE COURSE_DIM
(
    COURSE_KEY                      NUMBER,
    ACADEMIC_PERIOD                 VARCHAR2(64 CHAR),
    ACADEMIC_PERIOD_DESC            VARCHAR2(255 CHAR),
    SUB_ACADEMIC_PERIOD             VARCHAR2(12 CHAR),
    SUB_ACADEMIC_PERIOD_DESC        VARCHAR2(50 CHAR),
    COURSE_REFERENCE_NUMBER         VARCHAR2(5 CHAR),
    SUBJECT_CODE                    VARCHAR2(4 CHAR),
    SUBJECT_CODE_DESC               VARCHAR2(30 CHAR),
    COURSE_NUMBER                   VARCHAR2(5 CHAR),
    SECTION_NUMBER                  VARCHAR2(3 CHAR),
    COURSE_TITLE_SHORT              VARCHAR2(30 CHAR),
    COURSE_STATUS_CODE              VARCHAR2(63 CHAR),
    COURSE_STATUS_CODE_DESC         VARCHAR2(255 CHAR),
    CAMPUS_CODE                     VARCHAR2(63 CHAR),
    CAMPUS_CODE_DESC                VARCHAR2(255 CHAR),
    COLLEGE_CODE                    VARCHAR2(63 CHAR),
    COLLEGE_CODE_DESC               VARCHAR2(255 CHAR),
    DEPARTMENT_CODE                 VARCHAR2(63 CHAR),
    DEPARTMENT_CODE_DESC            VARCHAR2(255 CHAR),
    GENERATED_CREDITS               NUMBER(9,3),
    MIN_CREDIT_HRS                  NUMBER(7,3),
    MAX_CREDIT_HRS                  NUMBER(7,3),
    MIN_BILLING_HRS                 NUMBER(7,3),
    MAX_BILLING_HRS                 NUMBER(7,3),
```

```
    SCHEDULE_TYPE                       VARCHAR2(3 CHAR),
    SCHEDULE_TYPE_DESC                  VARCHAR2(30 CHAR),
    INSTRUCTIONAL_METHOD_CODE           VARCHAR2(8 CHAR),
    INSTRUCTIONAL_METHOD_CODE_DESC      VARCHAR2(255 CHAR),
    INTEGRATION_CODE                    VARCHAR2(5 CHAR),
    SESSION_ID                          VARCHAR2(8 CHAR),
    COURSE_LEVEL                        VARCHAR2(2 CHAR),
    COURSE_LEVEL_DESC                   VARCHAR2(120 CHAR),
    CROSS_LIST_GROUP_CODE               VARCHAR2(2 CHAR),
    ACTUAL_ENROLLMENT                   NUMBER(4),
    PREV_ENROLLMENT                     NUMBER(4),
    COURSE_FEES                         NUMBER(12,2),
    COURSE_START_DATE                   DATE,
    COURSE_END_DATE                     DATE,
    CENSUS_ENROLLMENT_DATE1             DATE,
    CENSUS_ENROLLMENT1                  NUMBER(4),
    CENUS_ENROLLMENT_DATE2              DATE,
    CENSUS_ENROLLMENT2                  NUMBER(4),
    EFFECTIVE_START_DATE                DATE,
    EFFECTIVE_END_DATE                  DATE,
    GRADE_TYPE                          CHAR(20 CHAR),
    GRADE_TYPE_DESC                     CHAR(40 CHAR),
    ACTIVE_FLAG                         NUMBER,
    ETL_TIMESTAMP                       TIMESTAMP(6)
);

CREATE TABLE COURSE_ENROLLMENT_FACT
(
```

```
TIME_KEY                  NUMBER,
COURSE_KEY                NUMBER,
DEPARTMENT_KEY            NUMBER,
INSTRUCTOR_GROUP_KEY      NUMBER,
CROSS_LIST_GROUP_CODE     VARCHAR2(2 CHAR),
TOTAL_ENROLLMENT          NUMBER,
A_PLUS_COUNT              NUMBER,
A_COUNT                   NUMBER,
A_MINUS_COUNT             NUMBER,
B_PLUS_COUNT              NUMBER,
B_COUNT                   NUMBER,
B_MINUS_COUNT             NUMBER,
C_PLUS_COUNT              NUMBER,
C_COUNT                   NUMBER,
C_MINUS_COUNT             NUMBER,
D_PLUS_COUNT              NUMBER,
D_COUNT                   NUMBER,
D_MINUS_COUNT             NUMBER,
F_COUNT                   NUMBER,
CR_COUNT                  NUMBER,
NR_COUNT                  NUMBER,
NC_COUNT                  NUMBER,
W_COUNT                   NUMBER,
WP_COUNT                  NUMBER,
WF_COUNT                  NUMBER,
WNC_COUNT                 NUMBER,
W_TOTAL_COUNT             NUMBER,
AUD_COUNT                 NUMBER,
```

```
    WHITE_COUNT                  NUMBER,
    AFRICAN_AMERICAN_COUNT       NUMBER,
    AMERICAN_INDIAN_COUNT        NUMBER,
    HISPANIC_COUNT               NUMBER,
    ASIAN_COUNT                  NUMBER,
    NATIVE_HAWAIIAN_COUNT        NUMBER,
    TWO_MORE_RACES_COUNT         NUMBER,
    RACE_ETHN_UNKOWN_COUNT       NUMBER,
    NON_RES_COUNT                NUMBER,
    ETL_TIMESTAMP                TIMESTAMP(6)
);

CREATE TABLE DEGREESAWARDED_FACT
(
    TIME_KEY                     NUMBER,
    STUDENT_KEY                  NUMBER,
    PERSON_KEY                   NUMBER,
    PERSON_UID                   NUMBER,
    STUDENT_ID                   VARCHAR2(9 CHAR),
    DEGREE_CODE                  VARCHAR2(63 CHAR),
    DEGREE_CODE_DESC             VARCHAR2(255 CHAR),
    AWARD_CATEGORY               VARCHAR2(63 CHAR),
    AWARD_CATEGORY_DESC          VARCHAR2(255 CHAR),
    STATUS_CODE                  VARCHAR2(63 CHAR),
    STATUS_CODE_DESC             VARCHAR2(255 CHAR),
    OUTCOME_AWARDED_IND          VARCHAR2(1 CHAR),
    GRADUATED_IND                VARCHAR2(1 CHAR),
    TRANSFER_WORK_EXISTS_IND     VARCHAR2(1 CHAR),
```

```
  OUTCOME_GRADUATION_DATE       DATE,
  ACADEMIC_PERIOD               VARCHAR2(63 CHAR),
  ACADEMIC_PERIOD_GRADUATION    VARCHAR2(63 CHAR),
  GRADUATION_STATUS             VARCHAR2(3 CHAR),
  GRADUATION_STATUS_DESC        VARCHAR2(255 CHAR),
  CREDITS_ATTEMPED              NUMBER,
  CREDITS_EARNED                NUMBER,
  GPA_CREDITS                   NUMBER,
  QUALITY_POINTS                NUMBER,
  CREDITS_PASSED                NUMBER,
  GPA                           NUMBER,
  ETL_TIMESTAMP                 TIMESTAMP(6)
);

CREATE TABLE DEPARTMENT_DIM
(
  DEPARTMENT_KEY          NUMBER,
  DEPARTMENT_CODE         VARCHAR2(63 CHAR),
  DEPARTMENT_CODE_DESC    VARCHAR2(255 CHAR),
  COLLEGE_CODE            VARCHAR2(63 CHAR),
  COLLEGE_CODE_DESC       VARCHAR2(255 CHAR),
  CAMPUS_CODE             VARCHAR2(63 CHAR),
  CAMPUS_CODE_DESC        VARCHAR2(255 CHAR),
  ORGANIZATION_LEVEL_2    VARCHAR2(63 CHAR),
  ORGANIZATION_DESC_2     VARCHAR2(255 CHAR),
  ETL_TIMESTAMP           TIMESTAMP(6)
);
```

```
CREATE TABLE FINANCIAL_AID_FACT
(
  TIME_KEY                    NUMBER,
  STUDENT_KEY                 NUMBER,
  FINANCIAL_AID_KEY           NUMBER,
  STUDENT_ID                  VARCHAR2(9 CHAR),
  PERSON_UID                  NUMBER,
  AID_YEAR                    VARCHAR2(63 CHAR),
  CAMPUS_CODE                 VARCHAR2(63 CHAR),
  AID_YEAR_DESC               VARCHAR2(255 CHAR),
  AWARD_STATUS                VARCHAR2(63 CHAR),
  AWARD_STATUS_DESC           VARCHAR2(255 CHAR),
  AWARD_STATUS_DATE           DATE,
  AWARD_OFFER_IND             VARCHAR2(63 CHAR),
  AWARD_ACCEPT_IND            VARCHAR2(63 CHAR),
  AWARD_DECLINE_IND           VARCHAR2(63 CHAR),
  AWARD_CANCEL_IND            VARCHAR2(63 CHAR),
  AWARD_OFFER_AMOUNT          NUMBER,
  AWARD_ACCEPT_AMOUNT         NUMBER,
  AWARD_PAID_AMOUNT           NUMBER,
  PELL_GRANT_RECEIVED_FLAG    NUMBER,
  PELL_ELIGIBLE_FLAG          NUMBER,
  ETL_TIMESTAMP               TIMESTAMP(6)
);

CREATE TABLE FINANCIAL_AID_FUND_DIM
(
  FINANCIAL_AID_FUND_KEY        NUMBER,
```

```
    AID_YEAR                      VARCHAR2(63 CHAR),
    AID_YEAR_DESC                 VARCHAR2(255 CHAR),
    FUND                          VARCHAR2(63 CHAR),
    FUND_TITLE                    VARCHAR2(255 CHAR),
    FUND_SOURCE                   VARCHAR2(63 CHAR),
    FUND_SOURCE_DESC              VARCHAR2(255 CHAR),
    FUND_TYPE_CODE                VARCHAR2(63 CHAR),
    FUND_TYPE_DESC                VARCHAR2(255 CHAR),
    GIFT_OR_SELF_HELP_AID         VARCHAR2(63 CHAR),
    GIFT_OR_SELF_HELP_AID_DESC    VARCHAR2(255 CHAR),
    FUND_DETAIL_CODE              VARCHAR2(63 CHAR),
    FEDERAL_FUND_ID               VARCHAR2(63 CHAR),
    ETL_TIMESTAMP                 TIMESTAMP(6)
);

CREATE TABLE INSTRUCTIONAL_ASSIGNMENT_FACT
(
    TIME_KEY                    NUMBER,
    INSTRUCTOR_KEY              NUMBER,
    COURSE_KEY                  NUMBER,
    SUB_ACADEMIC_PERIOD         VARCHAR2(63 CHAR),
    SUB_ACADEMIC_PERIOD_DESC    VARCHAR2(255 CHAR),
    CATEGORY                    VARCHAR2(2 CHAR),
    PRIMARY_IND                 VARCHAR2(1 CHAR),
    PERCENT_RESPONSIBILITY      NUMBER,
    SESSION_PERCENTAGE          NUMBER
);
```

```
CREATE TABLE INSTRUCTOR_DIM
(
    INSTRUCTOR_KEY                      NUMBER,
    INSTRUCTOR_ID                       VARCHAR2(9 CHAR),
    INSTRUCTOR_UID                      NUMBER,
    INSTRUCTOR_FIRST_NAME               VARCHAR2(60 CHAR),
    INSTRUCTOR_LAST_NAME                VARCHAR2(60 CHAR),
    INSTRUCTOR_RANK_CODE                VARCHAR2(63 CHAR),
    INSTRUCTOR_RANK_CODE_DESC           VARCHAR2(255 CHAR),
    INSTRUCTOR_BASE_SALARY              CHAR(20 CHAR),
    PRIM_APPOINTMENT_DESC               VARCHAR2(30 CHAR),
    PRIM_APPOINTMENT_DEPT_CODE          VARCHAR2(4 CHAR),
    PRIM_APPT_DEPT_DESC                 VARCHAR2(30 CHAR),
    PRIM_EFFECTIVE_START_DT             DATE,
    PRIM_EFFECTIVE_END_DT               DATE,
    ACADEMIC_TITLE                      CHAR(20 CHAR),
    PRIM_TENURE_CODE                    VARCHAR2(2 CHAR),
    PRIM_TENURE_DEPT_CODE               VARCHAR2(4 CHAR),
    PRIM_TENURE_EFF_DATE                DATE,
    PRIM_TENURE_TRACK_BEGIN_DATE        DATE,
    PRIM_TENURE_REVIEW_DATE             DATE,
    SEC_APPOINTMENT_DESC                VARCHAR2(30 CHAR),
    SEC_APPOINTMENT_DEPT_CODE           VARCHAR2(30 CHAR),
    SEC_APPT_DEPT_DESC                  VARCHAR2(30 CHAR),
    SEC_TENURE_CODE                     VARCHAR2(2 CHAR),
    SEC_TENURE_DEPT_CODE                VARCHAR2(4 CHAR),
    SEC_TENURE_EFF_DATE                 DATE,
    SEC_TENURE_TRACK_BEGIN_DATE         DATE,
```

```
    SEC_TENURE_REVIEW_DATE          DATE,
    RANK_EFFECTIVE_START_DT         DATE,
    RANK_EFFECTIVE_END_DT           DATE,
    ACTIVE_FLAG                     NUMBER,
    EFFECTIVE_START_DATE            DATE,
    EFFECTIVE_END_DATE              DATE,
    ETL_TIMESTAMP                   TIMESTAMP(6)
);

CREATE TABLE MAJOR_DEPT_XWALK
(
    MAJOR_CODE              VARCHAR2(10 CHAR),
    MAJOR_DESCRIPTION       VARCHAR2(31 CHAR),
    ORGANIZATION_LEVEL_5    VARCHAR2(7 CHAR),
    ORGANIZATION_DESC_5     VARCHAR2(34 CHAR),
    OBSOLETE                VARCHAR2(8 CHAR),
    BANNER_MAJOR_CODE       VARCHAR2(10 CHAR),
    BANNER_ORG_CODE         VARCHAR2(15 CHAR),
    ORGANIZATION_LEVEL_3    VARCHAR2(7 CHAR),
    ORGANIZATION_DESC_3     VARCHAR2(34 CHAR),
    ORGANIZATION_LEVEL_2    VARCHAR2(7 CHAR),
    ORGANIZAITON_DESC_2     VARCHAR2(25 CHAR)
);

CREATE TABLE PERSON_DIM
(
    PERSON_KEY                          NUMBER,
    PERSON_ID                           VARCHAR2(9 CHAR),
```

```
PERSON_UID                        NUMBER,
FIRST_NAME                        VARCHAR2(63 CHAR),
LAST_NAME                         VARCHAR2(63 CHAR),
MIDDLE_INITIAL                    VARCHAR2(15 CHAR),
MIDDLE_NAME                       VARCHAR2(63 CHAR),
NAME_SUFFIX                       VARCHAR2(20 CHAR),
FULL_NAME_FMIL                    VARCHAR2(255 CHAR),
FULL_NAME_LFMI                    VARCHAR2(255 CHAR),
NETID                             VARCHAR2(30 CHAR),
GENDER                            VARCHAR2(63 CHAR),
GENDER_DESC                       VARCHAR2(63 CHAR),
BIRTH_DATE                        DATE,
CURRENT_AGE                       NUMBER,
DECEASED_STATUS                   VARCHAR2(1 CHAR),
DECEASED_DATE                     DATE,
CONFIDENTIALITY_IND               VARCHAR2(1 CHAR),
PRIMARY_ETHNICITY                 VARCHAR2(63 CHAR),
PRIMARY_ETHNICITY_DESC            VARCHAR2(255 CHAR),
PRIM_ETHNICITY_CATEGORY           VARCHAR2(63 CHAR),
PRIM_ETHNICITY_CATEGORY_DESC      VARCHAR2(255 CHAR),
HISPANIC_LATINO_ETHNICITY_IND     VARCHAR2(1 CHAR),
IPEDS_VALUES                      NUMBER,
IPEDS_VALUES_DESC                 VARCHAR2(63 CHAR),
HISPANIC                          NUMBER,
AMERICAN_INDIAN                   NUMBER,
ASIAN                             NUMBER,
AFRICAN_AMERICAN                  NUMBER,
NATIVE_HAWAIIAN                   NUMBER,
```

```
WHITE                               NUMBER,
NON_RESIDENT_ALIEN                  NUMBER,
RACE_CATEGORY_COUNT                 NUMBER,
RACE_COUNT                          NUMBER,
RACE_ETHNICITY_CONFIRM_IND          VARCHAR2(1 CHAR),
RACE_ETHNICITY_CONFIRM_DATE         DATE,
CITIZENSHIP_TYPE                    VARCHAR2(63 CHAR),
CITIZENSHIP_TYPE_DESC               VARCHAR2(255 CHAR),
CITIZENSHIP_IND                     VARCHAR2(1 CHAR),
NATION_OF_CITIZENSHIP               VARCHAR2(63 CHAR),
NATION_OF_CITIZENSHIP_DESC          VARCHAR2(255 CHAR),
VISA_TYPE                           VARCHAR2(63 CHAR),
VISA_TYPE_DESC                      VARCHAR2(255 CHAR),
VETERAN_CATEGORY                    VARCHAR2(1 CHAR),
VETERAN_CATEGORY_DESC               VARCHAR2(45 CHAR),
VETERAN_SPECIAL_DISABLED_IND        VARCHAR2(1 CHAR),
MILITARY_SEPARATION_DATE            DATE,
MA_ADDRESS_TYPE                     VARCHAR2(2 CHAR),
MA_ADDRESS_TYPE_DESC                VARCHAR2(50 CHAR),
MA_ACTIVE_ADDRESS_IND               VARCHAR2(2 CHAR),
MA_STREET_LINE1                     VARCHAR2(100 CHAR),
MA_STREET_LINE2                     VARCHAR2(100 CHAR),
MA_STREET_LINE3                     VARCHAR2(100 CHAR),
MA_CITY                             VARCHAR2(63 CHAR),
MA_STATE_PROVINCE                   VARCHAR2(3 CHAR),
MA_STATE_PROVINCE_DESC              VARCHAR2(35 CHAR),
MA_POSTAL_CODE                      VARCHAR2(30 CHAR),
MA_COUNTY_CODE                      VARCHAR2(6 CHAR),
```

```
MA_COUNTY_CODE_DESC            VARCHAR2(20 CHAR),
MA_NATION_CODE                 VARCHAR2(5 CHAR),
MA_NATION_CODE_DESC            VARCHAR2(50 CHAR),
ADDRESS_COUNT                  NUMBER,
PHONE_NUMBER_COMBINED          VARCHAR2(35 CHAR),
PHONE_TYPE                     VARCHAR2(5 CHAR),
PHONE_DESC                     VARCHAR2(50 CHAR),
PHONE_COUNT                    NUMBER,
EMAIL_ADDRESS                  VARCHAR2(255 CHAR),
EMAIL_TYPE                     VARCHAR2(35 CHAR),
EMAIL_TYPE_DESC                VARCHAR2(255 CHAR),
EMAIL_COMMENT                  VARCHAR2(255 CHAR),
EMAIL_PREFERRED_ADDRESS        VARCHAR2(255 CHAR),
PE_ADDRESS_TYPE                VARCHAR2(63 CHAR),
PE_ADDRESS_TYPE_DESC           VARCHAR2(255 CHAR),
PE_ACTIVE_ADDRESS_IND          VARCHAR2(2 CHAR),
PE_STREET_LINE1                VARCHAR2(255 CHAR),
PE_STREET_LINE2                VARCHAR2(255 CHAR),
PE_STREET_LINE3                VARCHAR2(255 CHAR),
PE_CITY                        VARCHAR2(63 CHAR),
PE_STATE_PROVINCE              VARCHAR2(63 CHAR),
PE_STATE_PROVINCE_DESC         VARCHAR2(255 CHAR),
PE_POSTAL_CODE                 VARCHAR2(63 CHAR),
PE_COUNTY_CODE                 VARCHAR2(63 CHAR),
PE_COUNTY_CODE_DESC            VARCHAR2(255 CHAR),
PE_NATION_CODE                 VARCHAR2(63 CHAR),
PE_NATION_CODE_DESC            VARCHAR2(255 CHAR),
EFFECTIVE_START_DATE           DATE,
```

```
  EFFECTIVE_END_DATE                 DATE,
  SSN                                VARCHAR2(63 CHAR),
  STARS_ID                           VARCHAR2(50 CHAR),
  ACTIVE_FLAG                        NUMBER,
  ETL_TIMESTAMP                      TIMESTAMP(6)
);

CREATE TABLE PROGRAM_DIM
(
  PROGRAM_KEY      INTEGER,
  PROGRAM_CODE     VARCHAR2(12 CHAR),
  PROGRAM_DESC     VARCHAR2(30 CHAR),
  LEVEL_CODE       VARCHAR2(2 CHAR),
  CAMPUS_CODE      VARCHAR2(3 CHAR),
  COLLEGE_CODE     VARCHAR2(2 CHAR),
  DEGC_CODE        VARCHAR2(6 CHAR),
  ETL_TIMESTAMP    DATE
);

CREATE TABLE PROGRAM_ENROLLMENT_FACT
(
  TIME_KEY                    NUMBER,
  PROGRAM_KEY                 NUMBER,
  TOTAL_ENROLLMENT            NUMBER,
  WHITE_COUNT                 NUMBER,
  AFRICAN_AMERICAN_COUNT      NUMBER,
  AMERICAN_INDIAN_COUNT       NUMBER,
  HISPANIC_COUNT              NUMBER,
```

```
    ASIAN_COUNT                 NUMBER,
    NATIVE_HAWAIIAN_COUNT       NUMBER,
    TWO_MORE_RACES_COUNT        NUMBER,
    RACE_ETHN_UNKOWN_COUNT      NUMBER,
    NON_RES_COUNT               NUMBER,
    ETL_TIMESTAMP               DATE
);

CREATE TABLE STUDENT_DIM
(
    STUDENT_KEY                       NUMBER,
    STUDENT_ID                        VARCHAR2(15 CHAR),
    PERSON_UID                        NUMBER,
    ACADEMIC_PERIOD                   VARCHAR2(30 CHAR),
    ACADEMIC_PERIOD_DESC              VARCHAR2(30 CHAR),
    PROGRAM_CODE                      VARCHAR2(12 CHAR),
    PROGRAM_CODE_DESC                 VARCHAR2(30 CHAR),
    PRIMARY_PROGRAM_IND               VARCHAR2(1 CHAR),
    YEAR_ADMITTED                     VARCHAR2(4 CHAR),
    YEAR_ADMITTED_DESC                VARCHAR2(20 CHAR),
    AGE_ADMITTED                      NUMBER,
    CATALOG_ACADEMIC_PERIOD           VARCHAR2(6 CHAR),
    CATALOG_ACADEMIC_PERIOD_DESC      VARCHAR2(30 CHAR),
    AWARD_CATEGORY                    VARCHAR2(2 CHAR),
    AWARD_CATEGORY_DESC               VARCHAR2(30 CHAR),
    NEW_STUDENT_IND                   VARCHAR2(1 CHAR),
    ADMISSIONS_POPULATION             VARCHAR2(2 CHAR),
    ADMISSIONS_POPULATION_DESC        VARCHAR2(30 CHAR),
```

```
DEGREE_CODE                         VARCHAR2(6 CHAR),
DEGREE_CODE_DESC                    VARCHAR2(30 CHAR),
FIRST_MAJOR_CODE                    VARCHAR2(4 CHAR),
FIRST_MAJOR_CODE_DESC               VARCHAR2(30 CHAR),
FIRST_MAJOR_CIP_CODE                VARCHAR2(6 CHAR),
FIRST_MAJOR_CIP_DESC                VARCHAR2(30 CHAR),
FIRST_MAJOR_CONC1                   VARCHAR2(4 CHAR),
FIRST_MAJOR_CONC1_DESC              VARCHAR2(30 CHAR),
FIRST_MAJOR_CONC2                   VARCHAR2(4 CHAR),
FIRST_MAJOR_CONC2_DESC              VARCHAR2(30 CHAR),
FIRST_MAJOR_CONC3                   VARCHAR2(4 CHAR),
FIRST_MAJOR_CONC3_DESC              VARCHAR2(30 CHAR),
FIRST_MAJOR_DEPT_CODE               VARCHAR2(4 CHAR),
FIRST_MAJOR_DEPT_CODE_DESC          VARCHAR2(30 CHAR),
FIRST_MAJOR_COLLEGE_CODE            VARCHAR2(2 CHAR),
FIRST_MAJOR_COLLEGE_CODE_DESC       VARCHAR2(30 CHAR),
FIRST_MAJOR_CAMPUS_CODE             VARCHAR2(3 CHAR),
FIRST_MAJOR_CAMPUS_CODE_DESC        VARCHAR2(30 CHAR),
SECOND_MAJOR_CODE                   VARCHAR2(4 CHAR),
SECOND_MAJOR_DESC                   VARCHAR2(30 CHAR),
SECOND_MAJOR_CIP_CODE               VARCHAR2(6 CHAR),
SECOND_MAJOR_CIP_DESC               VARCHAR2(30 CHAR),
SECOND_MAJOR_CONC1                  VARCHAR2(4 CHAR),
SECOND_MAJOR_CONC1_DESC             VARCHAR2(30 CHAR),
SECOND_MAJOR_CONC2                  VARCHAR2(4 CHAR),
SECOND_MAJOR_CONC2_DESC             VARCHAR2(30 CHAR),
SECOND_MAJOR_CONC3                  VARCHAR2(4 CHAR),
SECOND_MAJOR_CONC3_DESC             VARCHAR2(30 CHAR),
```

```
SECOND_MAJOR_DEPT_CODE              VARCHAR2(4 CHAR),
SECOND_MAJOR_DEPT_CODE_DESC         VARCHAR2(30 CHAR),
FIRST_MINOR_CODE                    VARCHAR2(4 CHAR),
FIRST_MINOR_CODE_DESC               VARCHAR2(30 CHAR),
SECOND_MINOR_CODE                   VARCHAR2(4 CHAR),
SECOND_MINOR_CODE_DESC              VARCHAR2(30 CHAR),
STUDENT_STATUS_CODE                 VARCHAR2(2 CHAR),
STUDENT_STATUS_CODE_DESC            VARCHAR2(10 CHAR),
CURRENT_TIME_STATUS_CODE            VARCHAR2(2 CHAR),
CURRENT_TIME_STATUS_CODE_DESC       VARCHAR2(30 CHAR),
STUDENT_CLASS_BOAP_CODE             VARCHAR2(2 CHAR),
STUDENT_CLASS_BOAP_CODE_DESC        VARCHAR2(30 CHAR),
STUDENT_CLASSIFICATION              VARCHAR2(2 CHAR),
STUDENT_CLASSIFICATION_DESC         VARCHAR2(30 CHAR),
STUDENT_LEVEL_CODE                  VARCHAR2(2 CHAR),
STUDENT_LEVEL_CODE_DESC             VARCHAR2(30 CHAR),
RESIDENCY_CODE                      VARCHAR2(2 CHAR),
RESIDENCY_DESC                      VARCHAR2(30 CHAR),
RESIDENCY_IND                       VARCHAR2(1 CHAR),
FINANCIAL_AID_ELIGIBLE_FLAG         NUMBER,
FINANCIAL_AID_RECEIVED_FLAG         NUMBER,
FINAID_APPLICANT_IND                VARCHAR2(1 CHAR),
STUDENT_RATE_CODE                   VARCHAR2(2 CHAR),
STUDENT_RATE_CODE_DESC              VARCHAR2(21 CHAR),
STUDENT_ATTRIBUTE_CODE              VARCHAR2(63 CHAR),
STUDENT_ATTRIBUTE_CODE_DESC         VARCHAR2(255 CHAR),
ENROLLED_IND                        VARCHAR2(1 CHAR),
REGISTERED_IND                      VARCHAR2(1 CHAR),
```

```
    REGISTERED_ABQ                  VARCHAR2(1 CHAR),
    REGISTERED_LOS_ALAMOS           VARCHAR2(1 CHAR),
    REGISTERED_TAOS                 VARCHAR2(1 CHAR),
    REGISTERED_GALLUP               VARCHAR2(1 CHAR),
    REGISTERED_VALENCIA             VARCHAR2(1 CHAR),
    EFFECTIVE_START_DATE            DATE,
    EFFECTIVE_END_DATE              DATE,
    STUDENT_POPULATION              VARCHAR2(1 CHAR),
    STUDENT_POPULATION_DESC         VARCHAR2(30 CHAR),
    ACTIVE_FLAG                     NUMBER,
    ETL_TIMESTAMP                   TIMESTAMP(6)
);

CREATE TABLE STUDENT_ENROLLMENT_FACT
(
    TIME_KEY                    NUMBER,
    STUDENT_KEY                 NUMBER,
    PERSON_KEY                  NUMBER,
    COURSE_KEY                  NUMBER,
    PROGRAM_KEY                 NUMBER,
    INSTRUCTOR_GROUP_KEY        NUMBER,
    STUDENT_ID                  VARCHAR2(9 CHAR),
    CREDIT_HRS_ATTEMPTED        NUMBER,
    CREDIT_HRS_EARNED           NUMBER,
    COURSE_CREDITS              NUMBER,
    FINAL_GRADE_RECEIVED        VARCHAR2(63 CHAR),
    GRADE_POINTS_RECEIVED       NUMBER,
    REGISTRATION_STATUS         VARCHAR2(63 CHAR),
```

```
    REGISTRATION_STATUS_DESC    VARCHAR2(255 CHAR),
    COMPLETED_FLAG              NUMBER,
    ETL_TIMESTAMP               TIMESTAMP(6)
);

CREATE TABLE STUDENT_LEVEL_SUMMARY_FACT
(
    PERSON_KEY                    NUMBER,
    STUDENT_ID                    VARCHAR2(9 CHAR),
    PERSON_UID                    NUMBER,
    NAME                          VARCHAR2(255 CHAR),
    NO_OF_COURSES_ENROLLED        NUMBER,
    GPA_TYPE                      VARCHAR2(1 CHAR),
    GPA_TYPE_DESC                 VARCHAR2(11 CHAR),
    ACADEMIC_STUDY_VALUE          VARCHAR2(63 CHAR),
    ACADEMIC_STUDY_VALUE_DESC     VARCHAR2(255 CHAR),
    GPA                           NUMBER,
    GPA_CREDITS                   NUMBER,
    CREDITS_ATTEMPTED             NUMBER,
    CREDITS_EARNED                NUMBER,
    CREDITS_PASSED                NUMBER,
    QUALITY_POINTS                NUMBER,
    ETL_TIMESTAMP                 TIMESTAMP(6)
);

CREATE TABLE STUDENT_TERM_SUMMARY_FACT
(
    TIME_KEY                      NUMBER,
```

```
    PERSON_KEY                      NUMBER,
    STUDENT_KEY                     NUMBER,
    ACADEMIC_PERIOD                 VARCHAR2(6 CHAR),
    STUDENT_ID                      VARCHAR2(9 CHAR),
    PERSON_UID                      NUMBER,
    NO_OF_COURSES_ENROLLED          NUMBER,
    GPA_TYPE                        VARCHAR2(1 CHAR),
    GPA_TYPE_DESC                   VARCHAR2(11 CHAR),
    ACADEMIC_STUDY_VALUE            VARCHAR2(63 CHAR),
    ACADEMIC_STUDY_VALUE_DESC       VARCHAR2(255 CHAR),
    GPA                             NUMBER,
    GPA_CREDITS                     NUMBER,
    CREDITS_ATTEMPTED               NUMBER,
    CREDITS_EARNED                  NUMBER,
    CREDITS_PASSED                  NUMBER,
    QUALITY_POINTS                  NUMBER,
    ETL_TIMESTAMP                   TIMESTAMP(6)
);
```

References

[1] R. Kimball and M. Ross. The Data Warehouse Toolkit. *The definitive guide to dimensional modeling.*

[2] W. H. Inmon. Building the Data Warehouse. *Getting Started.*

[3] R. Kimball and J. Caserta. The Data Warehouse ETL Toolkit. *Practical Techniques for Extracting, Cleaning, Conforming, and Delivering data.*

[4] R. Kimball and M. Ross. The Kimball Group Reader. *Relentlessly Practical Tools for Data Warehousing and Business Intelligence.*

[5] T. Teorey, S. Lightstone and T.Nadeau. Database Modeling and Design. *Logical Design.*

[6] C. Adamson. Star Schema. *The complete reference.*

[7] SAS Institute Inc.. SAS® Data Integration Studio 4.7 *User Guide 2013.*