# Lecture 03

# Data Warehouse Life Cycle & Architecture

# Summary – last week


- Last week:
  - Assessment 01
  - Assessment 02

- This week:
  - DW Lifecycle and Architecture

Acknowledgment - Thanks to Wolf-Tilo Balke and Silviu Homoceanu - TU Braunschweig for the slides

# Life cycle of DW

- DW System Development Life Cycle (SDLC)
  - Design
    - End-user interview cycles
    - Source system cataloging
    - Definition of key performance indicators
    - Mapping of decision-making processes underlying information needs
    - Logical and physical schema design

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# Life cycle of DW (cont'd.)

- Prototype
  - Objective is to constrain and in some cases reframe end-user requirements
- Deployment
  - Development of documentation
  - Training
  - Operations and management processes
- Operation
  - Day-to-day maintenance of the DW needs a good management of ongoing Extraction,Transformation and Loading (ETL) process

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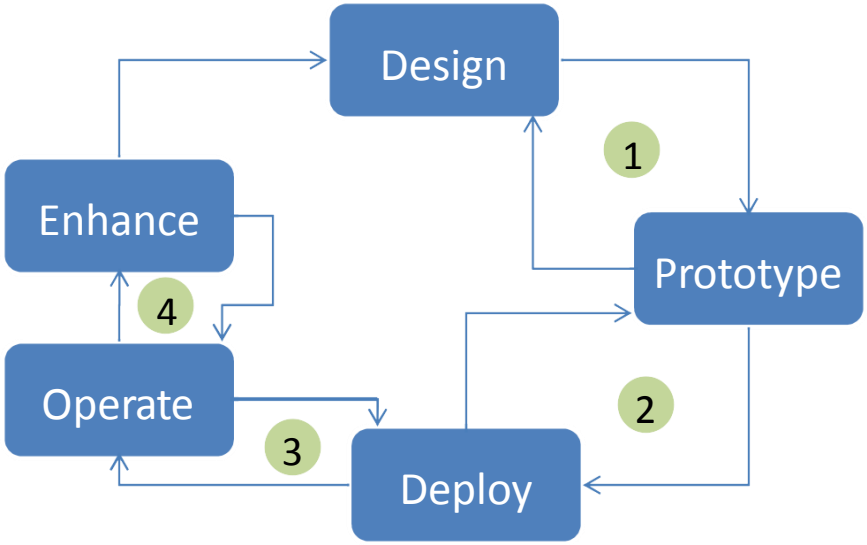
# Life cycle of DW (cont'd.)

- Enhancement needs the modification of
  - HW - physical components
  - Operations and management processes
  - Logical schema designs

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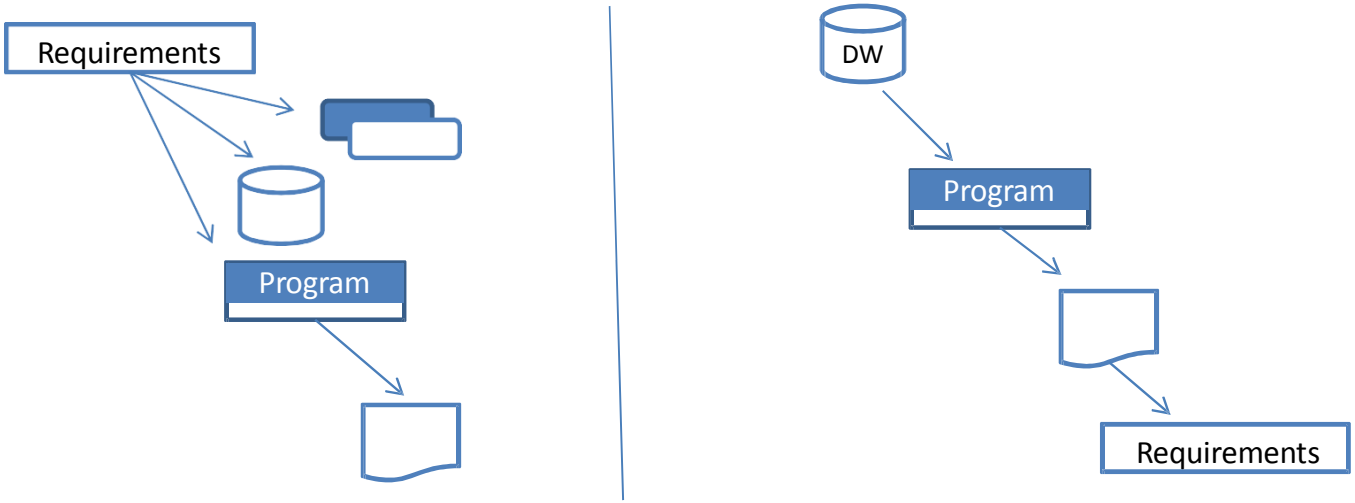
# Life cycle of DW (cont'd.)

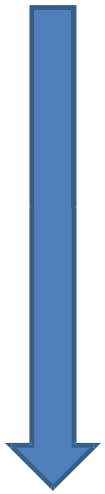
- Classical SDLC vs. DW SDLC




  - DW SDLC is almost the opposite of classical SDLC

# Life cycle of DW (cont'd.)

- Classical SDLC vs. DW SDLC



| Classical SDLC | DW SDLC |
|---|---|
| Requirements gathering | Implement warehouse |
| Analysis | Integrate data |
| Design | Test for bias |
| Programming | Program against data |
| Testing | Design DSS system |
| Integration | Analyze results |
| Implementation | Understand requirements |

  - Because it is the opposite of SDLC, DW SDLC is also called CLDS

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# Life cycle of DW (cont'd.)

- CLDS is a data driven development life cycle
  - It starts with data
    - Once data is at hand it is integrated and tested against bias
    - Programs are written against the data and the results are analyzed and finally the requirements of the system are understood
    - Once requirements are understood, adjustments are made to the design and the cycle starts all over
  - "spiral development methodology"

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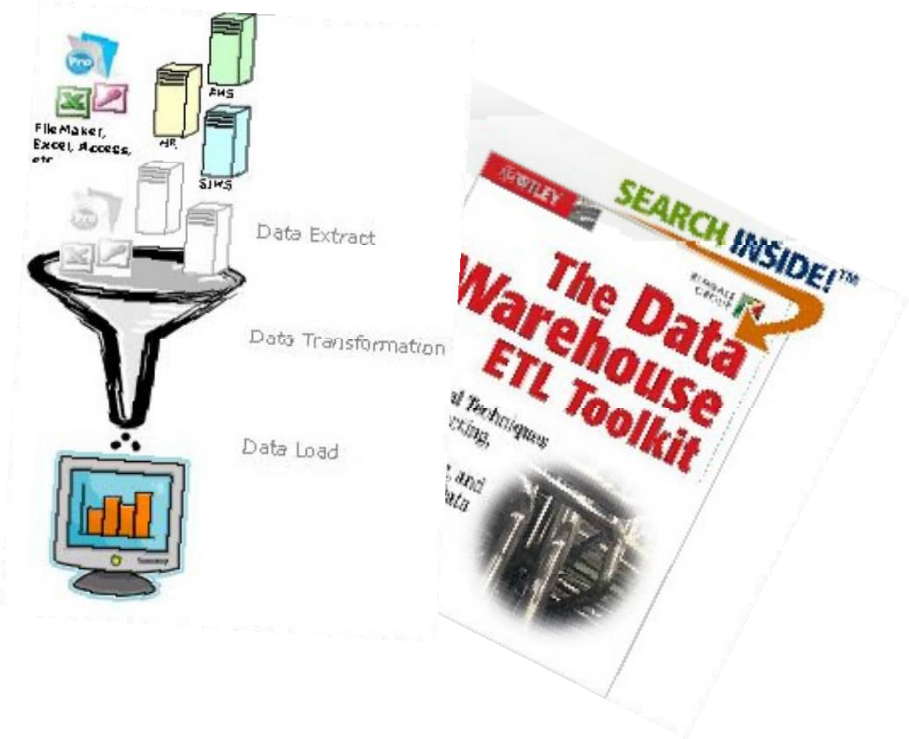
# Operating a DW

- In Operating a DW the following phases can be identified
  - Monitoring
  - Extraction
  - Transforming
  - Loading
  - Analyzing

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# Monitoring

- Monitoring
  - Surveillance of the data sources
  - Identification of data modification which is relevant to the DW
  - Monitoring has an important role over the whole process deciding on which data the next steps will be applied on

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# Monitoring (cont'd.)

- Monitoring techniques
  - Active mechanisms – Event Condition Action (ECA)

| | |
|---|---|
| EVENT | Payment |
| CONDITION | Account sum > 10 000 € |
| ACTION | Transfer to economy account |

  - Replication mechanisms
    - Snapshot:
      - Local copy of data, similar to aView
      - Used by Oracle 9i
    - Data replication
      - Replicates and maintains data in destination tables through data propagation processes
      - Used by IBM

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# Monitoring (cont'd.)

- Protocol based mechanisms
  - Since DBMS write protocol data for transaction management, the protocol can be used also for monitoring
  - Difficult due to the fact that the protocol format is proprietary and subject to change
- Application managed mechanisms
  - Hard to implement for legacy systems
  - Based on *time stamping* or *data comparison*

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# Extraction

- Extraction
  - Reads the data which was selected throughout the monitoring phase and inserts it in the data structures of the workplace
  - Due to large data volume, compression can be used
  - The time-point for performing extraction can be:
    - Periodical:
      - – Weather or stock market information can be actualized more times in a day, while product specification can be actualized in a longer period of time

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# Extraction (cont'd.)

- On request:
  - For example when a new item is added to a product group
- Event driven:
  - Event driven extraction can be helpful in scenarios where time, or the number of modifications over passing a specified threshold triggers the extraction. For example each night at 03:00 or each time 50 new modifications took place, an extraction is performed
- Immediate:
  - In some special cases like the stock market it can be necessary that the changes propagate immediately to the warehouse

– The extraction largely depends on hardware and the software used for the DW and the data source

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# Transforming

- Transforming
  - Implies adapting data, schema as well as data quality to the application requirements
  - Data integration:
    - Transformation in de-normalized data structures
    - Handling of key attributes
    - Adaptation of different types of the same data
    - Conversion of encoding:
      - "Buy", "Sell" → 1,2 vs. B,S → 1,2

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# Transforming (cont'd.)

- Normalization:
  - "Michael Hill" → "Michael, Hill" vs.

    "Hill Michael" → "Michael, Hill"
- Date handling:
  - "MM-DD-YYYY" → "MM.DD.YYYY"
- Measurement units and scaling:
  - 10 inch → 25,4 cm
  - 30 mph → 48,279 km/h
- Save calculated values
  - Price_incl_GST = Price_excl_GST * 1.15
- Aggregation
  - Daily sums can be added into weekly ones
  - Different levels of granularity can be used

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# Transforming (cont'd.)

- Data cleaning:
  - Consistency check
    - Delivery_date < Order_date
  - Completeness
    - Management of missing values as well as NULL values

# Loading

- Loading
  - Loading usually takes place during weekends or nights when the system is not under user stress
  - Split between initial load to initialize the DW and the periodical load to keep the DW updated
  - Initial loading
    - Implies big volumes of data and for this reason a bulk loader is used
  - Usually performed by partitioning, parallelization and incremental actualization

# Analyzing

- Analyze
  - Data access
    - Useful for extracting goal oriented information:
      - How many iPhones 6 were sold by Apple stores in Auckland in the last 3 calendar weeks of 2015?
      - Although it is a common OLTP query, it might be to complex for the operational environment to handle
  - OLAP
    - Falsely used as representing DW because it is used to analyze data contained in DW
    - Used to answer requests like:
      - In which district does a product group register the highest profit
      - How did the profit change in comparison to the previous month?

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# Analyzing (cont'd.)

  - Mostly known as organized on a multidimensional data model
  - Common operations for analyze are:
    - » Pivoting/Rotation
    - » Roll-up, Drill-down and Drill-across
    - » Slice and Dice
- Data mining
  - Useful for identifying hidden patterns
  - Refers to two separate processes:
    - KDD (Knowledge Discovery in Databases)
    - Prediction
  - Useful for answering questions like:
    - How did the sales of this product group evolve?
  - Methods and procedures for *data mining*
    - Clustering, Classification, Regression, Association rule learning

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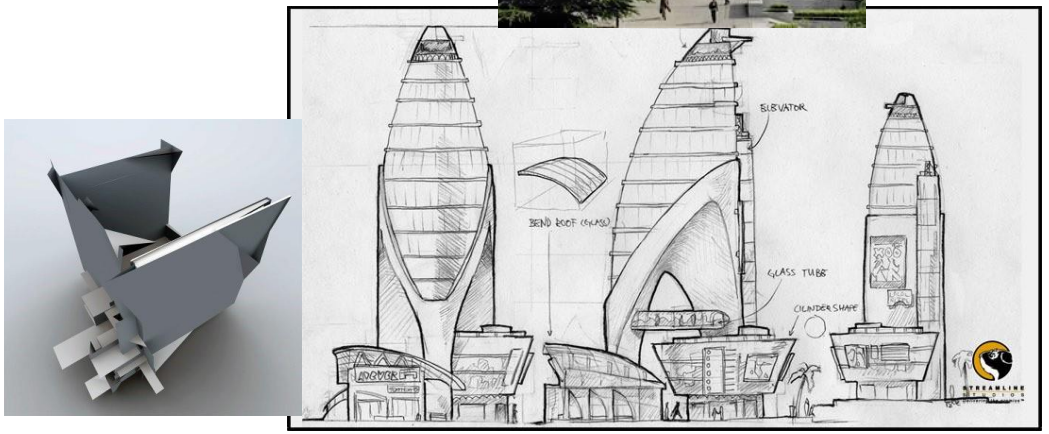
# Architecture

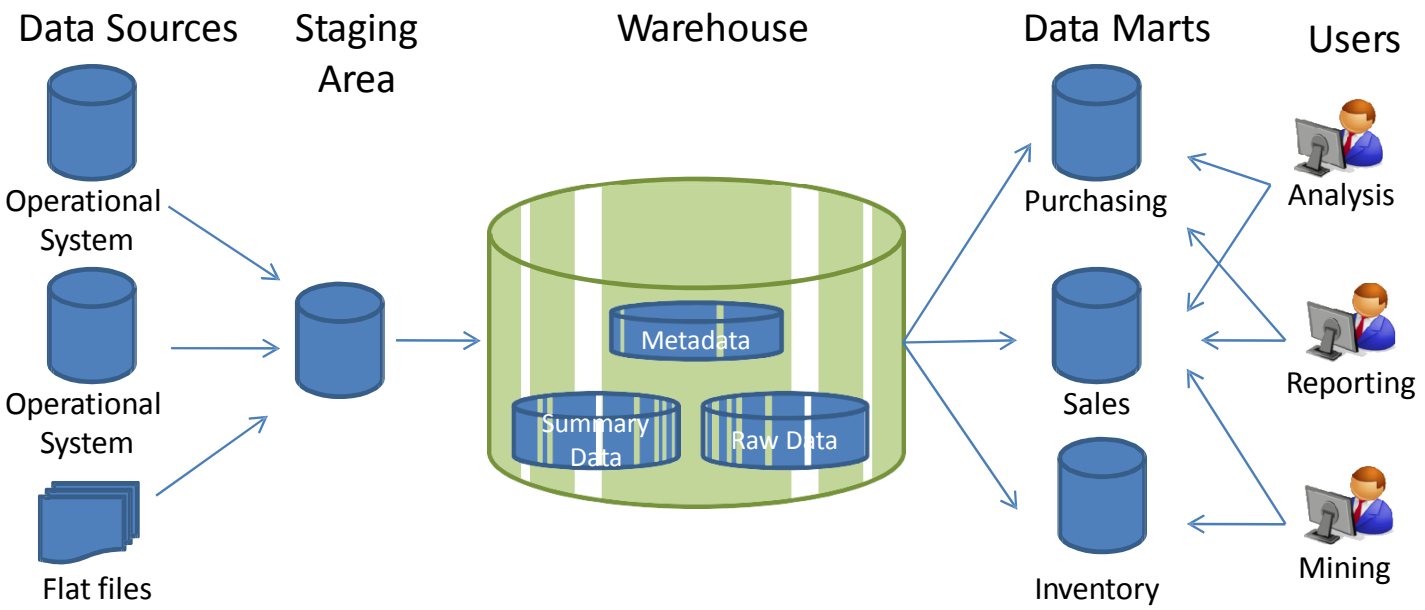
Architecture

1. Basic Architecture
2. Storage Structures
3. Tier Architectures
4. Distributed DW
5. DW Data Modeling



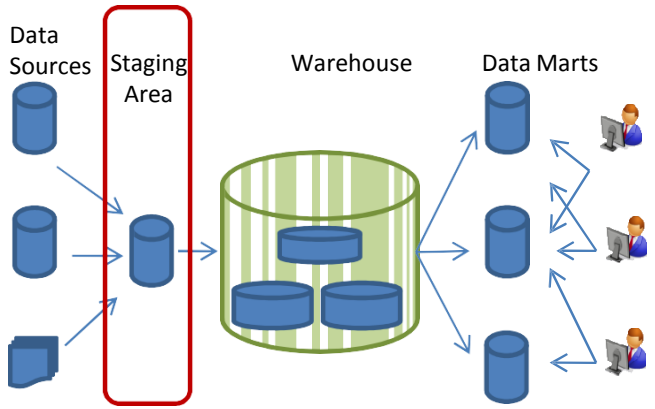
# Basic Architecture

- Architecture of a DW



# Basic Architecture (cont'd.)

- The Data Staging Area
  - Is both a storage and process area (the ETL process)
  - It represents everything that happens between the operational source system and the data presentation area
  - The key architectural requirement for data staging area is that it is off-limits to business users and does not provide query and presentation services

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# Basic Architecture (cont'd.)

- Customers aren't invited to visit the kitchen…
  - Similar to a restaurant's kitchen, the data staging area should be accessible only to skilled professionals

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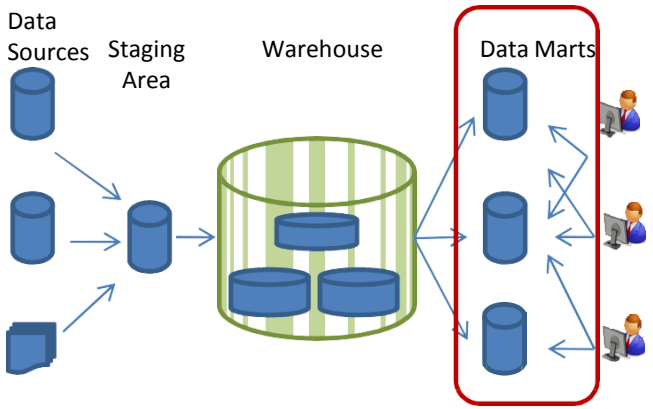
# Basic Architecture (cont'd.)

- The Data Presentation Area
  - Is where data is organized, stored and made available for queries, report writers, and other analytical processing
  - This area is the Warehouse as far as the business community is concerned



# Storage Structure

- Storage structure
  - After extraction from the operational data, in DW information is stored in databases
  - The databases are operated by a DBMS
  - Different database structures can be used for a DW:
    - Relational model (RDB) operated by a RDBMS
    - MultiDimensional model (MDB) operated by a MDBMS

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# Storage Structure (cont'd.)

- RDB and MDB are complementary and do not have to exclude each other
  - In the staging area some RDBMS can be used, however it must be off-limits to user queries because of performance reasons
  - By default, normalized databases are excluded from the presentation area, which should be strictly multi-dimensionally (MDBMS)

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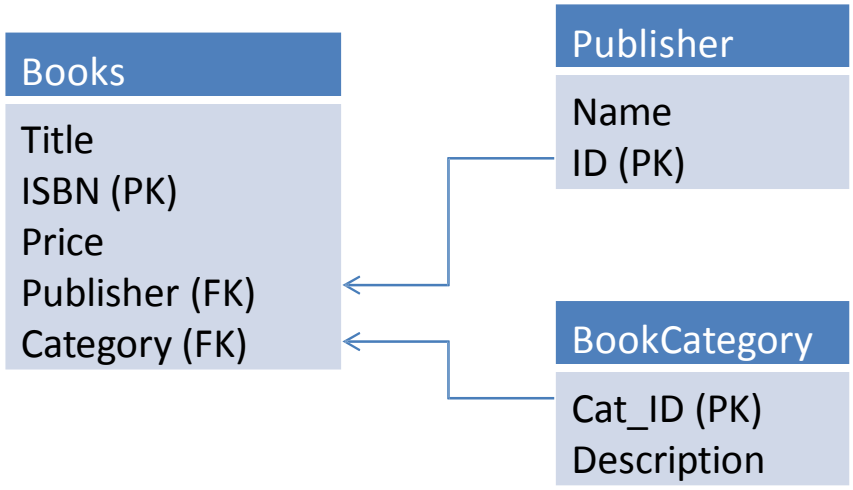
# Relational DB

- DB in relational model
  - A database is seen as a collection of predicates over a finite set of variables
  - The content of the DB is modeled as a set of relations in which all predicates are satisfied

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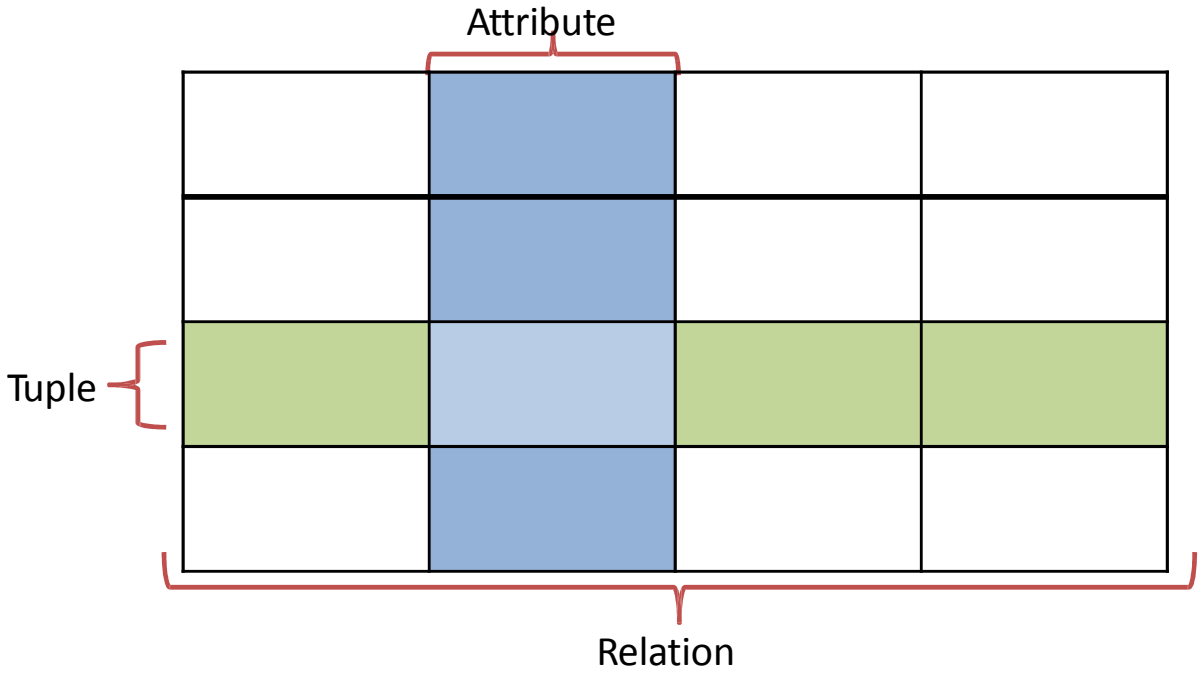
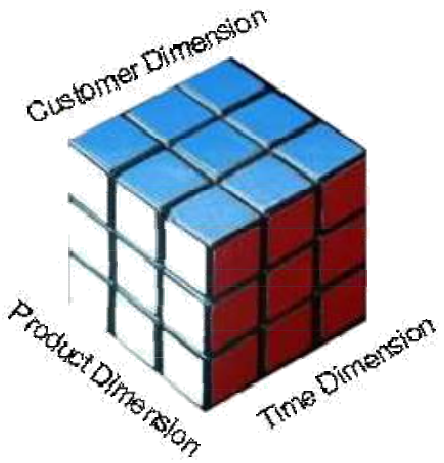
# Relational DB (cont'd.)

- A relation is defined as a set of tuples that have the same attributes
  - It is usually described as a table



# Multidimensional DB

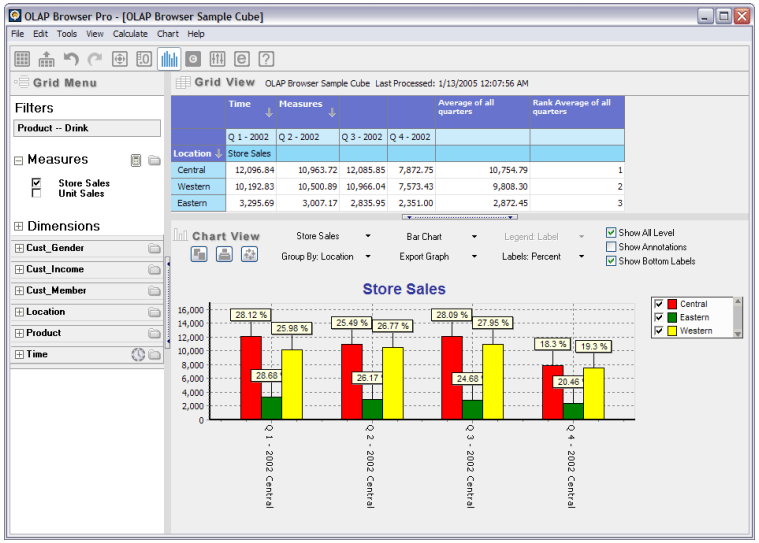
- Multidimensional DB (MDB) are optimized for DW and OLAP applications
  - They are created using input from the staging area
  - Designed for efficient and convenient storage and retrieval of large volumes of data
  - Stored, viewed and analyzed from different perspectives called dimensions



# Multidimensional DB (cont'd.)

Detour

- Example: an automobile manufacturer wants to increase sale volumes
  - Evaluation requires to view historical sale volume figures from multiple dimensions
  - Sales volume by model, by color, by dealer, over time

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# Multidimensional DB (cont'd.)

Detour

- A relational structure of the given evaluation would be

| Model | Color | Sales volume |
|---|---|---|
| Mini VAN | Blue | 324 |
| Mini VAN | Black | 113 |
| Mini VAN | Red | 18 |
| Sedan | Black | 160 |
| Sedan | Blue | 115 |
| Sedan | Red | 6 |
| Sports coupe | Red | 16 |
| Sports coupe | Black | 16 |
| Sports coupe | Blue | 12 |

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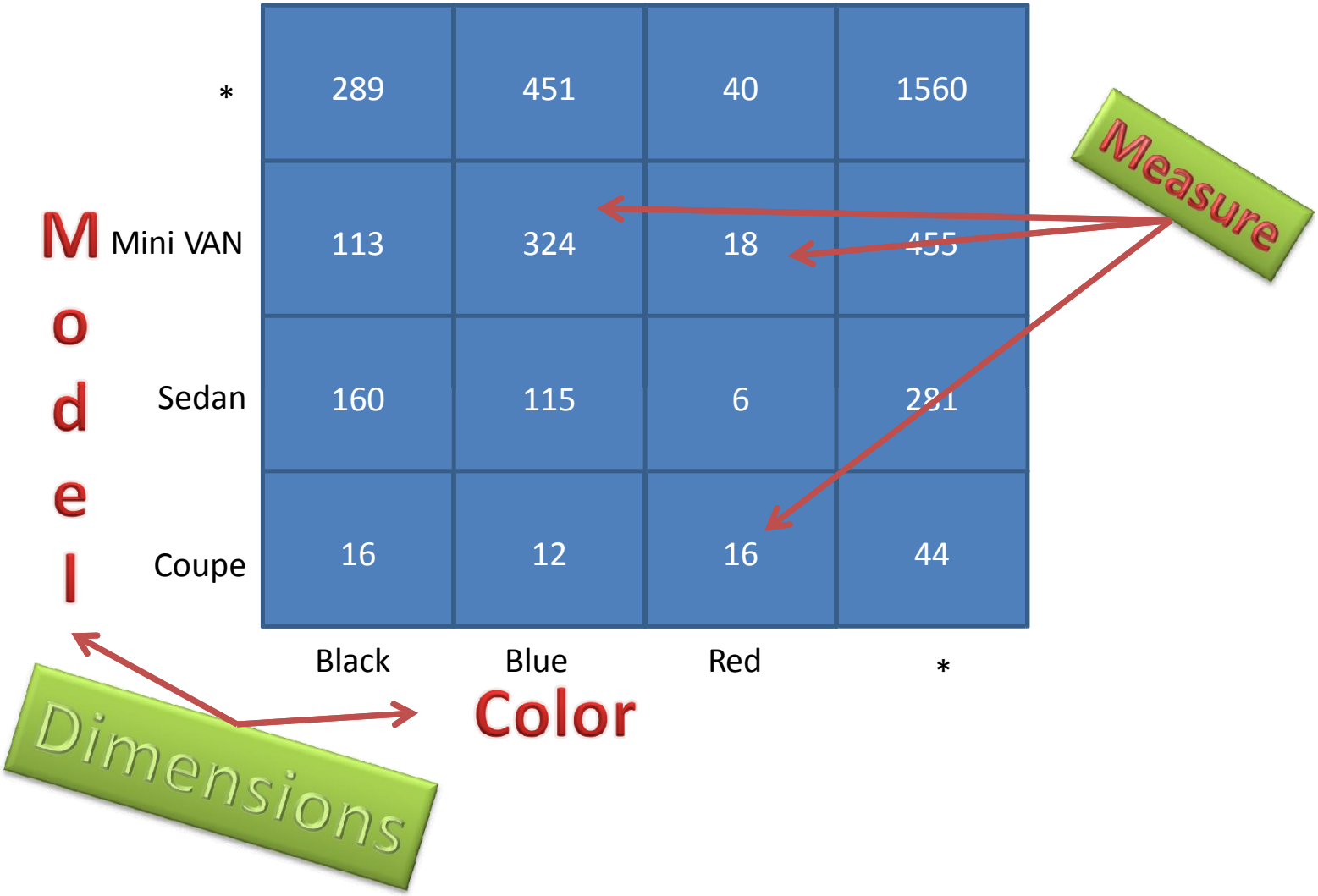
# Multidimensional DB (cont'd.)

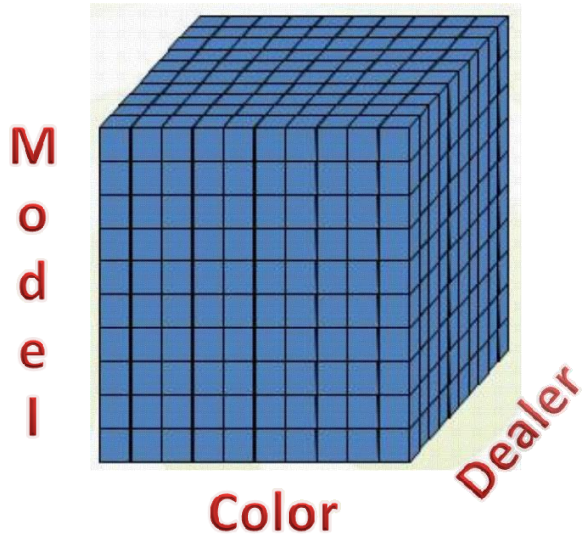
Detour

- Structure



# Multidimensional DB (cont'd.)

- The complexity grows quickly with the number of dimensions and the number of positions
  - Example: 3 dimensions with 10 values each and no indexes
  - If we consider viewing information in a RDB it would result in a worst case of $10^3=1000$ records view



# Multidimensional DB (cont'd.)


- Now, if we consider performance
  - For responding to a query when car type = Sedan, color = Blue, and dealer = Berg
    - RDBMS has to search through 1000 records to find the right record
    - MDB has more knowledge about where data lies
    - The maximum of searches in the case of MDB is of 30 positions
    - Average case 18 vs. 501 positions

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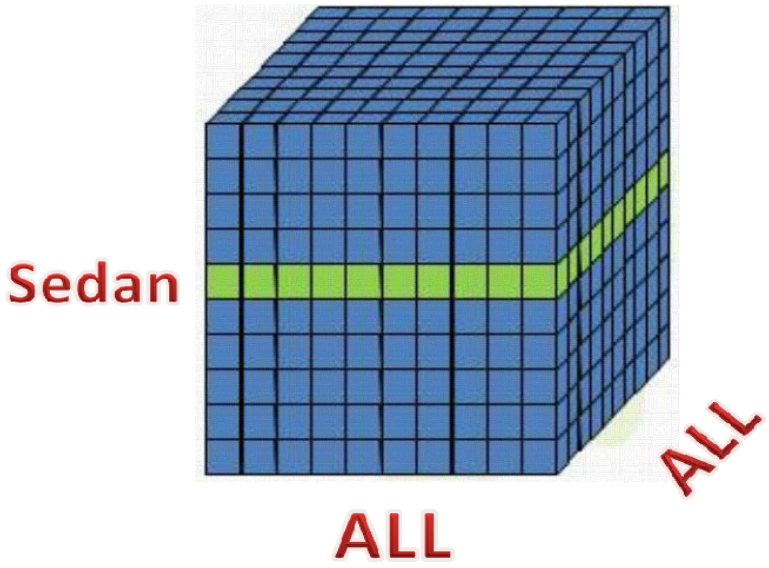
# Multidimensional DB (cont'd.)

Detour

- If the query is more relaxed
  - Total sales across all dealers for all colors when car type = sedan
    - RDBMS still has to go through the 1000 records
    - MDB, however, goes only through a slice of 10x10

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# Multidimensional DB (cont'd.)

Detour

- Performance advantages
  - MDBs are an order of magnitude faster than RDBMSs
  - Performance benefits are more for queries that generate cross-tab views of data (the case of DW)
- Conclusion
  - The performance advantages offered by MDBs facilitates the development of interactive decision support applications like OLAP that can be impractical in a relational environment

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# RDB vs. MDB

Detour

- Any database manipulation is possible with both technologies
- MDBs however offer some advantages in the context of DW:
  - Ease of data presentation
  - Ease of maintenance
  - Performance

# RDB vs. MDB (cont'd.)

Detour

- Ease of data presentation
  - Data views are natural output of the MDBs
  - Obtaining the same views in RDB requires a complex query
    - Example with Walmart and Sybase:
      - select sum(sales.quantity_sold) from sales, products, product_categories, manufacturers, stores, cities where manufacturer_name = 'Colgate'

and product_category_name = 'toothpaste'
and cities.population < 40 000
and trunc(sales.date_time_of_sale) = trunc(sysdate-1)
and sales.product_id = products.product_id
and sales.store_id = stores.store_id
and products.product_category_id = product_categories.product_category_id
and products.manufacturer_id = manufacturers.manufacturer_id
and stores.city_id = cities.city_id

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# RDB vs. MDB (cont'd.)

Detour

- Ease of data presentation
  - Top k queries cannot be expressed well in SQL
    - Find the five cheapest hotels in Auckland
      - SELECT * FROM hotels h WHERE h.city = Auckland AND 5 > (SELECT count(*) FROM hotels h1 WHERE h1.city = Auckland AND h1.price < h.price);
    - Some RDBMS extended the functionality of SQL with STOP AFTER functionality
      - SELECT * FROM hotelsWHERE city = Auckland Order By price STOPAFTER 5;

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# RDB vs. MDB (cont'd.)


- Ease of maintenance
  - No additional overhead to translate user queries into requests for data
    - Data is stored as it is viewed
  - RDBs use indexes and sophisticated joins which require significant maintenance and storage to provide same intuitiveness

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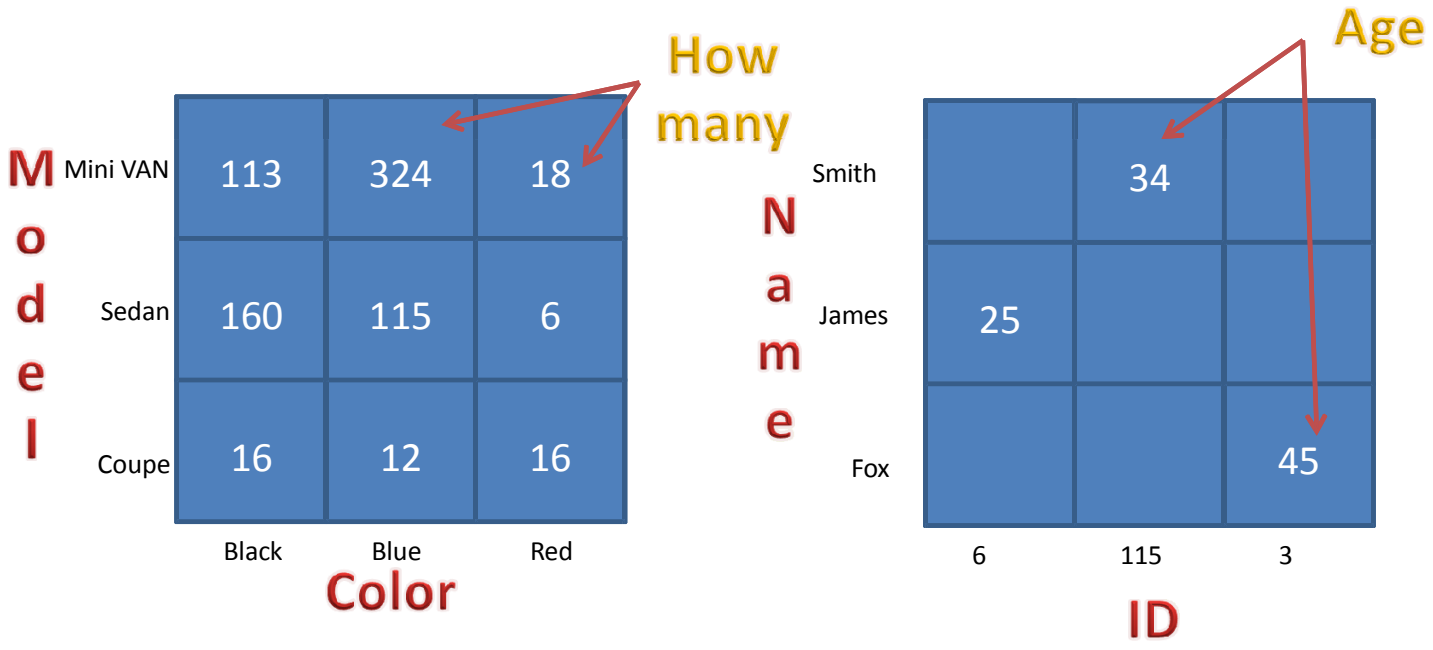
# RDB vs. MDB (cont'd.)


- Performance
  - —Performance of MDBs can be matched by RDBs through database tuning
  - —Not possible to tune the database for all possible ad- hoc queries
  - —Aggregate navigators are helping RDBs to

# When MDBs are In-appropriate?

Detour

- When MDBs are in-appropriate?
  - If the dataset types are not highly related, using a MDB results in a sparse representation



# When MDBs are Appropriate?

Detour

- When MDBs are appropriate?
  - In the case of highly interrelated dataset types MDBs are recommended for greatest ease of access and analysis
  - Examples of applications
    - Financial Analysis and Reporting
    - Budgeting
    - Promotion Tracking
    - Quality Assurance and Quality Control
    - Product Profitability

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# Summary


- DW life cycle:
  - DW life cycle
  - Operating a DW
    - Monitoring
    - Extraction
    - Transforming
    - Loading
    - Analyzing
- DW architectures:
  - Basic architecture
  - Storage architecture

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# Next lecture

- DW architecture (cont'd.)
  - Tier architecture
  - Distributed DW
  - DW data modeling

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