BI and Data Warehousing

OBJECTIVES

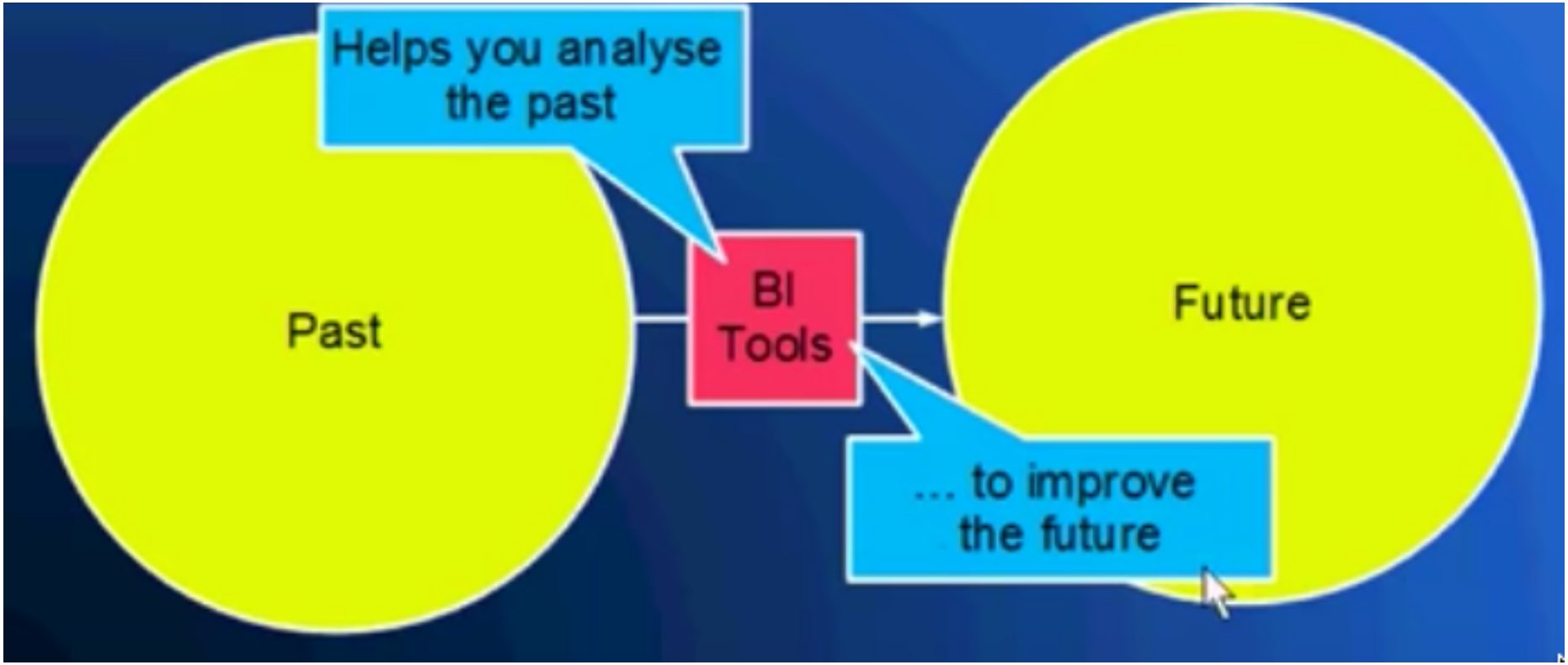
- **To understand the concepts of BI (Business Intelligence)**
- **Define Data Warehouse, Data Mart**
- **Differentiate Design Principles for a Data Warehouse, contrasted to designing a transactional database.**

BI and Data Warehousing

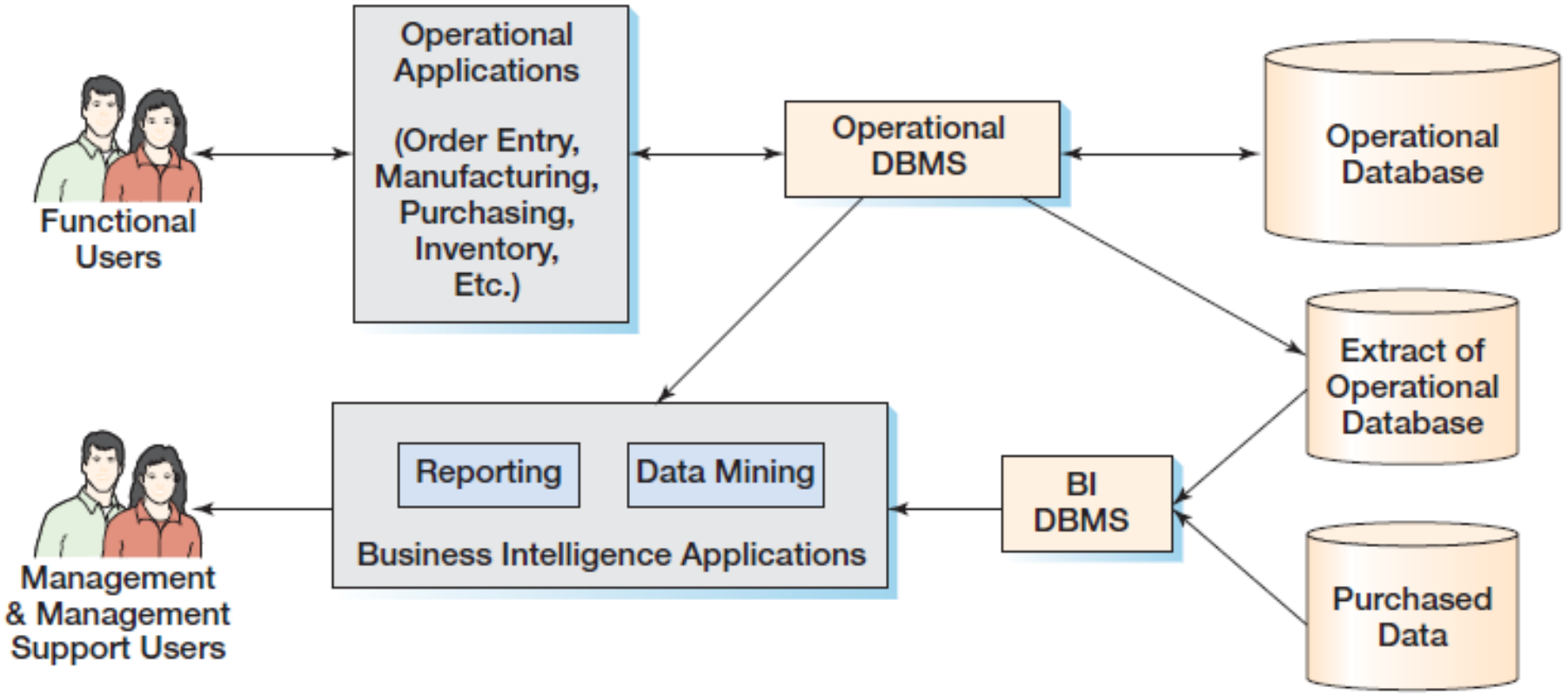
What do we mean by Business Intelligence?

- **Analyze current and past events in order to predict future events**
- **Operational Activities**
  - Manufacturing Products, Inventory
  - Sales, Shipping
  - Financial Transactions, Payroll, Payables
  - Order Processing and Billing
- **BI Activities**
  - Analysis, planning, control
  - Decision Making

BI and Data Warehousing



BI and Data Warehousing



What do we mean by Business Intelligence?

- **Operational Activities – Referred to as OLTP**
  - Online Transaction Processing
- **BI Activities – Referred to as DSS**
  - Decision support systems

What do we mean by Business Intelligence?

- **Two main types of application systems**
  - Reporting Systems
  - Data Mining Systems

What do we mean by Business Intelligence?

- **Two main types of application systems**
  - Reporting Systems
    - Largely use SQL
    - Many, Many Powerful Software tools - see article:
      - http://bigdata-madesimple.com/top-business-intelligence-bi-tools-in-the-market/
  - Data Mining Systems
    - Implement data mining algorithms
    - Many, Many Powerful Software tools - see article:
      - https://www.softwareadvice.com/bi/data-mining-comparison/

Videos illustrating BI concepts

1. https://www.youtube.com/watch?v=LRdsZqrwOrc
2. https://www.youtube.com/watch?v=N8FbarXC0Og
3. https://www.youtube.com/watch?v=LFnewuBsYiY
4. https://www.youtube.com/watch?v=yoE6bgJv08E

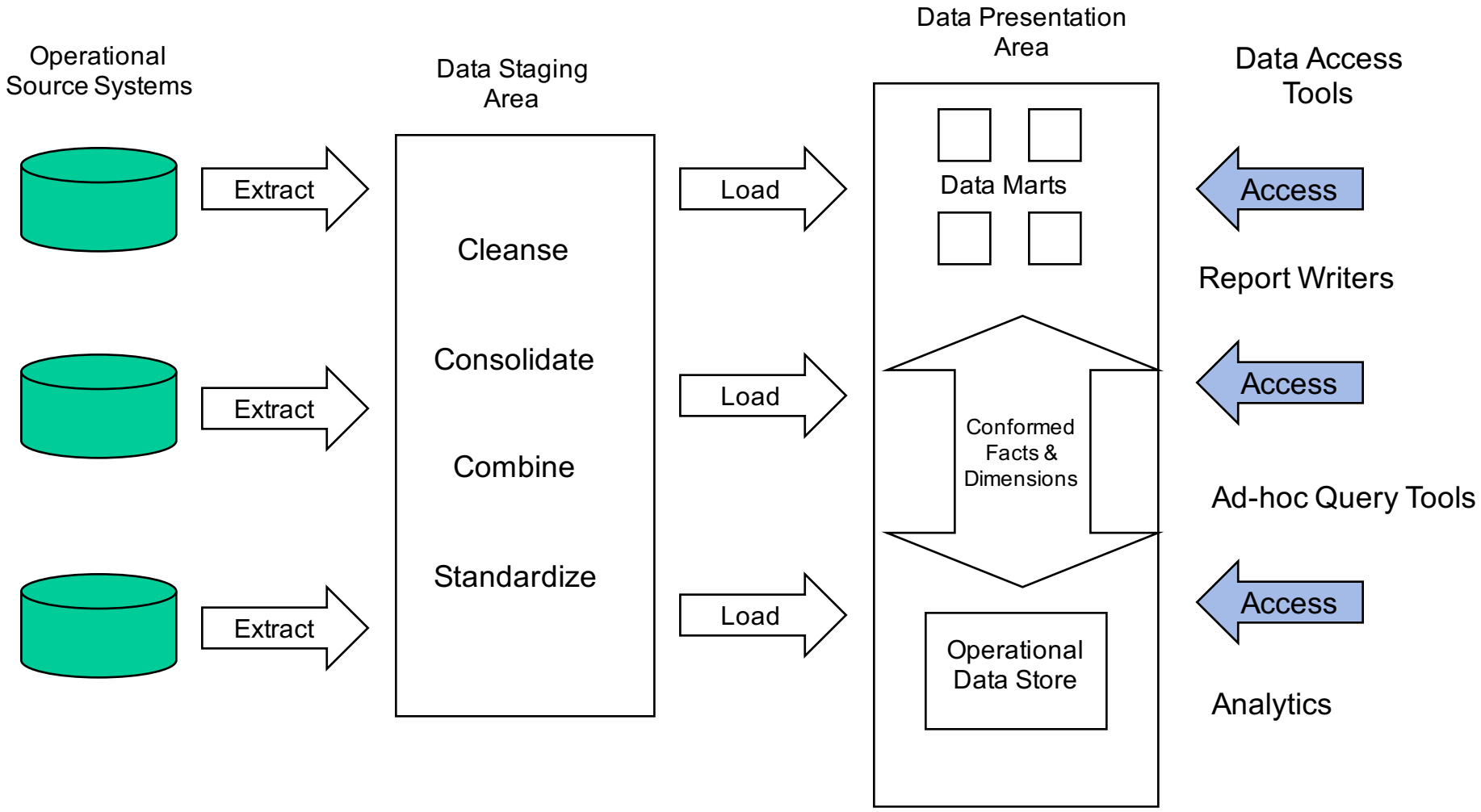
Reporting

- **Filter, sort, group data**
- **Make simple calculations**
- **Summarize current status of things we measure**
- **Compare current status to past or predicted status**
- **Classify entities (customers, products, employees, etc.)**
- **Report delivery is crucial**

Data Mining

- **Often employ sophisticated statistical and mathematical techniques**
- **Used for:**
  - What-if analyses
  - Predictions
  - Decisions
- **Results often incorporated into some other reporting system**

BI and Data Warehousing



- **Data Warehouse Components**
  - Operational Source System
  - Data Staging Area
  - Data Presentation Area
  - Data Access Tools
  - Metadata
  - Operational Data Store

- **Extract Transform Load ("ETL")**

  - Software that
    - Retrieves data from Operational Systems
    - Stages data in temporary databases
    - Cleanses and standardizes the data
    - Provides metadata regarding data sources

https://www.glassdoor.com/Salaries/etl-developer-salary-SRCH_KO0,13.htm

- **ETL Tools**

https://www.etltool.com/list-of-etl-tools/

Why?

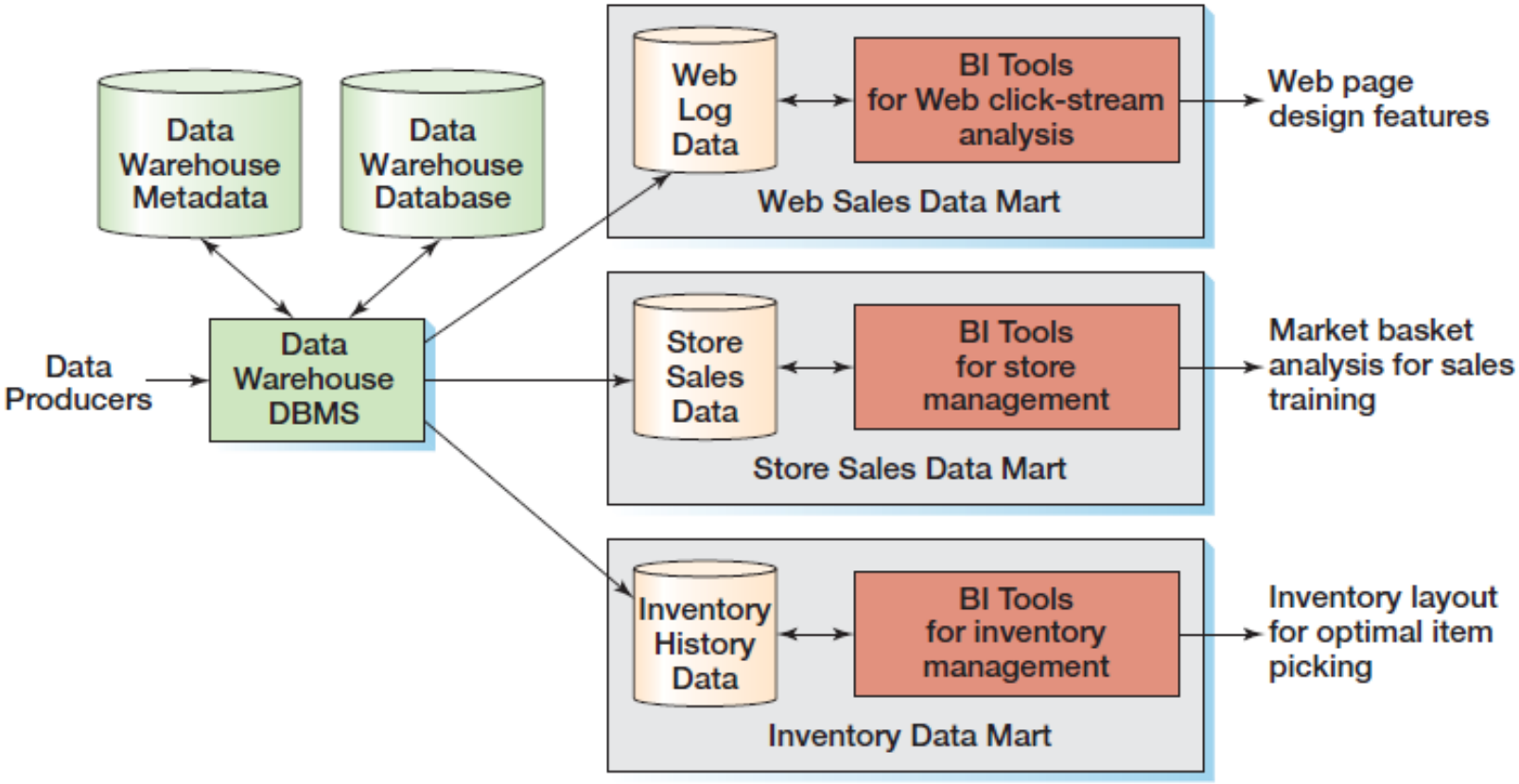
- Dirty data
- Missing values
- Inconsistent data
- Data not integrated
- Wrong format, wrong level of detail
  - Too fine
  - Not fine enough
- Too much data
  - Too many attributes
  - Too much volume -- summarize

Organizations Purchase Data

- Voter Registration Data
- Click data
- Name and Address lists

The Data Mart

A subset of a data warehouse for a group or department



The Data Presentation area

- **Data Marts**
- **Dimensional design**
  - Star schemas
    - Less complex
    - More easily optimized
- **Conformed Facts**
- **Conformed Dimensions**
- **RDBMS or MDBMS**

The Dimensional Model

- **Fills the need to store historical data**
  - Trend analysis over time
  - Keep it forever
  - Store data from many sources

Operational Database	Dimensional Database
Used for structured transaction data processing	Used for unstructured analytical data processing
Current data are used	Current and historical data are used
Data are inserted, updated, and deleted by users	Data are loaded and updated systematically, not by users

- **Facts**
  - What we are measuring
  - Numeric
  - Fact tables
- **Dimensions**
  - How we want to describe the facts
  - Text
  - Dimension tables

- **FACTS: Represent measurements**
  - Additive
    - Amounts & quantities
  - Semi-Additive
    - Point in time balances
  - Non-Additive
    - Ratios & percentages

- **FACTS examples**

- **Sales**
  - Amount
  - Quantity
- **Interest**
  - Paid
  - Received
- **Miles**
- **Length of Stay**

Dimensions

- **How we describe the facts**
- **Text information**
- **Stored in dimension tables**
- **Facts join to dimensions by foreign key**

- **DIMENSION examples**

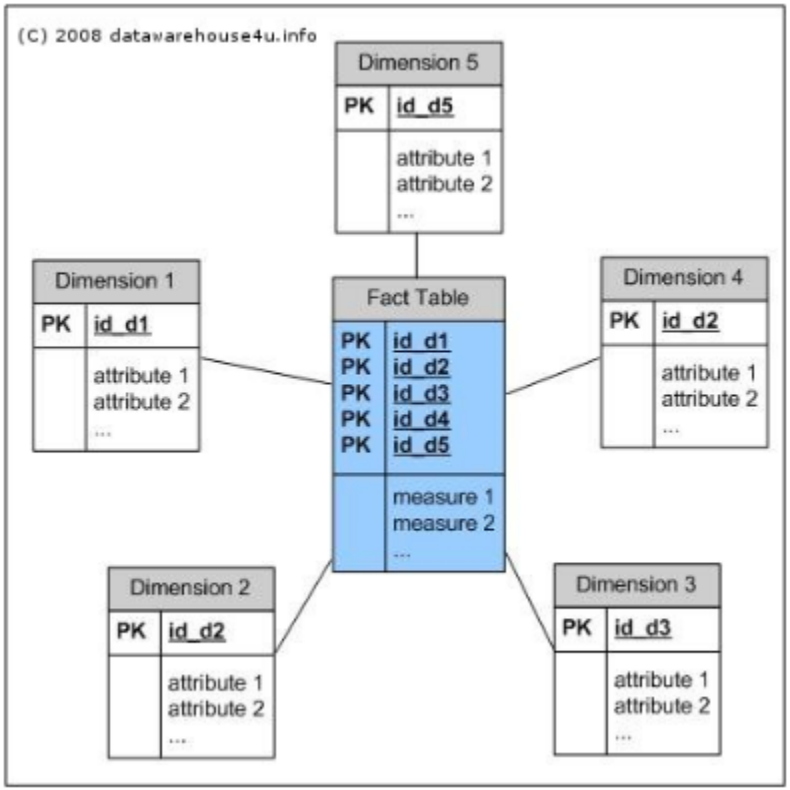
- **Date**
  - Always found in a data warehouse
  - Measuring over time
- **Product**
- **Customer**
- **Location**
- **5-15 dimensions is good rule of thumb**

- **Granularity: "Grain" What does one row represent?**
  - Transaction
    - One row = one transaction
  - Periodic Snapshot
    - One row = one period of information
  - Accumulating Snapshot
    - One row = lifetime of a process

Kimball's 4-Step Design Process

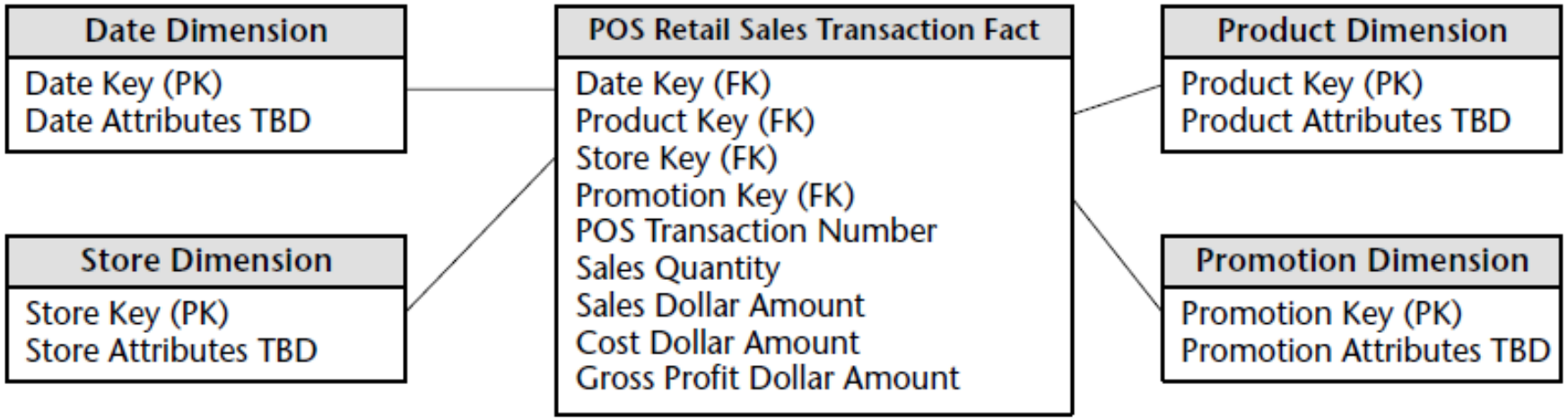
- **Select the Business Process**
  - What process are we modeling?
- **Declare the Grain**
  - What does one row of the fact table represent?
- **Choose the Dimensions**
  - How do we describe what we are measuring?
- **Identify the Facts**
  - What are we measuring?

- **The STAR schema:**
  - Fact table in the middle
  - Dimensions around the outside



- **Data Warehouse Design Principles**
  - Dimensions have fewer wide rows
  - Facts have many narrow rows
  - All PK and FK keys are surrogates
    - Meaningless (invisible) to users
    - Very fast for DBMS

- **The retail store example**

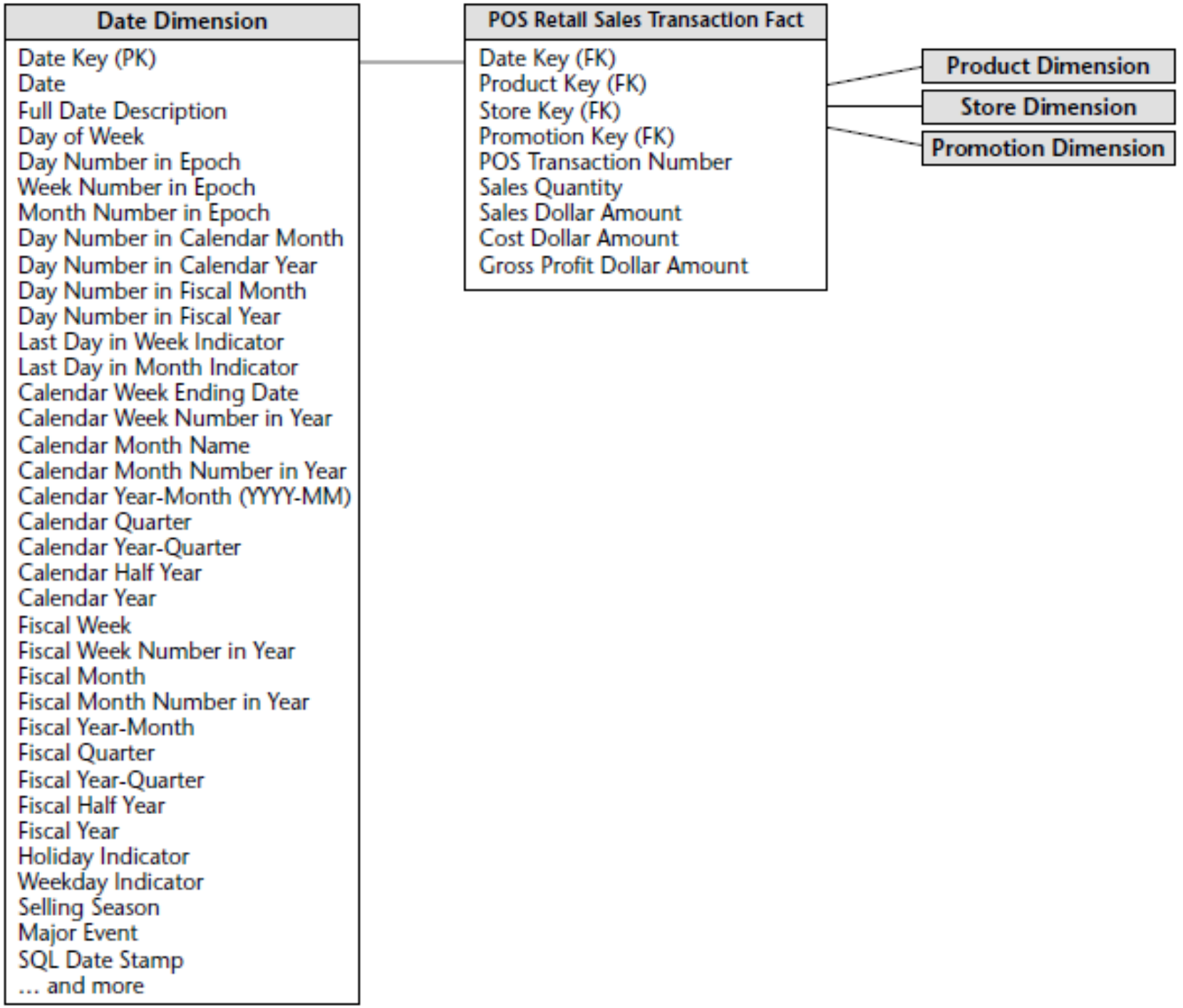


- **FACT table keys -- Designer's Choice:**
  - Your FACT table PK may be a composite key consisting of all dimension foreign keys
    - One less column, avoid overhead
  - But the combination may or may not be unique
    - Add a surrogate key (Auto-Increment) for uniqueness
    - Dimension keys are FKs
    - Turn off PK "unique" constraint
    - Adding a unique ID requires an index that is likely NOT ever used

https://www.kimballgroup.com/2006/07/design-tip-81-fact-table-surrogate-key/

- **FACT table indexes -- Designer's Choice:**
  - If there is a PK defined, the DBMS will create a clustering index
    - Rows arranged in physical clustering order.
  - With a surrogate key, the order is ascending on the chronological order of inserts
  - Without a surrogate key, putting the DATE Dimension FK first in a composite does the same thing
  - Without a surrogate key, index columns must be used in order
  - Best Practice: Define indexes based on users' query usage

- **The Date Dimension**
  - Populated once for every day in the organization's past, present, future operating horizon
  - Once written, a date dimension row should never change again
  - Not too big
    - 25 years * 365(366) days per year = 9,150 rows.
  - Allows for "Date Not Known" or Date TBD


Date Dimension
Date Key (PK)
Date
Full Date Description
Day of Week
Day Number in Epoch
Week Number in Epoch
Month Number in Epoch
Day Number in Calendar Month
Day Number in Calendar Year
Day Number in Fiscal Month
Day Number in Fiscal Year
Last Day in Week Indicator
Last Day in Month Indicator
Calendar Week Ending Date
Calendar Week Number in Year
Calendar Month Name
Calendar Month Number in Year
Calendar Year-Month (YYYY-MM)
Calendar Quarter
Calendar Year-Quarter
Calendar Half Year
Calendar Year
Fiscal Week
Fiscal Week Number in Year
Fiscal Month
Fiscal Month Number in Year
Fiscal Year-Month
Fiscal Quarter
Fiscal Year-Quarter
Fiscal Half Year
Fiscal Year
Holiday Indicator
Weekday Indicator
Selling Season
Major Event
SQL Date Stamp
... and more
POS Retail Sales Transaction Fact
Date Key (FK)
Product Key (FK)
Store Key (FK)
Promotion Key (FK)
POS Transaction Number
Sales Quantity
Sales Dollar Amount
Cost Dollar Amount
Gross Profit Dollar Amount
Product Dimension
Store Dimension
Promotion Dimension

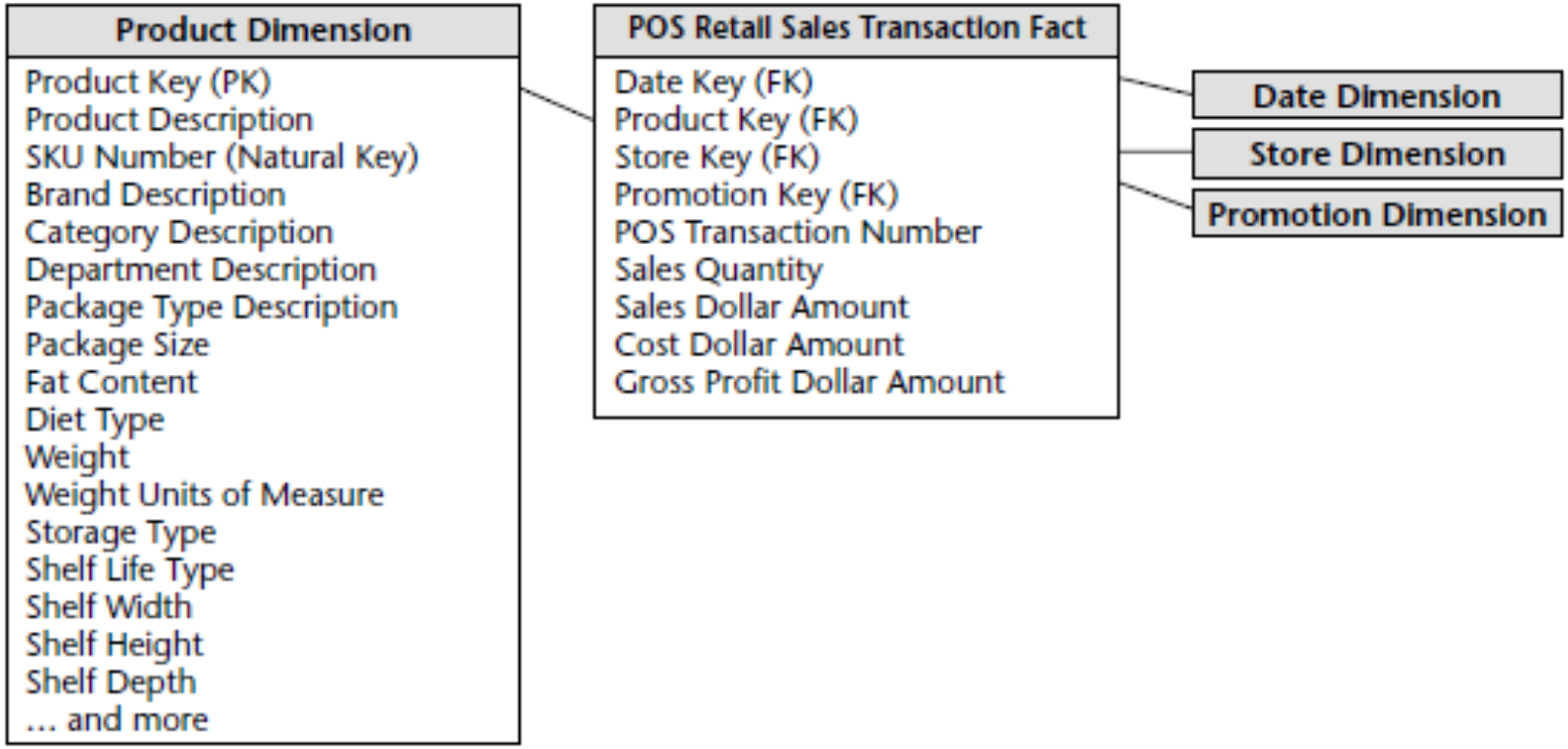
- **The DATE dimension**
  - The need for unassigned dates

Date Key	Date	Full Date Description	Day of Week	Calendar Month	Calendar Year	Fiscal Year-Month	Holiday Indicator	Weekday Indicator
1	01/01/2002	January 1, 2002	Tuesday	January	2002	F2002-01	Holiday	Weekday
2	01/02/2002	January 2, 2002	Wednesday	January	2002	F2002-01	Non-Holiday	Weekday
3	01/03/2002	January 3, 2002	Thursday	January	2002	F2002-01	Non-Holiday	Weekday
4	01/04/2002	January 4, 2002	Friday	January	2002	F2002-01	Non-Holiday	Weekday
5	01/05/2002	January 5, 2002	Saturday	January	2002	F2002-01	Non-Holiday	Weekend
6	01/06/2002	January 6, 2002	Sunday	January	2002	F2002-01	Non-Holiday	Weekend
7	01/07/2002	January 7, 2002	Monday	January	2002	F2002-01	Non-Holiday	Weekday
8	01/08/2002	January 8, 2002	Tuesday	January	2002	F2002-01	Non-Holiday	Weekday

- **Dates as a Natural Key?**
  - Dates make bad keys
    - Not unique – must be combined with a unique ID
    - CPU cycles to convert between text ➔ binary ➔ text
    - If it includes TIME: Time zone issues?
    - Format issues: U.S. versus other countries
  - Storage:
    - Date types typically use 8 bytes
    - Integer key typically use 4 bytes or less

- **SQL Date doesn't handle**
  - Date to be determined
  - Date not yet happened

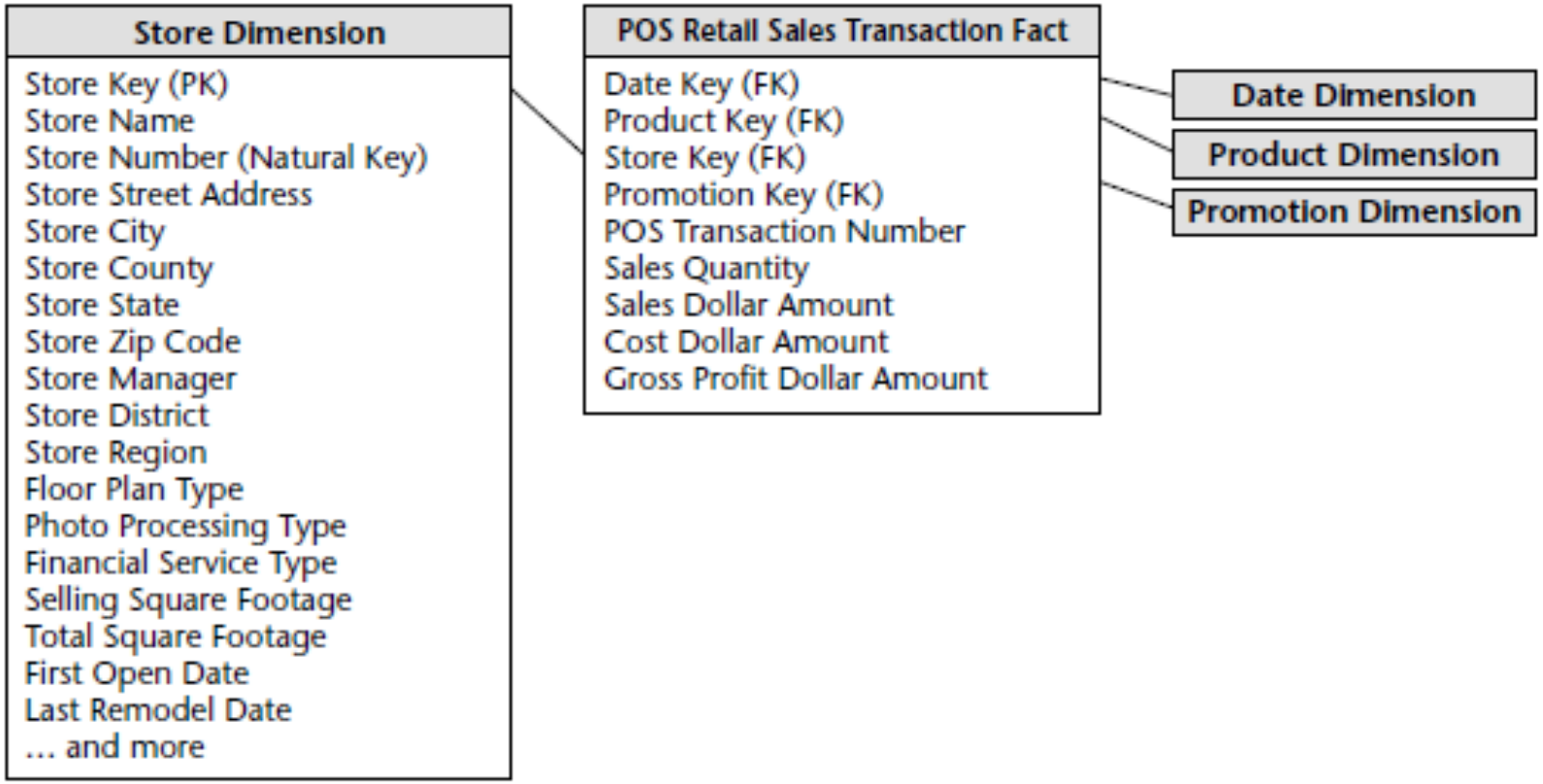
- **The Product dimension**



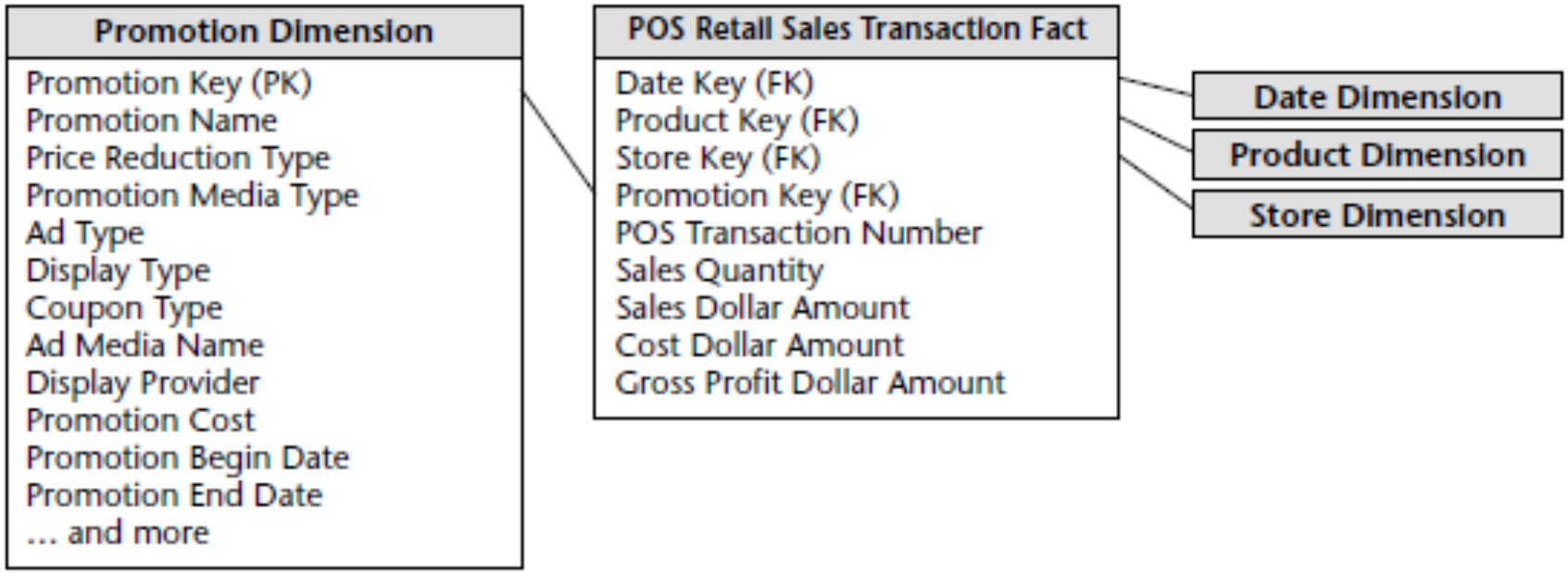
- **The Product dimension**

Product Key	Product Description	Brand Description	Category Description	Department Description	Fat Content
1	Baked Well Light Sourdough Fresh Bread	Baked Well	Bread	Bakery	Reduced Fat
2	Fluffy Sliced Whole Wheat	Fluffy	Bread	Bakery	Regular Fat
3	Fluffy Light Sliced Whole Wheat	Fluffy	Bread	Bakery	Reduced Fat
4	Fat Free Mini Cinnamon Rolls	Light	Sweeten Bread	Bakery	Non-Fat
5	Diet Lovers Vanilla 2 Gallon	Coldpack	Frozen Desserts	Frozen Foods	Non-Fat
6	Light and Creamy Butter Pecan 1 Pint	Freshlike	Frozen Desserts	Frozen Foods	Reduced Fat
7	Chocolate Lovers 1/2 Gallon	Frigid	Frozen Desserts	Frozen Foods	Regular Fat
8	Strawberry Ice Creamy 1 Pint	Icy	Frozen Desserts	Frozen Foods	Regular Fat
9	Icy Ice Cream Sandwiches	Icy	Frozen Desserts	Frozen Foods	Regular Fat

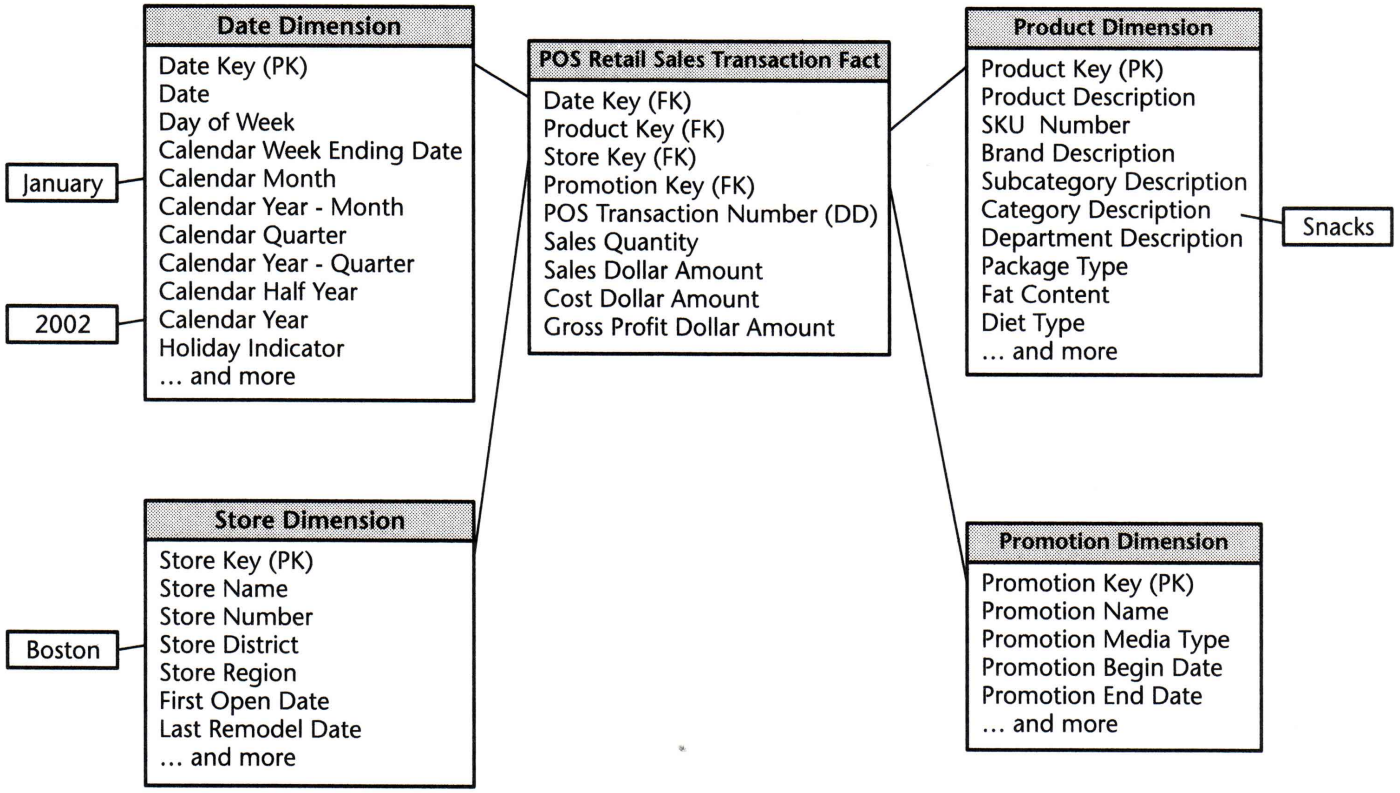
- **The Store dimension**



- **The Promotion dimension**



- **Using the design**



More Dimensions

- **Degenerate Dimensions**
- **Junk Dimensions**
- **Multiple Dates or Time Stamps (dimension role playing)**

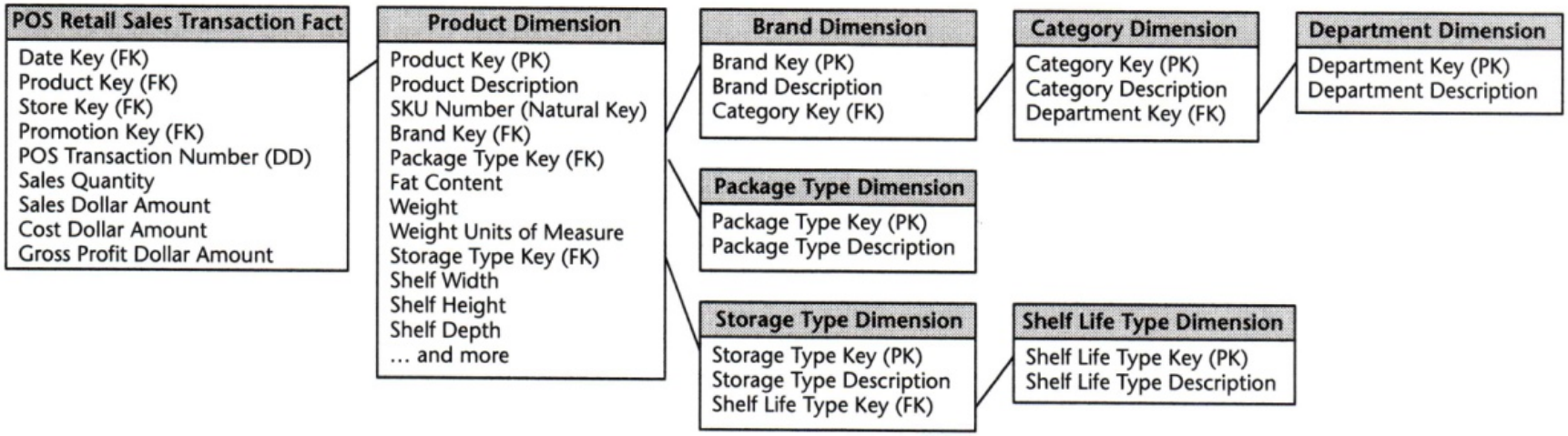
Degenerate Dimension

- **Useful information**
  - Grouping line items by POS receipt
- **Belongs in Fact table**
- **Does not link to a Dimension table**

- **When?**
  - You need the ability to group, but you store NO DATA about the dimension

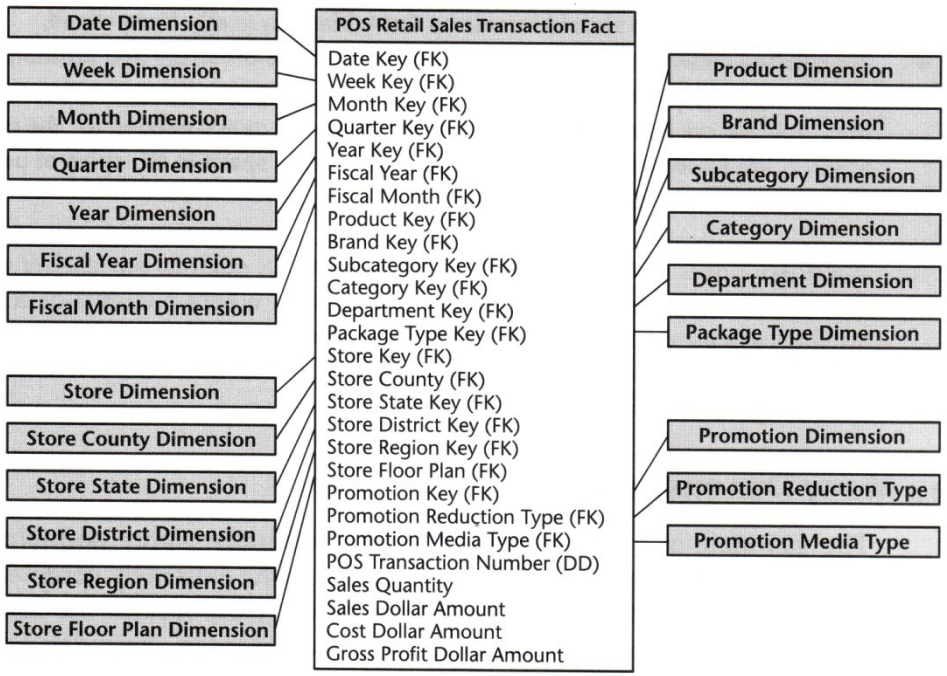
Snow Flaked Dimension

- **Don't Over-Normalize Design**



Too Many Dimensions

- **Centipede Fact Table**

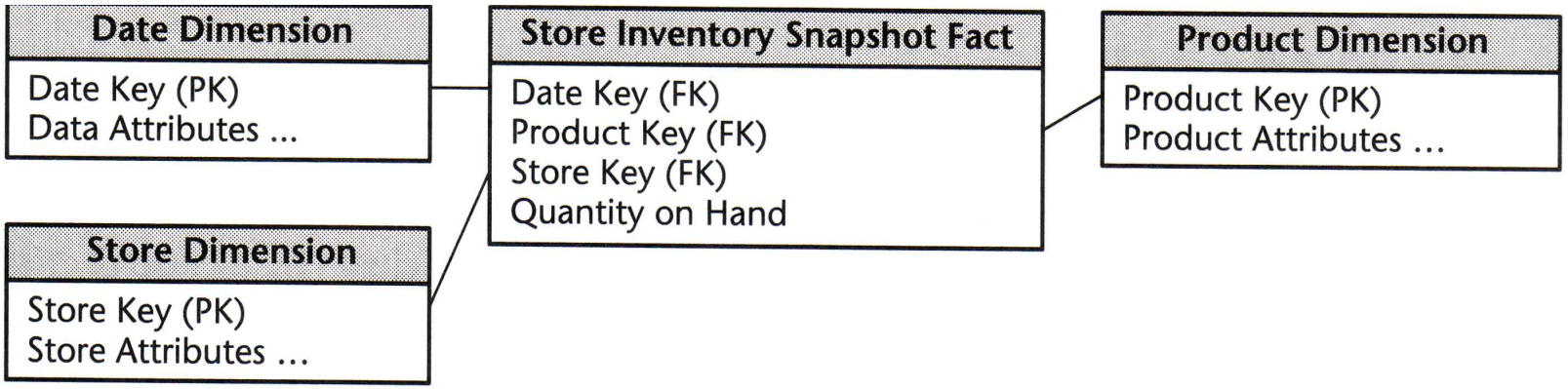


Natural or Meaningless Keys?

- **Integer, artificial, synthetic, surrogate**
  - Generated by sequence number
- **Much smaller (4 bytes) than character keys**
  - Provide faster searching
- **Insulates DW from operational changes**
  - Avoids re-use of dormant or unused codes
  - DW timeframe is longer than op systems
  - Not vulnerable to acquisition or consolidations

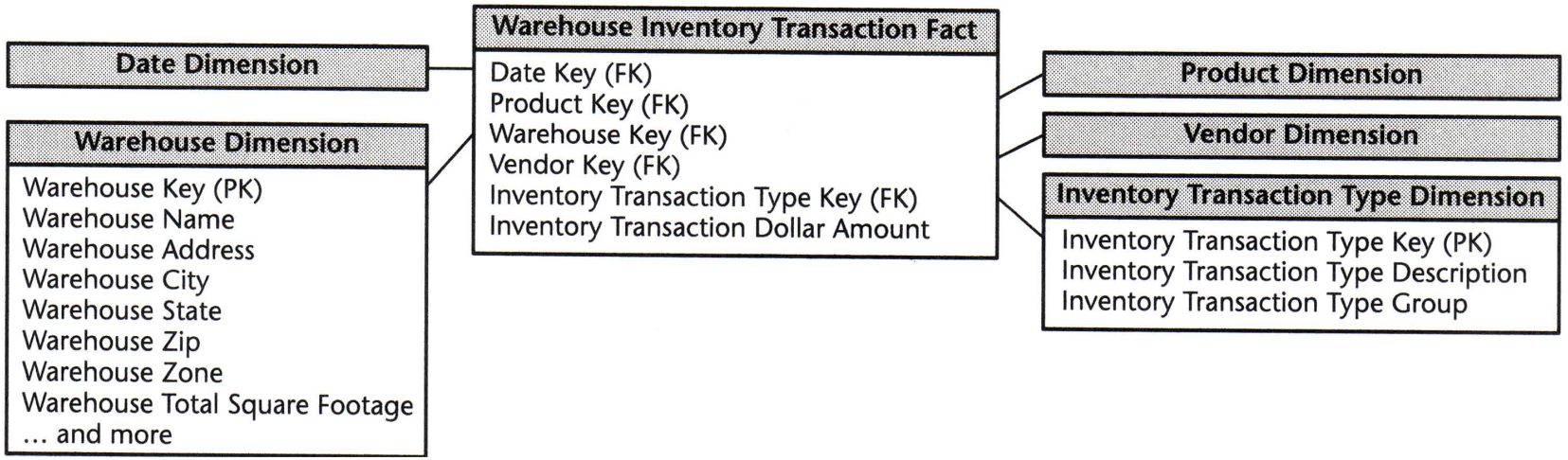
Inventory Periodic Snapshot

- **Periodic Snapshot Fact**



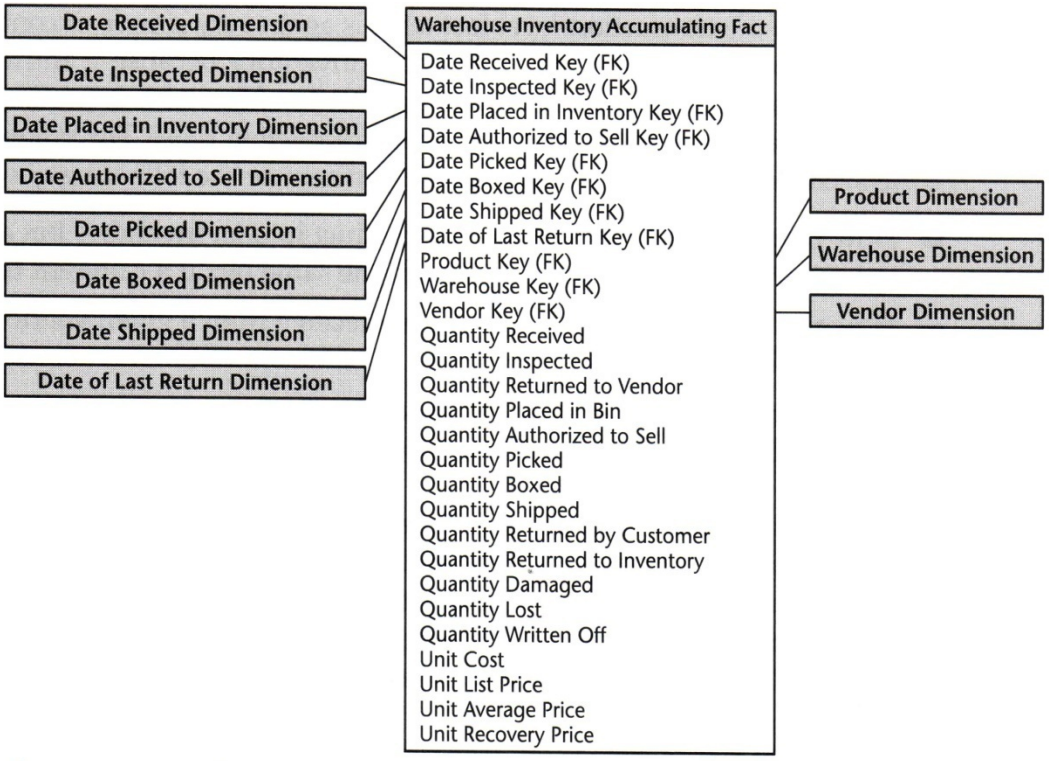
Warehouse Inventory

- **Transaction Fact**

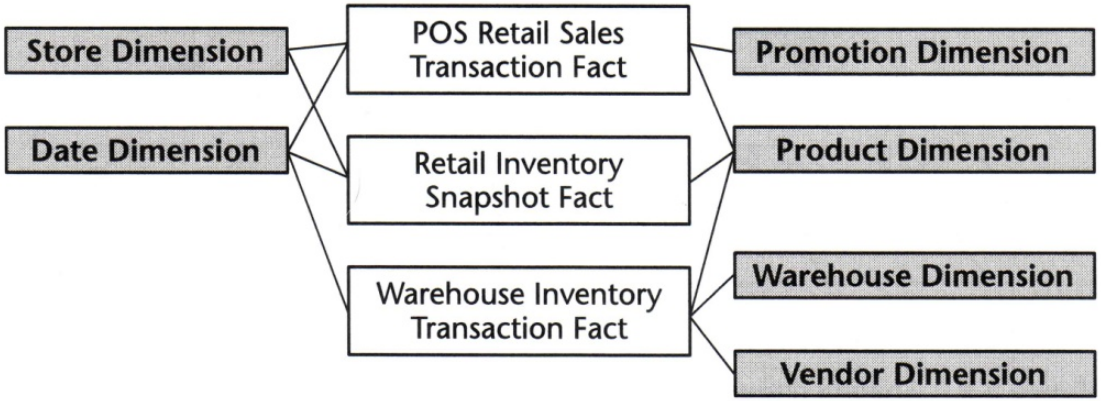


Warehouse Inventory

- **Accumulating Snapshot Fact**



Sharing Dimensions



BUSINESS PROCESSES	COMMON DIMENSIONS: Date	Product	Store	Promotion	Warehouse	Vendor	Contract	Shipper
Retail Sales	X	X	X	X				
Retail Inventory	X	X	X					
Retail Deliveries	X	X	X					
Warehouse Inventory	X	X			X	X		
Warehouse Deliveries	X	X			X	X		
Purchase Orders	X	X			X	X	X	X

Leftover Stuff

- **What to do with flags and indicators?**
  - Leave in Fact table row
    - Increases row size
  - Make each a separate dimension
    - Increases dimensions
  - Remove from design
    - Decreases usability of information

Junk Dimension

- **Convenient grouping of low-cardinality flags and indicators**

Order Indicator Key	Payment Type Description	Payment Type Group	Inbound/ Outbound Order Indicator	Commission Credit Indicator	Order Type Indicator
1	Cash	Cash	Inbound	Commissionable	Regular
2	Cash	Cash	Inbound	Non-Commissionable	Display
3	Cash	Cash	Inbound	Non-Commissionable	Demonstration
4	Cash	Cash	Outbound	Commissionable	Regular
5	Cash	Cash	Outbound	Non-Commissionable	Display
6	Discover Card	Credit	Inbound	Commissionable	Regular
7	Discover Card	Credit	Inbound	Non-Commissionable	Display
8	Discover Card	Credit	Inbound	Non-Commissionable	Demonstration
9	Discover Card	Credit	Outbound	Commissionable	Regular
10	Discover Card	Credit	Outbound	Non-Commissionable	Display
11	MasterCard	Credit	Inbound	Commissionable	Regular
12	MasterCard	Credit	Inbound	Non-Commissionable	Display
13	MasterCard	Credit	Inbound	Non-Commissionable	Demonstration
14	MasterCard	Credit	Outbound	Commissionable	Regular

Figure 5.5 Sample rows of an order indicator junk dimension.

Dimension Role Playing

- **Single dimension appears multiple times in same fact table**
- **Single physical dimension table**
- **Use *views* to allow joins with different foreign keys**
- **Most common with Date dimension**

Fact Table Comparisons

	Transaction	Periodic Snapshot	Accumulating Snapshot
Time Period	Point in Time	Regular Intervals	Short lived, indeterminate
Grain	One row per transaction (event)	One row per period	One row per process life
Loads	Insert	Insert	Insert and Update
Updates	Only for Error correction	Only for Error correction	Whenever Activity
Date Dim	Transaction Date	End of Period Date	Multiple Dates representing Milestones
Facts	Transaction Activity	Performance for Interval	Performance over finite lifetime

Dimensional Modeling Mistakes To Avoid

1. Putting text attributes in fact tables
2. Limiting descriptions to save space
3. Splitting hierarchies into multiple dimensions
4. Ignoring need to track dimension changes
5. Solving query performance problems by adding hardware

Dimensional Modeling Mistakes To Avoid

6. **Using "smart" keys in dimension tables**
7. **Not complying with fact table grain**
8. **Designing the model based on one specific report**
9. **Having users query atomic data in normalized format**
10. **Creating stovepipes by not conforming facts and dimensions**

Slowly Changing Dimensions

- **Additional slides on Slowly Changing Dimensions**

Slowly Changing Dimensions

- **Want to handle changes gracefully**
- **Dimension maintenance**
  - Should accurately reflect present
  - What about the past?
- **What happens when dimension change info not received on time?**

Type 1 SCD

- **Overwrite the Value**

Product Key	Product Description	Department	SKU Number (Natural Key)
12345	IntelliKidz 1.0	Education	ABC922-Z

Product Key	Product Description	Department	SKU Number (Natural Key)
12345	IntelliKidz 1.0	Strategy	ABC922-Z

Type 2 SCD

- **Add a new row in the dimension table**
  - Good for partitioning history

Product Key	Product Description	Department	SKU Number (Natural Key)
12345	IntelliKidz 1.0	Education	ABC922-Z

Product Key	Product Description	Department	SKU Number (Natural Key)
12345	IntelliKidz 1.0	Education	ABC922-Z
25984	IntelliKidz 1.0	Strategy	ABC922-Z

Type 3 SCD

- **Add a new column**
  - Good for presenting alternate realities

Product Key	Product Description	Current Department	Historical Department	SKU Number (Natural Key)
12345	IntelliKidz 1.0	Education	Education	ABC922-Z

Product Key	Product Description	Department	Prior Department	SKU Number (Natural Key)
12345	IntelliKidz 1.0	Strategy	Education	ABC922-Z

Hybrid SCD

- Preserve historical accuracy (Type 2)
- Report historical data according to current values (Type 3)

Product Key	Product Description	Current Department	Historical Department	SKU Number (Natural Key)
12345	IntelliKidz 1.0	Education	Education	ABC922-Z

Product Key	Product Description	Current Department	Historical Department	SKU Number (Natural Key)
12345	IntelliKidz 1.0	Strategy	Education	ABC922-Z
25984	IntelliKidz 1.0	Strategy	Strategy	ABC922-Z

Product Key	Product Description	Current Department	Historical Department	SKU Number (Natural Key)
12345	IntelliKidz 1.0	Critical Thinking	Education	ABC922-Z
25984	IntelliKidz 1.0	Critical Thinking	Strategy	ABC922-Z
31726	IntelliKidz 1.0	Critical Thinking	Critical Thinking	ABC922-Z