Database Systems -

Introduction to Databases and Data Warehouses

CHAPTER 9 - Data Warehouse Implementation and Use

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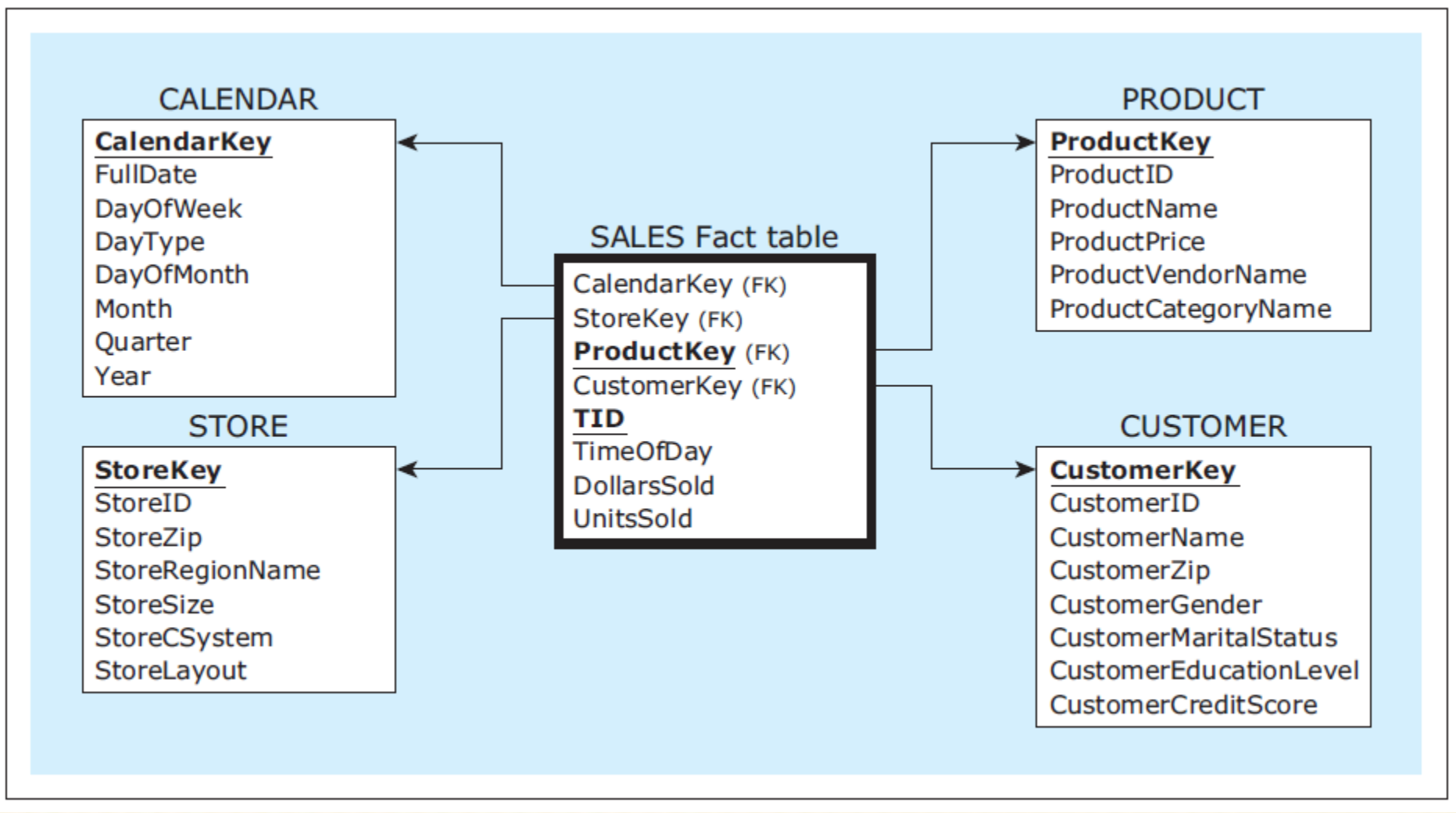
CREATING A DATA WAREHOUSE

- **Creating a data warehouse**
  - Involves using the functionalities of database management software to implement the data warehouse model as a collection of physically created and mutually connected database tables
  - Most often, data warehouses are modeled as relational databases
    - Consequently, they are implemented using a relational DBMS

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Creating a data warehouse - Example

A data warehouse model



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SPEAKER NOTES

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Creating a data warehouse - Example

CREATE TABLE statements

```
CREATE TABLE calendar
        (       calendarkey             INT,
                fulldate                DATE,
                dayofweek               CHAR(15),
                daytype                 CHAR(20),
                dayofmonth              INT,
                month                   CHAR(10),
                quarter                 CHAR(2),
                year                    INT,
PRIMARY KEY (calendarkey));

CREATE TABLE store
        (       storekey                INT,
                storeid                 CHAR(5),
                storezip                CHAR(5),
                storeregionname         CHAR(15),
                storesize               INT,
                storecsystem            CHAR(15),
                storelayout             CHAR(15),
PRIMARY KEY (storekey));
```


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SPEAKER NOTES

This example is discussed on Pages 273-274.

Creating a data warehouse - Example

CREATE TABLE statements

```
CREATE TABLE product
        (       productkey              INT,
                productid               CHAR(5),
                productname             CHAR(25),
                productprice            NUMBER(7,2),
                productvendorname       CHAR(25),
                productcategoryname     CHAR(25),
PRIMARY KEY (productkey));

CREATE TABLE customer
        (       customerkey             INT,
                customerid              CHAR(7),
                customername            CHAR(15),
                customerzip             CHAR(5),
                customergender          CHAR(15),
                customermaritalstatus   CHAR(15),
                customereducationlevel  CHAR(15),
                customercreditscore INT,
PRIMARY KEY (customerkey));
```


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Creating a data warehouse - Example

CREATE TABLE statements

```
CREATE TABLE sales
        (       calendarkey             INT,
                storekey                INT,
                productkey              INT,
                customerkey             INT,
                tid                     CHAR(15),
                timeofday               TIME,
                dollarssold             NUMBER(10,2),
                unitssold               INT,
                PRIMARY KEY (productkey, tid),
                FOREIGN KEY (calendarkey) REFERENCES calendar,
                FOREIGN KEY (storekey) REFERENCES store,
                FOREIGN KEY (productkey) REFERENCES product,
                FOREIGN KEY (customerkey) REFERENCES customer);
```


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ETL

- **Extraction** - the retrieval of analytically useful data from the operational data sources that will eventually be loaded into the data warehouse
  - The data to be extracted is data that is analytically useful in the data warehouse
  - What to extract is determined within the requirements and modeling stages
    - Requirements and modeling stages of the data warehouse include the examination of the available sources
    - During the process of creation of the ETL infrastructure the data model provides a blueprint for the extraction procedures

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It is possible that, in the process of creating the ETL infrastructure, the data warehouse development team may realize that certain ETL actions should be done differently from what is prescribed by the given data model. In such cases the project will move iteratively back from the creation of ETL infrastructure to the requirement stage.

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ETL

- **Transformation** - transforming the structure of extracted data in order to fit the structure of the target data warehouse model
  - E.g. adding surrogate keys

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ETL

- **Transformation**
  - The data quality control and improvement are included in the transformation process
    - Commonly, some of the data in the data sources exhibit data quality problems
    - Data sources often contain overlapping information
  - **Data cleansing (scrubbing)** - the detection and correction of low-quality data

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- **Load** - loading the extracted, transformed, and quality assured data into the target data warehouse
  - A batch process that inserts the data into the data warehouse tables in an automatic fashion without user involvement

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ETL

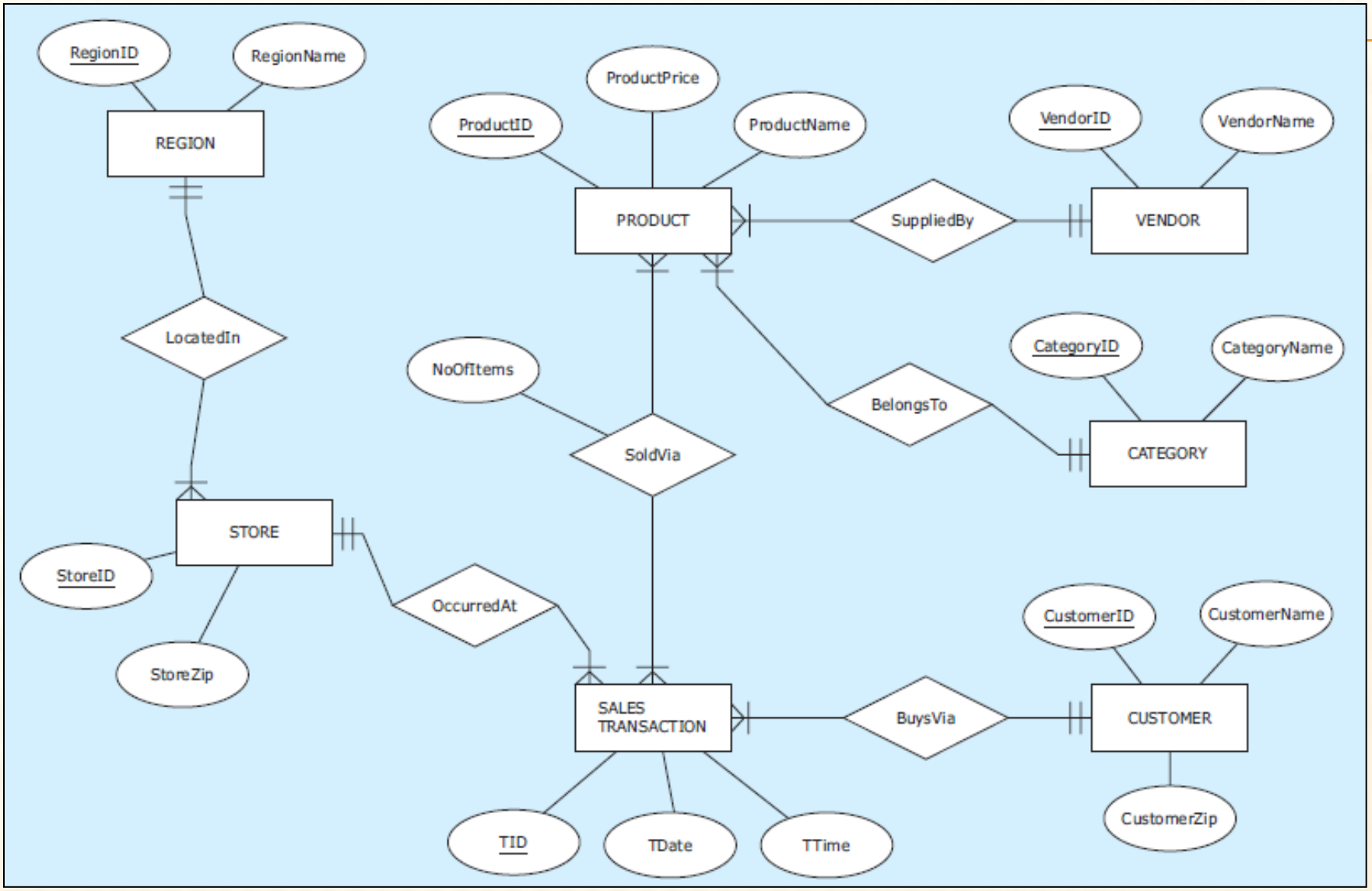
- Load
  - The **initial load** (**first load**), populates initially empty data warehouse tables
    - It can involve large amounts of data, depending on what is the desired time horizon of the data in the newly initiated data warehouse
  - Every subsequent load is referred to as a **refresh load**
  - **Refresh cycle** is the period in which the data warehouse is reloaded with the new data (e.g. hourly, daily)
    - Determined in advance, based on the analytical needs of the business users of the data warehouse and the technical feasibility of the system
  - In **active data warehouses** the loads occur in micro batches that occur continuously

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ETL - Example

Source 1 – ER diagram



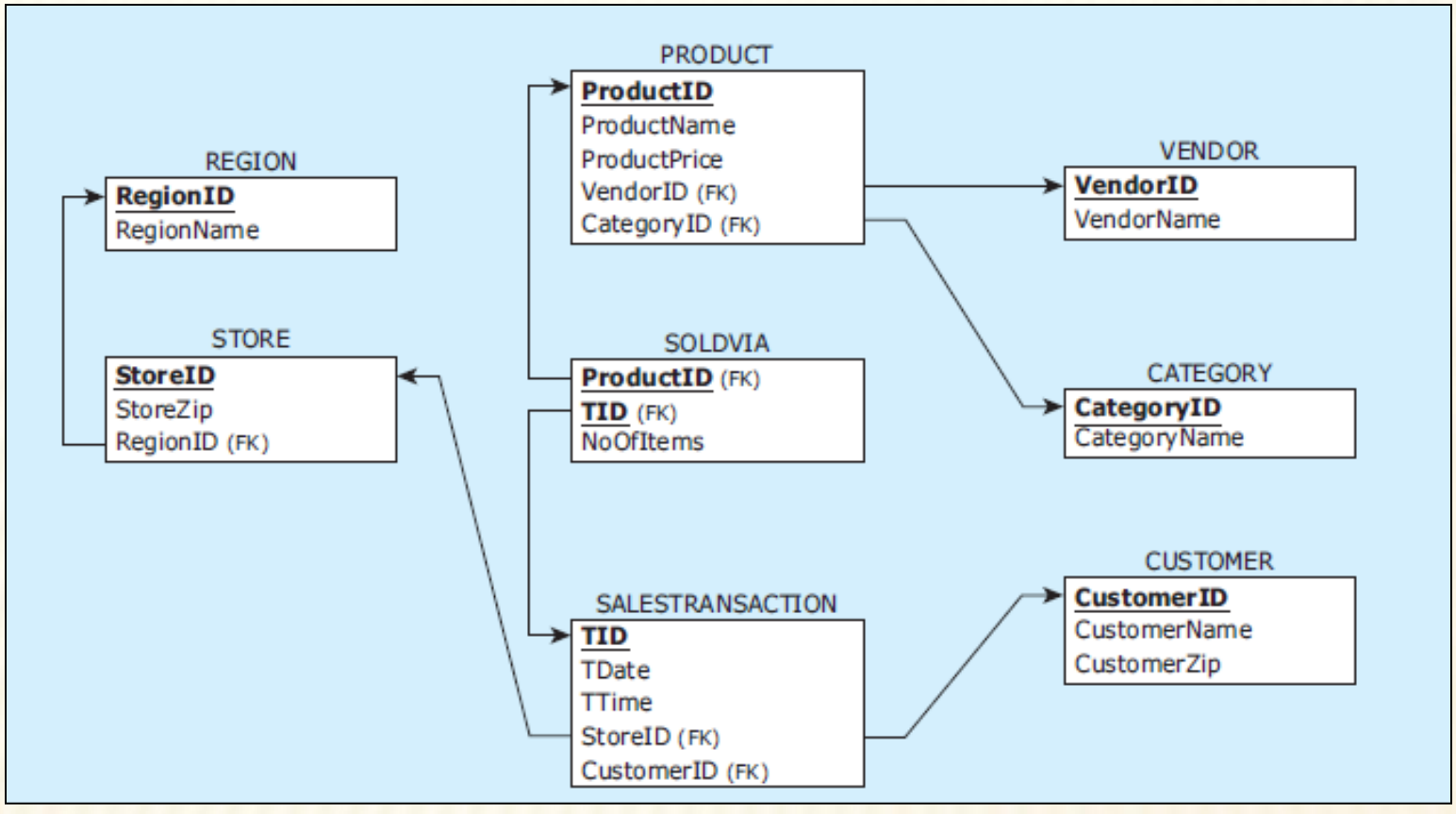
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ETL - Example

Source 1 – Relational schema



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ETL - Example Source 1 – Data records

REGION

RegionID	RegionName
C	Chicagoland
T	Tristate

PRODUCT

ProductID	ProductName	ProductPrice	VendorID	CategoryID
1X1	Zzz Bag	$100	PG	CP
2X2	Easy Boot	$70	MK	FW
3X3	Cosy Sock	$15	MK	FW
4X4	Dura Boot	$90	PG	FW
5X5	Tiny Tent	$150	MK	CP
6X6	Biggy Tent	$250	MK	CP

VENDOR

VendorID	VendorName
PG	Pacifica Gear
MK	Mountain King

STORE

StoreID	StoreZip	RegionID
S1	60600	C
S2	60605	C
S3	35400	T

CATEGORY

CategoryID	CategoryName
CP	Camping
FW	Footwear

SALES TRANSACTION

TID	CustomerID	StoreID	TDate	TTime
T111	1-2-333	S1	1-Jan-2013	8:23:59 AM
T222	2-3-444	S2	1-Jan-2013	8:24:30 AM
T333	1-2-333	S3	2-Jan-2013	8:15:08 AM
T444	3-4-555	S3	2-Jan-2013	8:20:33 AM
T555	2-3-444	S3	2-Jan-2013	8:30:00 AM
T666	2-3-444	S1	3-Jan-2013	8:00:00 AM
T777	3-4-555	S2	3-Jan-2013	8:10:00 AM
T888	1-2-333	S3	4-Jan-2013	8:05:00 AM
T999	2-3-444	S2	4-Jan-2013	9:07:33 AM
T1000	2-3-444	S2	4-Jan-2013	9:07:33 AM

SOLDVIA

ProductID	TID	NoOfItems
1X1	T111	1
2X2	T222	1
3X3	T333	5
1X1	T333	1
4X4	T444	1
2X2	T444	2
4X4	T555	4
5X5	T555	2
6X6	T555	1
1X1	T666	1
2X2	T777	1
3X3	T777	2
1X1	T888	2
1X1	T999	3
3X3	T999	4
4X4	T999	2
1X1	T1000	3
3X3	T1000	4
4X4	T1000	2

CUSTOMER

CustomerID	CustomerName	CustomerZip
1-2-333	Tina	60137
2-3-444	Tony	60611
3-4-555	Pam	35401

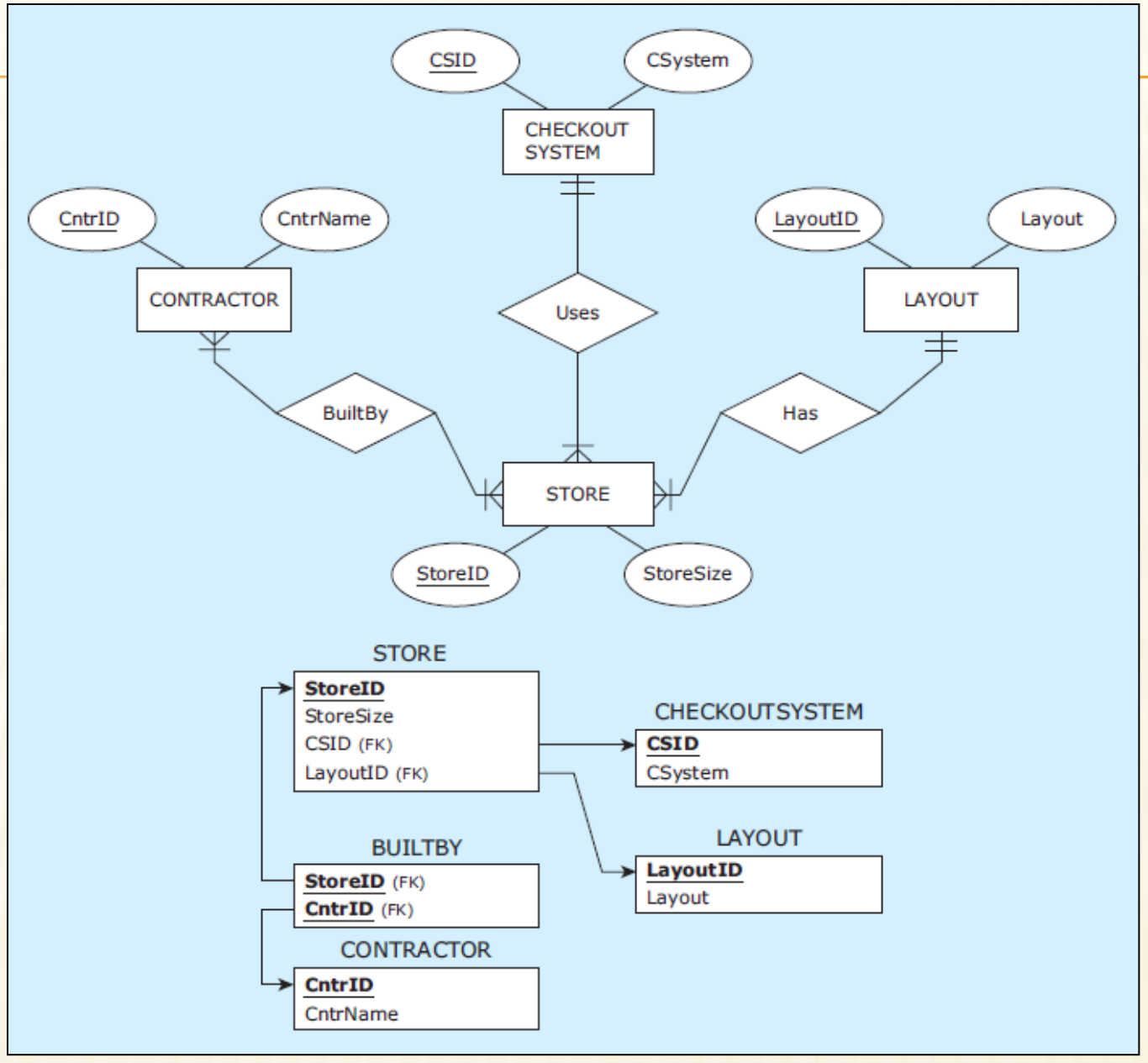
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ETL - Example

Source 2 – ER diagram and relational schema



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ETL - Example

Source 2 – data records

CONTRACTOR

CntrID	CntrName
C1	Acme Construction
C2	GIN Builders
C3	Rauker G.C.

CHECKOUTSYSTEM

CSID	CSystem
CR	Cashiers
AC	Self Service
MX	Mixed

LAYOUT

LayoutID	Layout
M	Modern
T	Traditional

BUILTBY

StoreID	CntrID
S1	C1
S1	C2
S1	C3
S2	C1
S2	C3
S3	C1
S3	C3

STORE TABLE

StoreID	StoreSize (m^2)	CSID	LaoyutID
S1	51000	CR	M
S2	35000	AC	T
S3	55000	MX	T

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ETL - Example
Source 3

CUSTOMER TABLE

CustomerID	Customer Name	Gender	Marital Status	Education Level	Credit Score
1-2-333	Tina	Female	Single	College	700
2-3-444	Tony	Male	Single	High School	650
3-4-555	Pammy	Female	Married	College	623

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ETL - Example

Data warehouse populated with the data from Sources 1, 2, and 3

CALENDAR Dimension

Calendar Key	FullDate	DayOfWeek	DayType	DayOfMonth	Month	Qtr	Year
1	1/1/2013	Tuesday	Weekend/Holiday	1	January	Q1	2013
2	1/2/2013	Wednesday	Workday	2	January	Q1	2013
3	1/3/2013	Thursday	Workday	3	January	Q1	2013
4	1/4/2013	Friday	Workday	4	January	Q1	2013

PRODUCT Dimension

ProductKey	ProductID	ProductName	ProductPrice	ProductVendor Name	ProductCategory Name
1	1X1	Zzz Bag	$100	Pacifica Gear	Camping
2	2X2	Easy Boot	$70	Mountain King	Footwear
3	3X3	Cosy Sock	$15	Mountain King	Footwear
4	4X4	Dura Boot	$90	Pacifica Gear	Footwear
5	5X5	Tiny Tent	$150	Mountain King	Camping
6	6X6	Biggy Tent	$250	Mountain King	Camping

STORE Dimension

StoreKey	StoreID	StoreZip	StoreRegion Name	Store Size (m^2)	Store CSystem	Store Layout
1	S1	60600	Chicagoland	51000	Cashiers	Modern
2	S2	60605	Chicagoland	35000	Self Service	Traditional
3	S3	35400	Tristate	55000	Mixed	Traditional

CUSTOMER Dimension

Customer Key	CustomerID	Customer Name	Customer Zip	Customer Gender	Customer Marital Status	Customer Education Level	Customer Credit Score
1	1-2-333	Tina	60137	Female	Single	College	700
2	2-3-444	Tony	60611	Male	Single	High School	650
3	3-4-555	Pam	35401	Female	Married	College	623

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ETL - Example

Data warehouse populated with the data from Sources 1, 2, and 3

SALES Fact table

CalendarKey	StoreKey	ProductKey	Customer Key	TID	TimeOfDay	Dollars Sold	UnitsSold
1	1	1	1	T111	8:23:59 AM	$100	1
1	2	2	2	T222	8:24:30 AM	$70	1
2	3	3	1	T333	8:15:08 AM	$75	5
2	3	1	1	T333	8:15:08 AM	$100	1
2	3	4	3	T444	8:20:33 AM	$90	1
2	3	2	3	T444	8:20:33 AM	$140	2
2	3	4	2	T555	8:30:00 AM	$360	4
2	3	5	2	T555	8:30:00 AM	$300	2
2	3	6	2	T555	8:30:00 AM	$250	1
3	1	1	2	T666	8:00:00 AM	$100	1
3	2	2	3	T777	8:10:00 AM	$70	1
3	2	3	3	T777	8:10:00 AM	$30	2
4	3	1	1	T888	8:05:00 AM	$200	2
4	2	1	2	T999	9:07:33 AM	$300	3
4	2	3	2	T999	9:07:33 AM	$60	4
4	2	4	2	T999	9:07:33 AM	$180	2

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ETL

- ETL Infrastructure
  - Typically, the process of creating the ETL infrastructure includes using specialized ETL software tools and/or writing code
  - Due to the amount of detail that has to be considered, creating ETL infrastructure is often the most time and resource consuming part in the data warehouse development process
  - Although labor intensive, the process of creating the ETL infrastructure is essentially predetermined by the results of the requirements collection and data warehouse modeling processes which specify the sources and the target

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OLAP

- **Online transaction processing (OLTP)** - updating (i.e. inserting, modifying and deleting), querying and presenting data from databases for operational purposes
- **Online analytical processing (OLAP)** - querying and presenting data from data warehouses and/or data marts for analytical purposes

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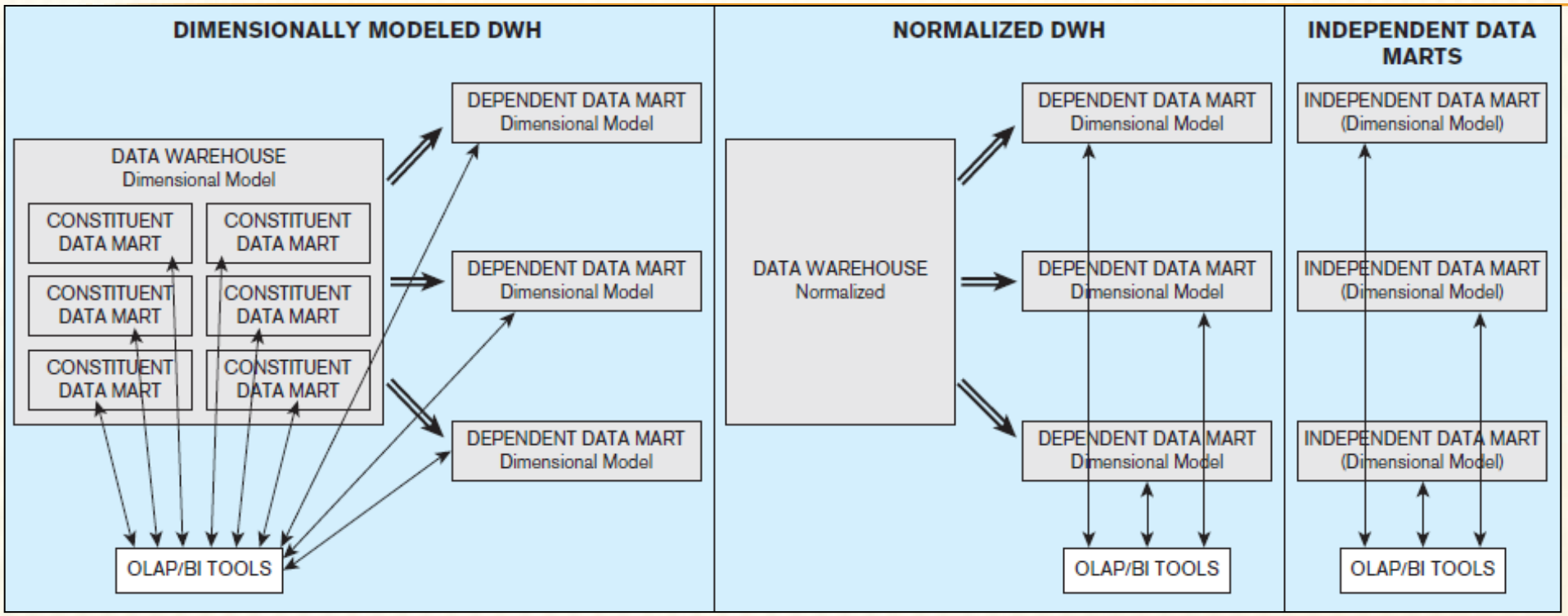
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OLAP

- OLAP/BI Tools
  - Designed for analysis of dimensionally modeled data
  - Regardless of which data warehousing approach is chosen, the data that is accessible by the end user is typically structured as a dimensional model
    - OLAP/BI tools can be used on analytical data stores created with different modeling approaches

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OLAP/BI tools as an interface to data warehouses modeled using different approaches



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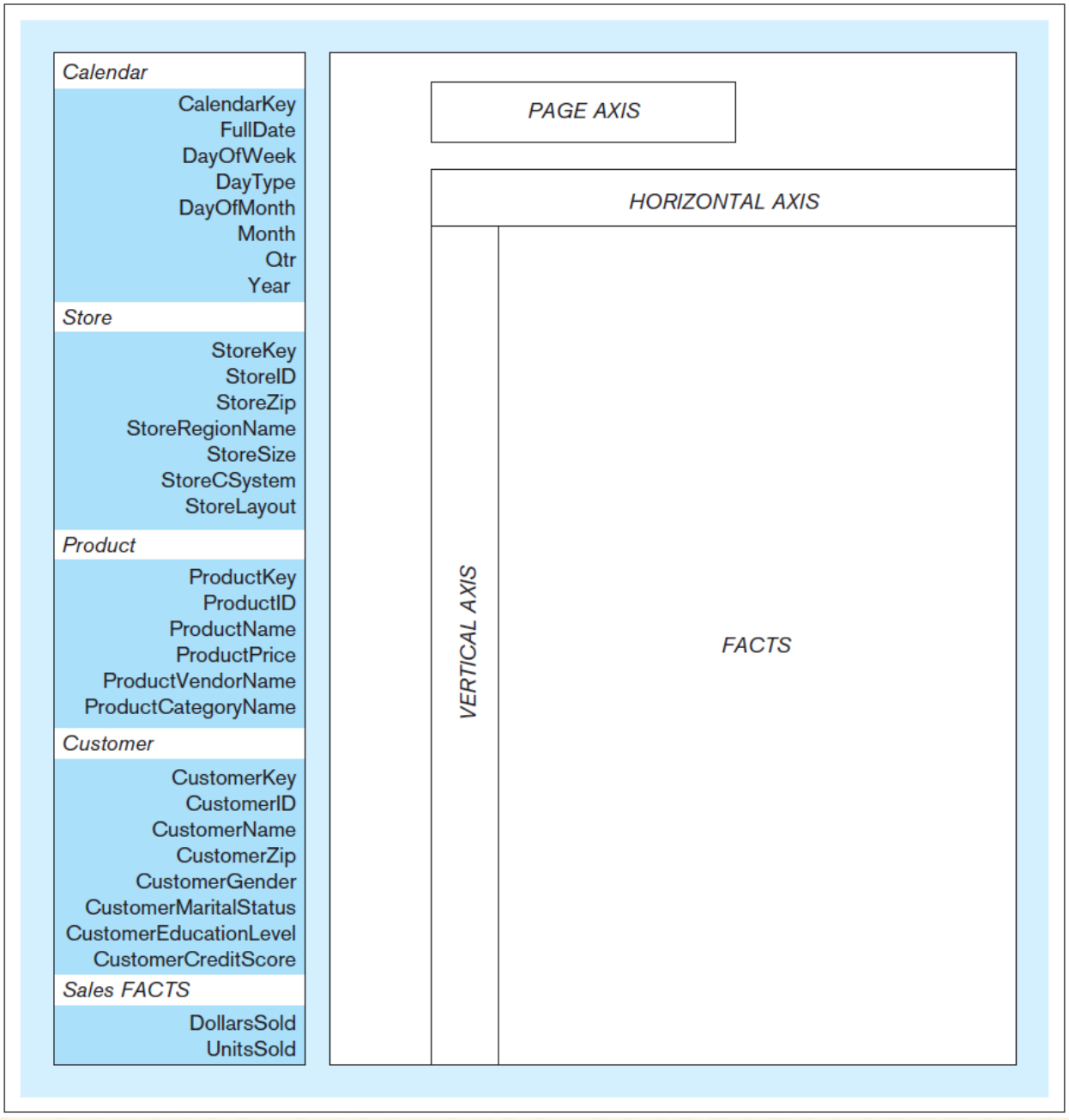
This example is discussed on Pages 275-280.

OLAP

- OLAP/BI Tools
  - Allow users to query fact and dimension tables by using simple point-and-click query-building applications
  - Based on the point-and-click actions by the user of the OLAP/BI tool, the tool writes and executes the code in the language of the data management system (e.g. SQL) that hosts the data warehouse or data mart that is being queried

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A typical OLAP/BI tool query construction space



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OLAP Query 1 - Text

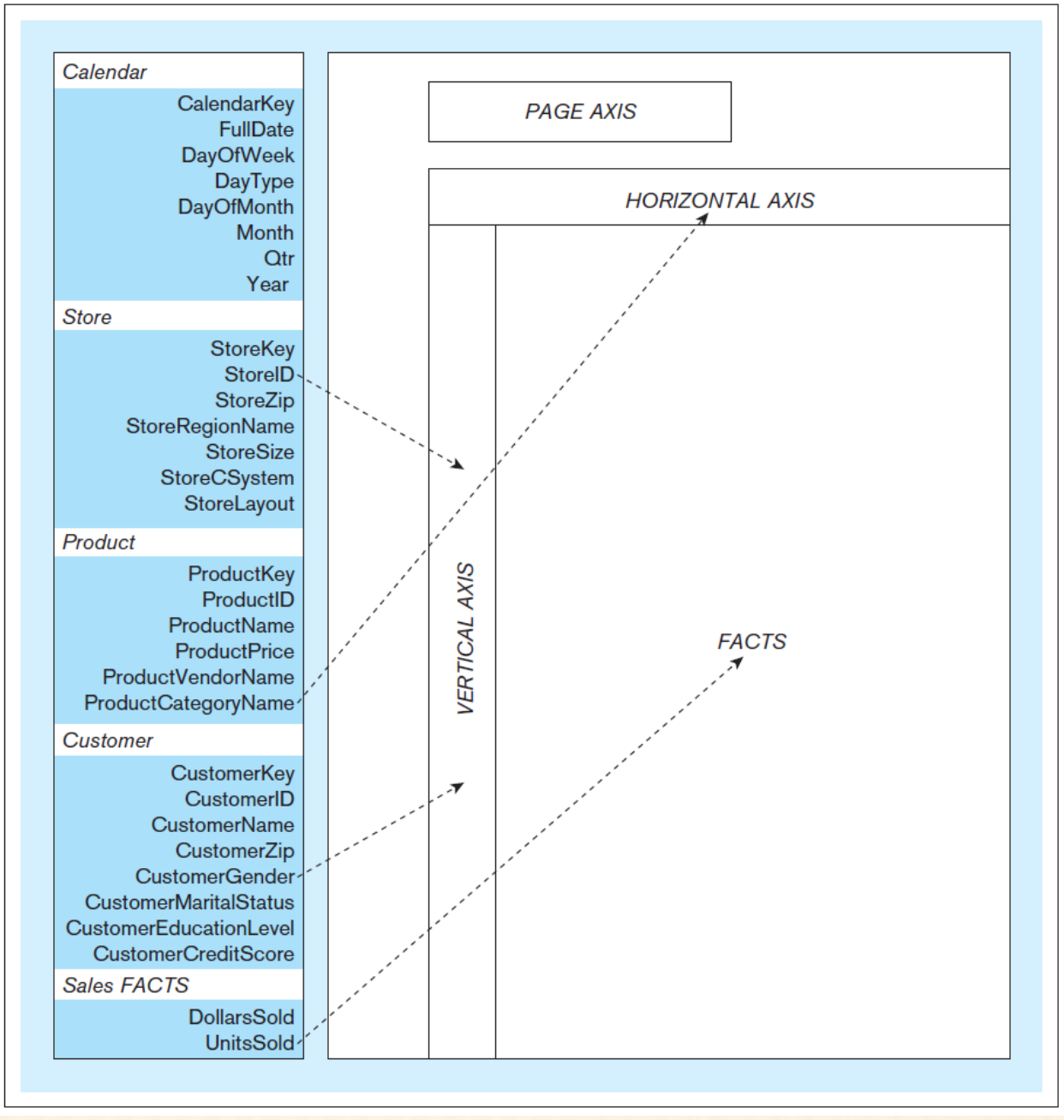
OLAP Query 1: For each individual store, show separately for male and female shoppers the number of product units sold for each product category

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SPEAKER NOTES

This example is discussed on Pages 282-283.

OLAP Query 1 - OLAP/BI tool query construction actions



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SPEAKER NOTES

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OLAP Query 1 - Result

		Sales-Units Sold	
		Camping	Footwear
Store 1			
	Female	1	0
	Male	1	0
Store 2			
	Female	0	3
	Male	3	7
Store 3			
	Female	3	8
	Male	3	4

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SPEAKER NOTES

This example is discussed on Pages 282-283.

OLAP

- OLAP/BI Tools
  - Basic OLAP/BI tool features:
    - Slice and Dice
    - Pivot (Rotate)
    - Drill Down / Drill Up

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OLAP

- Slice and Dice
  - Adds, replaces, or eliminates specified dimension attributes (or particular values of the dimension attributes) from the already displayed result

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Slice and Dice – Example (Query 1 starting point)
OLAP Query 1 - Result

		Sales-Units Sold	
		Camping	Footwear
Store 1			
	Female	1	0
	Male	1	0
Store 2			
	Female	0	3
	Male	3	7
Store 3			
	Female	3	8
	Male	3	4

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Slice and Dice - Example
OLAP Query 2 - Text

OLAP Query 2: For stores 1 and 2, show separately for male and female shoppers the number of product units sold for each product category

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SPEAKER NOTES

This example is discussed on Pages 283-285.

Slice and Dice - Example (Query 1 starting point)
OLAP Query 1 - Result

		Sales-Units Sold	
		Camping	Footwear
Store 1			
	Female	1	0
	Male	1	0
Store 2			
	Female	0	3
	Male	3	7
Store 3			
	Female	3	8
	Male	3	4

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Slice and Dice - Example
OLAP Query 2 - Result

		Sales-Units Sold	
		Camping	Footwear
Store 1			
	Female	1	0
	Male	1	0
Store 2			
	Female	0	3
	Male	3	7

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SPEAKER NOTES

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Slice and Dice – Another Example
OLAP Query 3 - Text

OLAP Query 3: For each individual store, show separately for male and female shoppers the number of product units sold on workdays and on weekends/holidays

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Slice and Dice – Another Example (Query 1 starting point)
OLAP Query 1 - Result

		Sales-Units Sold	
		Camping	Footwear
Store 1			
	Female	1	0
	Male	1	0
Store 2			
	Female	0	3
	Male	3	7
Store 3			
	Female	3	8
	Male	3	4

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SPEAKER NOTES

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Slice and Dice – Another Example
OLAP Query 3 - Result

		Sales-Units Sold	
		Weekend/ Holiday	Workday
Store 1			
	Female	1	0
	Male	0	1
Store 2			
	Female	0	3
	Male	1	9
Store 3			
	Female	0	11
	Male	0	7

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OLAP

- Pivot (Rotate)
  - Reorganizes the values displayed in the original query result by moving values of a dimension column from one axis to another

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Pivot – Example
OLAP Query 1 - Result

		Sales-Units Sold	
		Camping	Footwear
Store 1			
	Female	1	0
	Male	1	0
Store 2			
	Female	0	3
	Male	3	7
Store 3			
	Female	3	8
	Male	3	4

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Pivot – Example
OLAP Query 1 – Result *pivoted*

		Sales-Units Sold	
		Female	Male
Store 1			
	Camping	1	1
	Footwear	0	0
Store 2			
	Camping	0	3
	Footwear	3	7
Store 3			
	Camping	3	3
	Footwear	8	4

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OLAP

- **Drill Down**
  - Makes the granularity of the data in the query result *finer*
- **Drill Up**
  - Makes the granularity of the data in the query result *coarser*

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OLAP

- **Drill hierarchy**
  - Set of attributes within a dimension where an attribute is related to one or more attributes at a lower level but only related to one item at a higher level
    - For example: *StoreRegionName* → *StoreZip* → *StoreID*
  - Used for drill down/drill up operations

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Drill Down – Example
OLAP Query 4 - Text

OLAP Query 4: For each individual store, show separately for male and female shoppers the number of product units sold for each individual product in each category.

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Drill Down – Example (Query 1 starting point)
OLAP Query 1 - Result

		Sales-Units Sold	
		Camping	Footwear
Store 1			
	Female	1	0
	Male	1	0
Store 2			
	Female	0	3
	Male	3	7
Store 3			
	Female	3	8
	Male	3	4

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Drill Down – Example
OLAP Query 4 - Result

		Sales-Units Sold					
			Camping			Footwear	
		Biggy Tent	Tiny Tent	Zzz Bag	Cosy Sock	Dura Boot	Easy Boot
Store 1							
	Female	0	0	1	0	0	0
	Male	0	0	1	0	0	0
Store 2							
	Female	0	0	0	2	0	1
	Male	0	0	3	4	2	1
Store 3							
	Female	0	0	3	5	1	2
	Male	1	2	0	0	4	0

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Drill Up – Example (Query 4 starting point)
OLAP Query 1 - Result

		Sales-Units Sold	
		Camping	Footwear
Store 1			
	Female	1	0
	Male	1	0
Store 2			
	Female	0	3
	Male	3	7
Store 3			
	Female	3	8
	Male	3	4

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SPEAKER NOTES

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OLAP

- OLAP/BI Tools
  - Require dimensional organization of underlying data for performing basic OLAP operations (slice, pivot, drill)
  - Additional OLAP/BI Tool functionalities:
    - Graphically visualizing the answers
    - Creating and examining calculated data
    - Determining comparative or relative differences
    - Performing exception analysis, trend analysis, forecasting, and regression analysis
    - Number of other analytical functions
  - Many OLAP/BI tools are web-based

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The listed additional functionalities are found in other non-OLAP applications, such as statistical tools or spreadsheet software. What truly distinguishes OLAP/BI tools from other applications is the capability to easily interact with the dimensionally modeled data marts and data warehouses and, consequently, the capability to perform OLAP functions on large amounts of data.

Result Visualization Example
OLAP Query 1 – Result

		Sales-Units Sold	
		Camping	Footwear
Store 1			
	Female	1	0
	Male	1	0
Store 2			
	Female	0	3
	Male	3	7
Store 3			
	Female	3	8
	Male	3	4

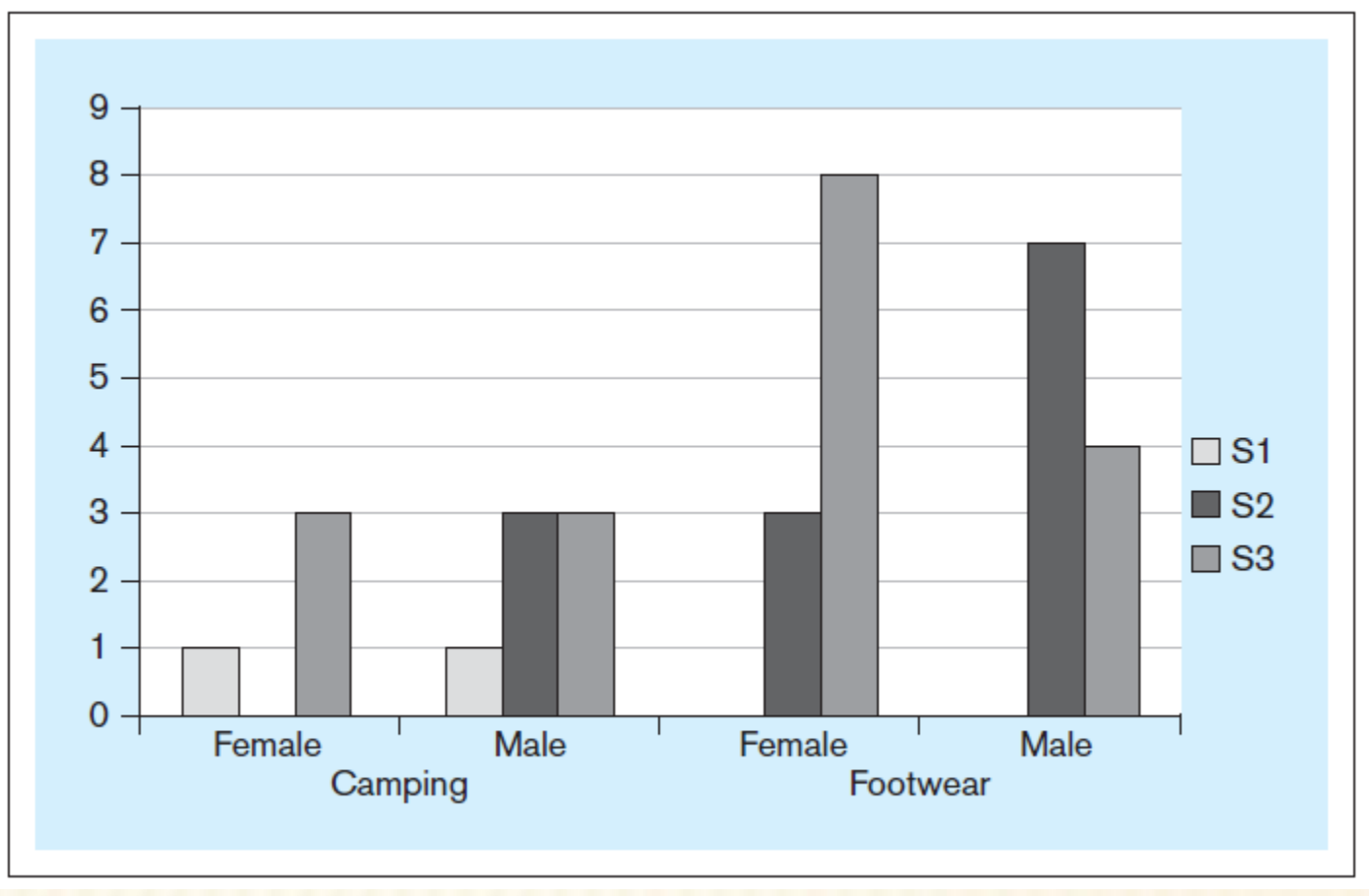
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Result Visualization Example

OLAP Query 1 – Result, visualized as a chart



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OLAP

- **OLAP/BI Tools** – two purposes:
  - Ad-hoc direct analysis of dimensionally modeled data
  - Creation of front-end (BI) applications

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SPEAKER NOTES

Ad-hoc direct analysis of dimensionally modeled data - occurs when a user accesses the data in the data warehouse via an OLAP/BI tool, and performs actions, such as pivoting, slicing and drilling. This process is also sometimes referred to as data interrogation, because often the answers to one query lead into new questions. For example, an analyst may create a query using an OLAP/BI tool. The answer to that query may prompt an additional question which is then answered by pivoting, slicing or drilling the result of the original query.
Creation of front-end (BI) applications - the data warehouse front end application can be created simply as a collection of the OLAP/BI tool queries created by OLAP/BI tool expert users. Such a collection can be accompanied with a menu structure for navigation and then provided to the users of the data warehouse who do not have the access privilege, expertise and/or the time to use OLAP/BI tools directly.

DATA WAREHOUSE/DATA MART FRONT-END (BI) APPLICATIONS

- Data Warehouse/Data Mart Front-End (BI) Applications
  - Provide access for indirect use

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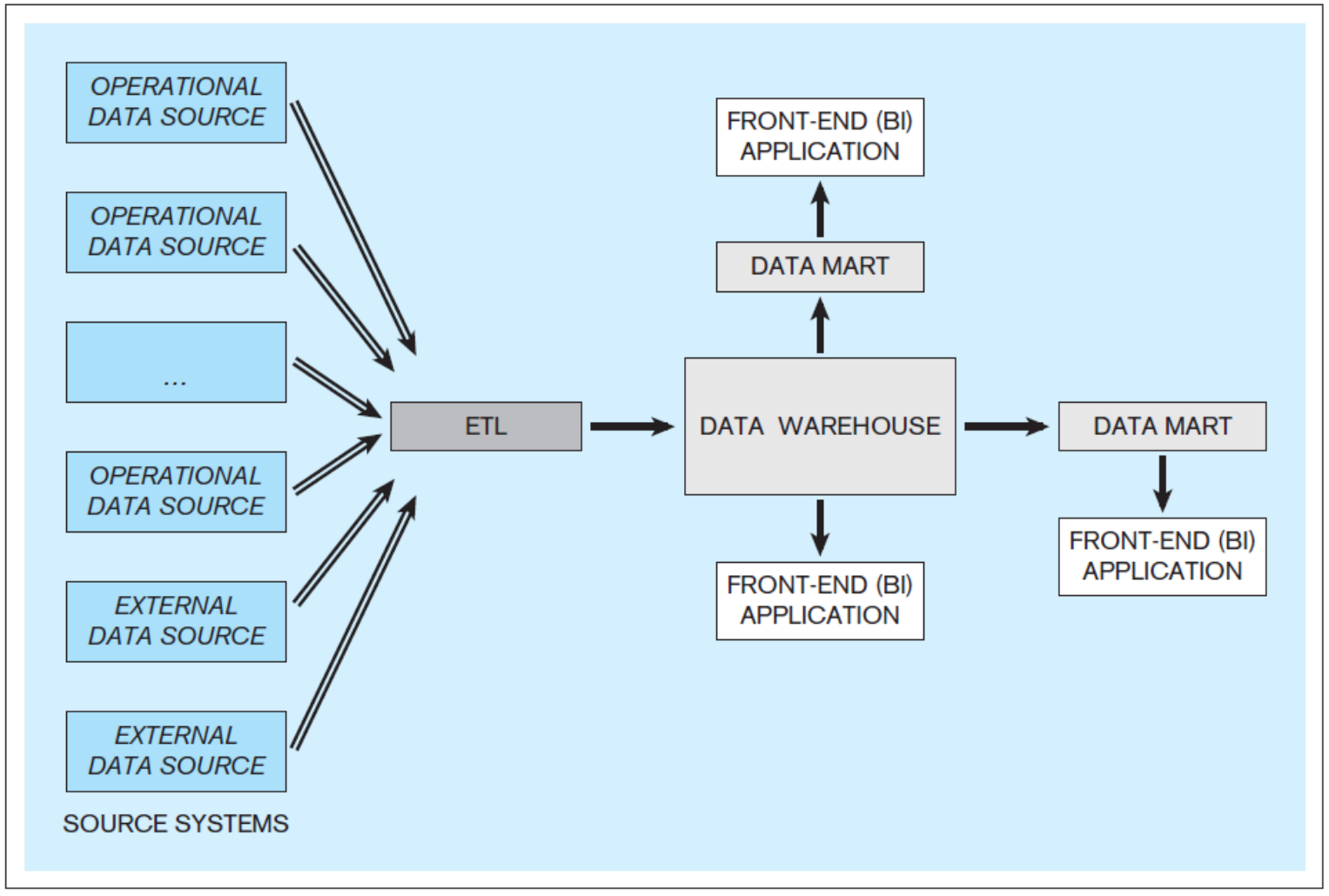
SPEAKER NOTES

In most cases, a portion of intended users (often a majority of the users) of the data warehouse lack the time and/or expertise to engage in open-ended direct analysis of the data. It is not reasonable to expect every person who needs to use the data from the data warehouse as a part of their workplace responsibilities, to develop their own queries by writing the SQL code or engaging in the ad-hoc use of OLAP/BI tools. Instead, many of the data warehouse and data mart end-users access the data through front-end (BI) applications.

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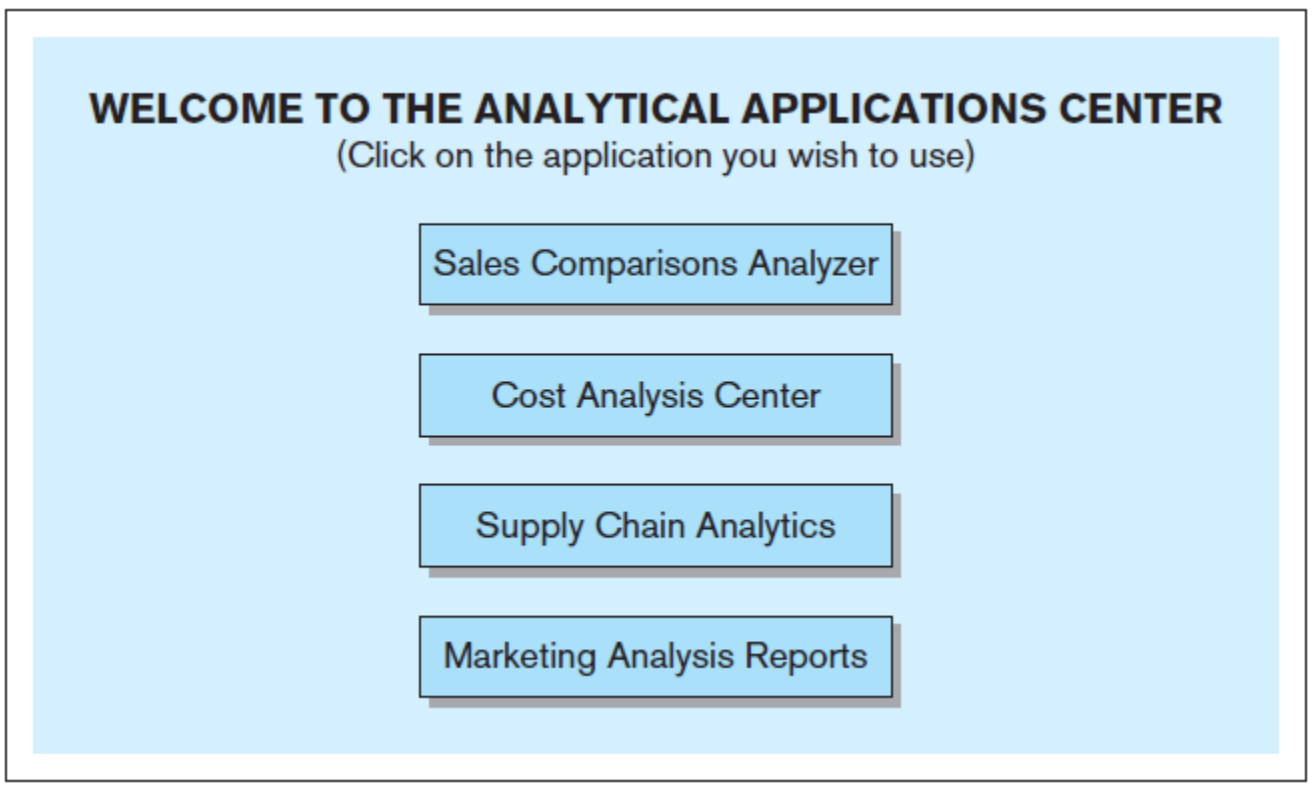
DATA WAREHOUSE/DATA MART FRONT-END (BI) APPLICATIONS

A data warehousing system with front-end applications



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Example – An interface to a collection of data warehouse front-end applications



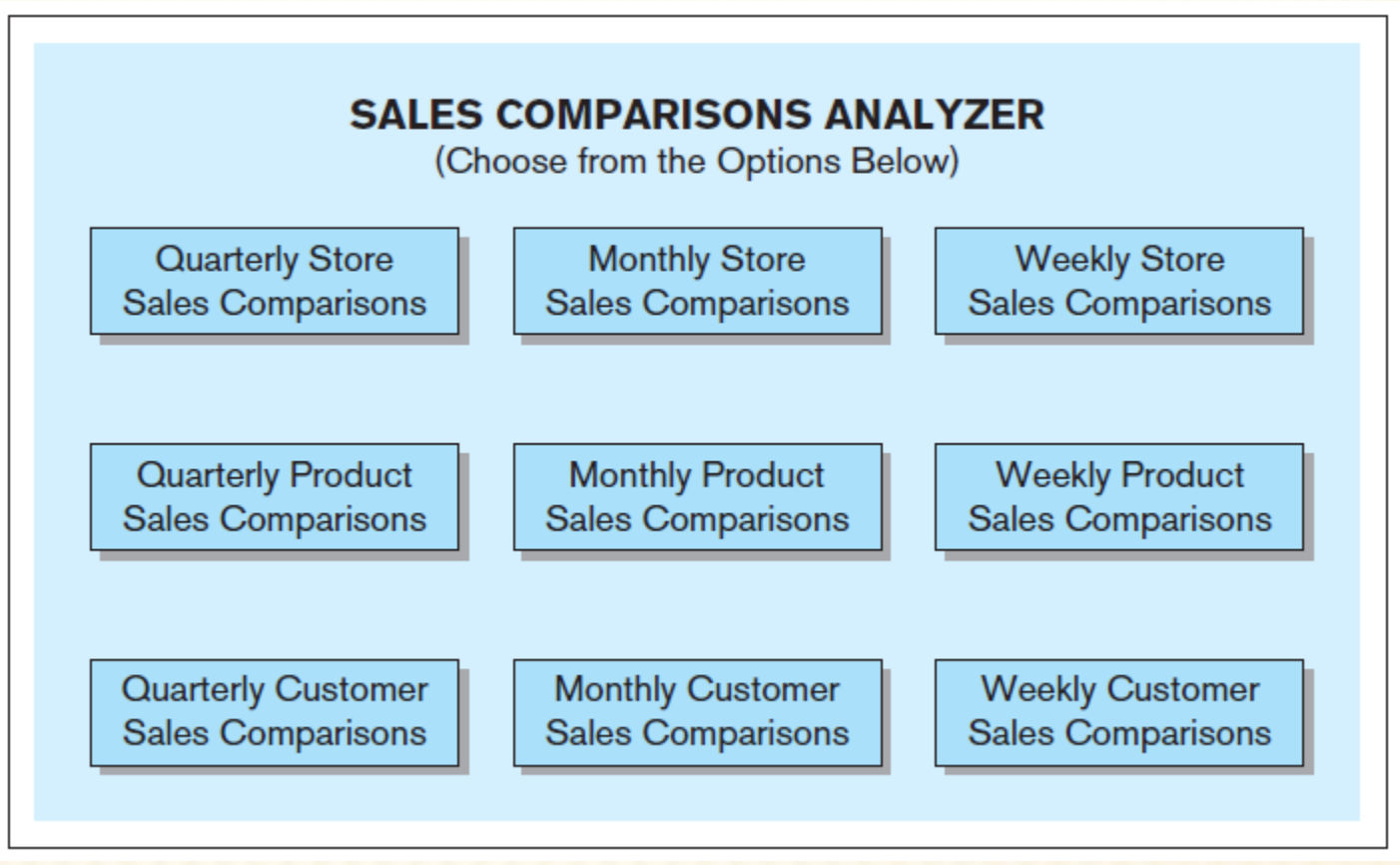
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This example is discussed on Pages 290-291.

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Example – An interface to a data warehouse front-end application

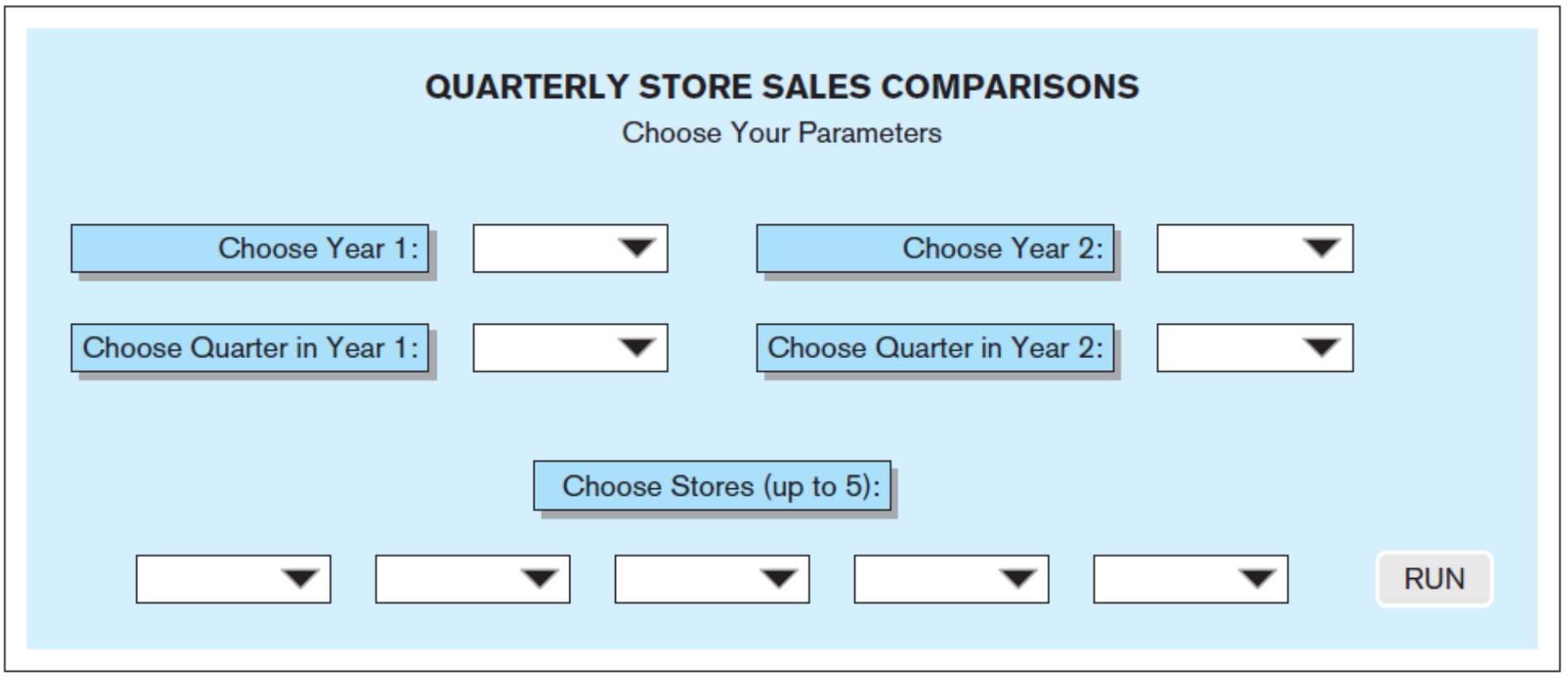


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SPEAKER NOTES

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Example – An interface to a predeveloped data warehouse query



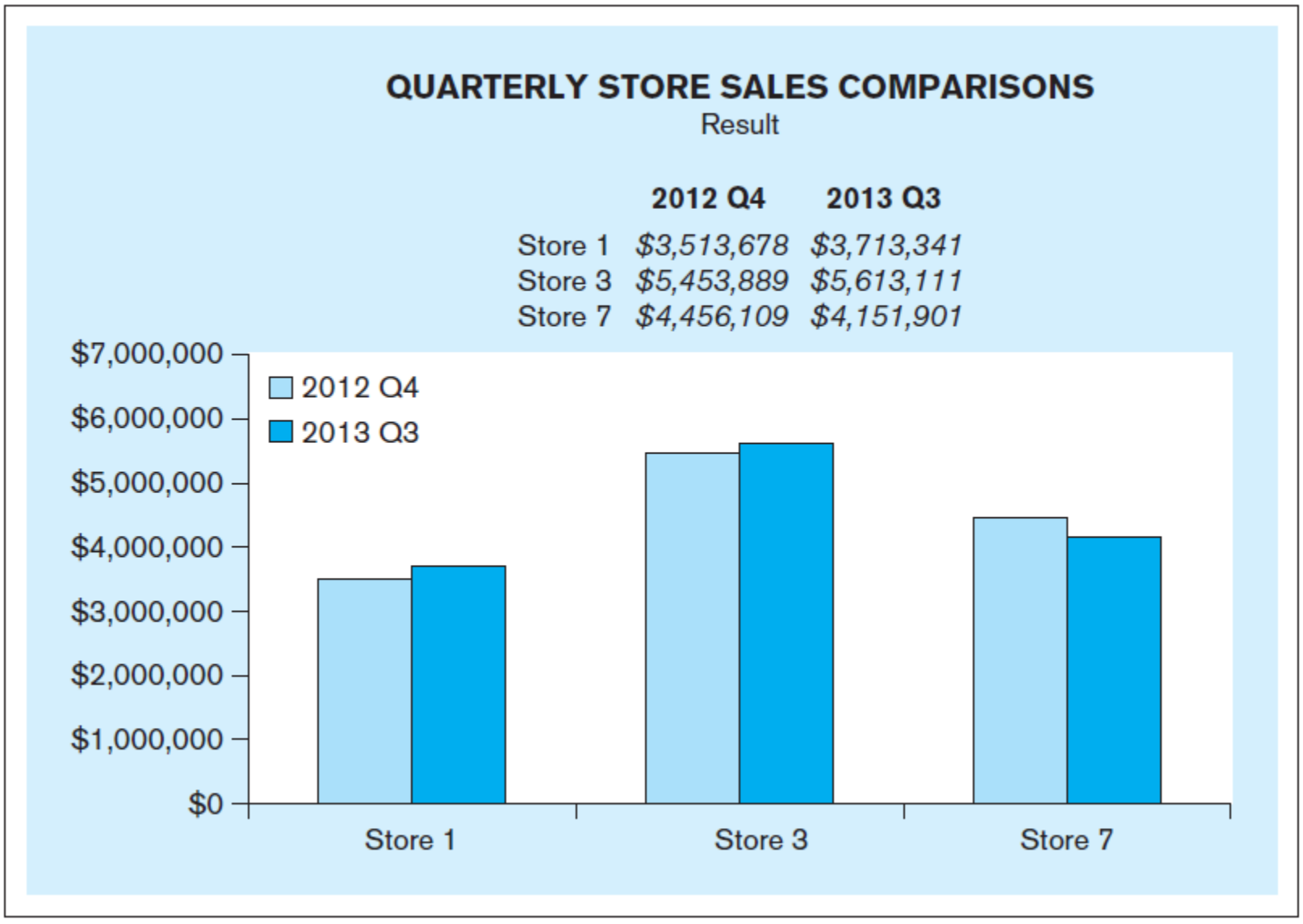
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Example – The results of selecting particular parameter values in the interface to the predeveloped data warehouse query



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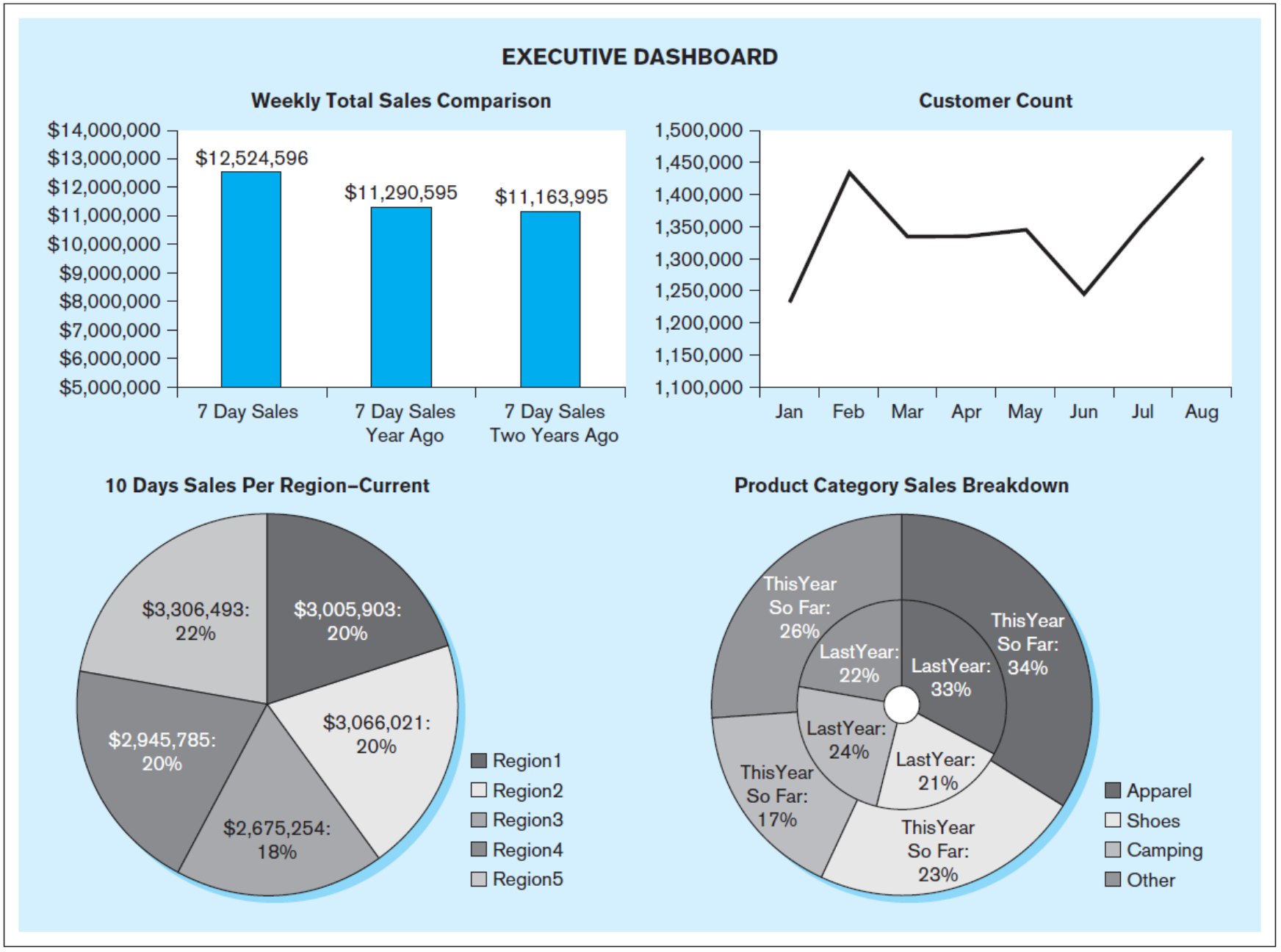
DATA WAREHOUSE/DATA MART FRONT-END (BI) APPLICATIONS

- **Executive dashboard**
  - Intended for use by higher level decision makers within an organization
  - Contains an organized easy-to-read display of a number of critically important queries describing the performance of the organization
  - In general, the usage of executive dashboards should require little or no effort or training
  - Executive dashboards can be web-based

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Example – Executive Dashboard



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DATA WAREHOUSE DEPLOYMENT

- **Data warehouse deployment**
  - Releasing the created and populated data warehouse and its front-end (BI) applications for use by the end-users
  - **Alpha release**
    - Internal deployment of a system to the members of the development team for initial testing of its functionalities
  - **Beta release**
    - Deployment of a system to a selected group of users to test the usability of the system
  - **Production release**
    - The actual deployment of a functioning system

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The feedback from the testing phases may result in making modifications to the system prior to the actual deployment of a functioning data warehousing system.

Typically, the deployment does not occur all at once for the entire population of the intended end-users instead the deployment process is more gradual.

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OLAP/BI TOOLS DATABASE MODELS

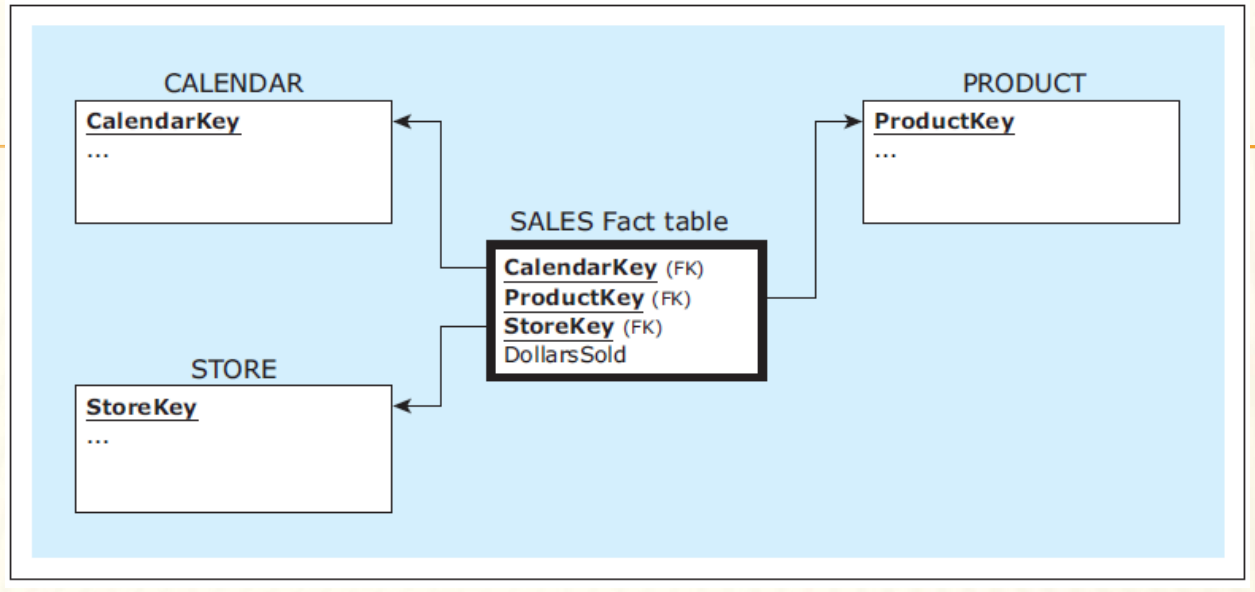
- OLAP/BI Tools database models
  - OLAP/BI tools are designed for access of dimensionally modeled data
  - Dimensionally modeled data stores can be implemented as
    - *Relational database model* (database is a collection of tables)
    - *Multidimensional database model* (database is a collection of cubes)

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Conceptually, there is no difference in dimensional modeling for relational models or cubes. The conceptual design still involves creating star schemas with dimensions and facts. The difference is in the physical implementation.

Example – Relational implementation of a fact table in a dimensional model



SALES FACT TABLE

CalendarKey	ProductKey	StoreKey	DollarsSold
1	1	1	$100
1	2	1	$70
1	3	1	$15
.	.	.	.

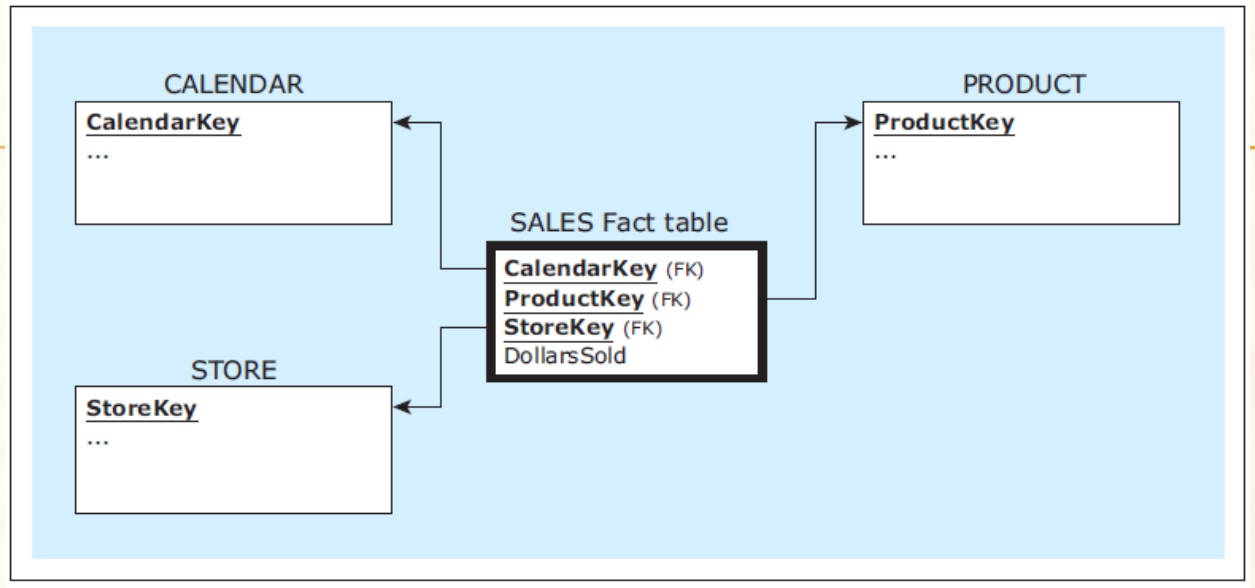
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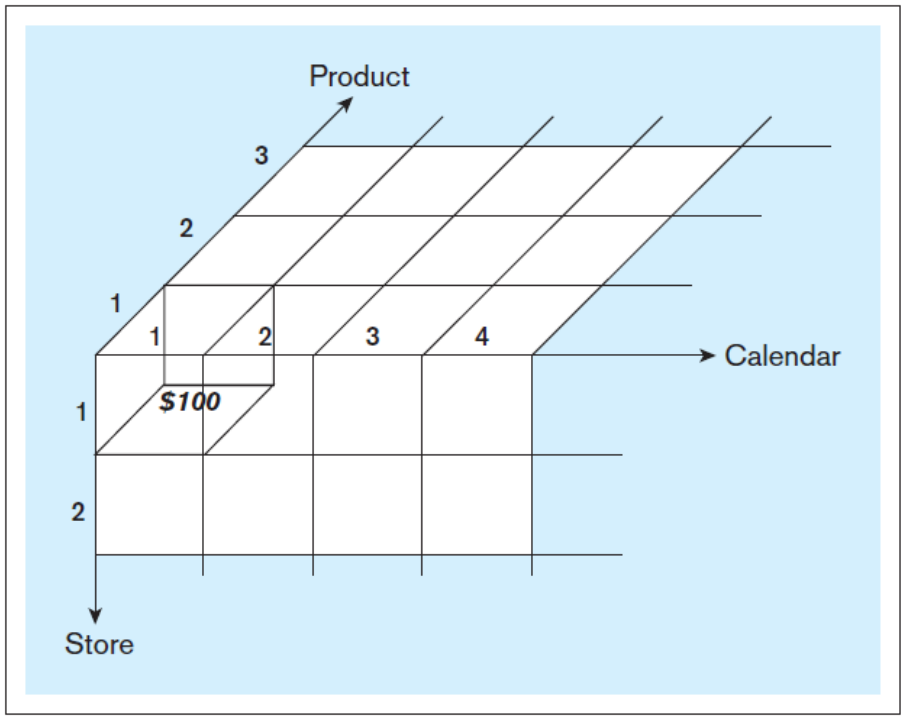
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Example – Multidimensional (cube) implementation of a fact table in a dimensional model





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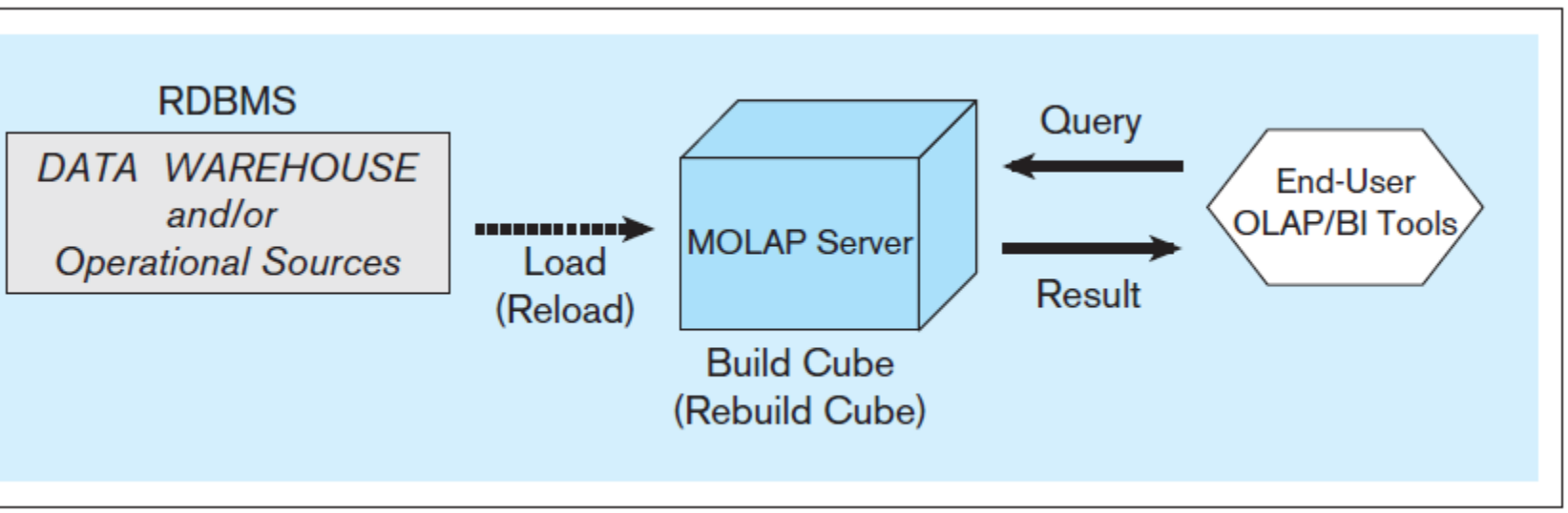
OLAP/BI TOOLS DATA ARCHITECTURE OPTIONS

- **OLAP/BI Tools Data Architecture Options**
  - Three common categories
    - Multidimensional online analytical processing - **MOLAP**
    - Relational online analytical processing - **ROLAP**
    - Hybrid online analytical processing - **HOLAP**

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MOLAP architecture

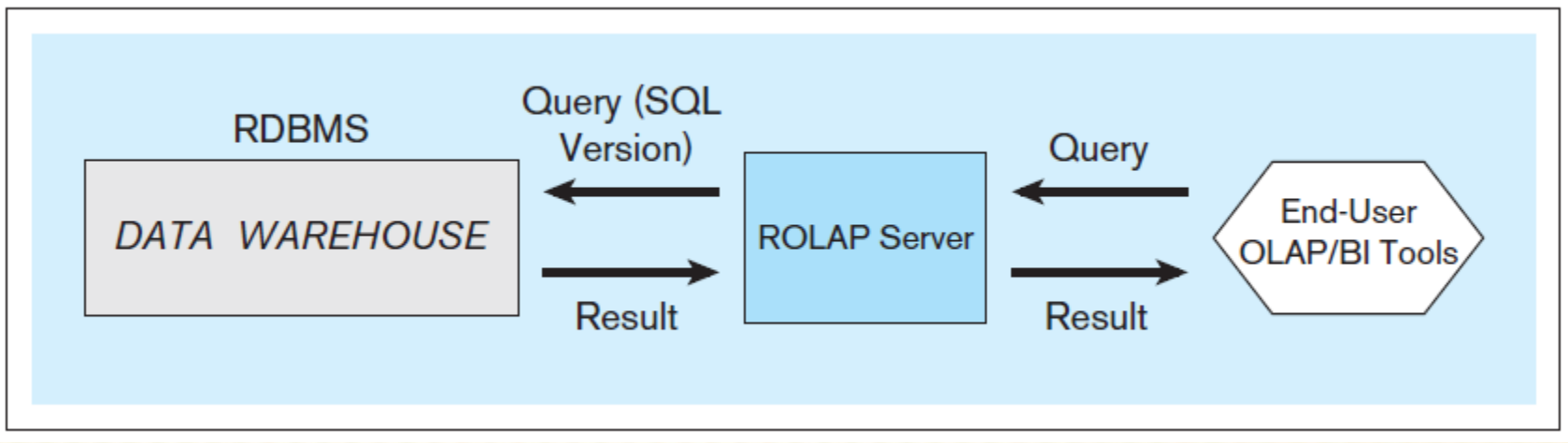


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MOLAP architecture is discussed on Pages 295-296.

ROLAP architecture

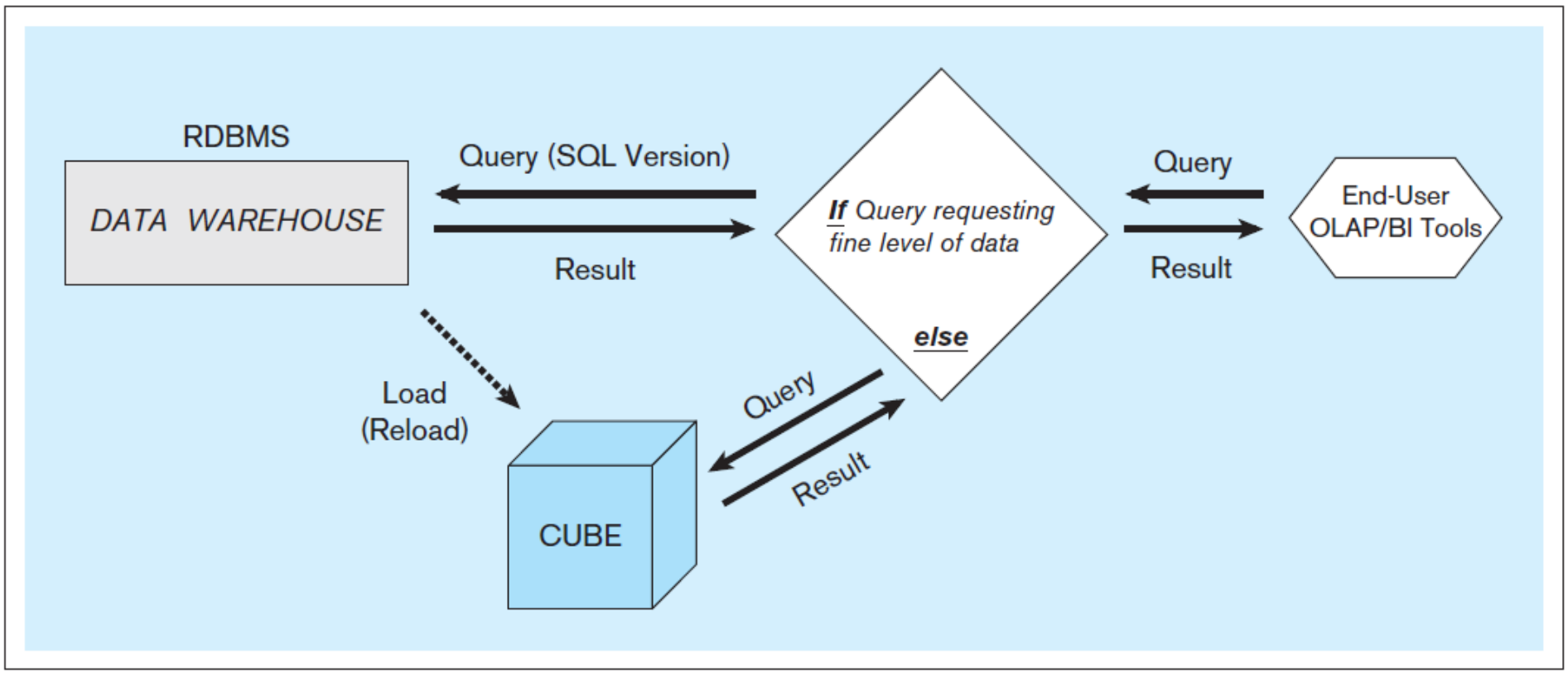


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ROLAP architecture is discussed on Pages 296-297.

HOLAP architecture



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HOLAP architecture is discussed on Page 297.