商業智慧實務
Practices of Business Intelligence

資料倉儲
(Data Warehousing)

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Wed, 9,10 (16:10-18:00) (B113)

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2014-03-12
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<td>1</td>
<td>103/02/19</td>
<td>商業智慧導論 (Introduction to Business Intelligence)</td>
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<td>103/02/26</td>
<td>管理決策支援系統與商業智慧 (Management Decision Support System and Business Intelligence)</td>
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<td>商業智慧的資料探勘 (Data Mining for Business Intelligence)</td>
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<td>7</td>
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<td>13</td>
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<td>畢業考試週 (Final Exam)</td>
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A High-Level Architecture of BI

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Decision Support and Business Intelligence Systems
(9th Ed., Prentice Hall)

Chapter 8:
Data Warehousing
Learning Objectives

• Definitions and concepts of data warehouses
• Types of data warehousing architectures
• Processes used in developing and managing data warehouses
• Data warehousing operations
• Role of data warehouses in decision support
• Data integration and the extraction, transformation, and load (ETL) processes
• Data warehouse administration and security issues
Main Data Warehousing (DW) Topics

• DW definitions
• Characteristics of DW
• Data Marts
• ODS, EDW, Metadata
• DW Framework
• DW Architecture & ETL Process
• DW Development
• DW Issues

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Data Warehouse Defined

- A physical repository where relational data are specially organized to provide enterprise-wide, cleansed data in a standardized format

- “The data warehouse is a collection of integrated, subject-oriented databases designed to support DSS functions, where each unit of data is non-volatile and relevant to some moment in time”

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Characteristics of DW

- Subject oriented
- Integrated
- Time-variant (time series)
- Nonvolatile
- Summarized
- Not normalized
- Metadata
- Web based, relational/multi-dimensional
- Client/server
- Real-time and/or right-time (active)

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Data Mart

A departmental data warehouse that stores only relevant data

- **Dependent data mart**
  A subset that is created directly from a data warehouse

- **Independent data mart**
  A small data warehouse designed for a strategic business unit or a department

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Data Warehousing Definitions

• Operational data stores (ODS)
  A type of database often used as an interim area for a data warehouse

• Oper marts
  An operational data mart.

• Enterprise data warehouse (EDW)
  A data warehouse for the enterprise.

• Metadata
  Data about data. In a data warehouse, metadata describe the contents of a data warehouse and the manner of its acquisition and use

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
A Conceptual Framework for DW

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Generic DW Architectures

• Three-tier architecture
  1. Data acquisition software (back-end)
  2. The data warehouse that contains the data & software
  3. Client (front-end) software that allows users to access and analyze data from the warehouse

• Two-tier architecture
  First 2 tiers in three-tier architecture is combined into one
  ... sometime there is only one tier?

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
DW Architecture Considerations

- Issues to consider when deciding which architecture to use:
  - Which database management system (DBMS) should be used?
  - Will parallel processing and/or partitioning be used?
  - Will data migration tools be used to load the data warehouse?
  - What tools will be used to support data retrieval and analysis?

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
A Web-based DW Architecture

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Alternative DW Architectures

(a) Independent Data Marts Architecture

Source Systems → Staging Area → Independent data marts (atomic/summarized data) → End user access and applications

(b) Data Mart Bus Architecture with Linked Dimensional Datamarts

Source Systems → Staging Area → Dimensionalized data marts linked by conformed dimensions (atomic/summarized data) → End user access and applications

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Alternative DW Architectures

(c) Hub and Spoke Architecture (Corporate Information Factory)

Source Systems  →  Staging Area  →  Normalized relational warehouse (atomic data)  →  End user access and applications

(d) Centralized Data Warehouse Architecture

Source Systems  →  Staging Area  →  Normalized relational warehouse (atomic/some summarized data)  →  End user access and applications

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Alternative DW Architectures

(e) Federated Architecture

Existing data warehouses
Data marts and legacy systems

Data mapping / metadata
Logical/physical integration of common data elements

End user access and applications

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
# Alternative DW Architectures

![Alternative DW Architectures Diagram](image)

## Independent Data Marts
- Pros:
  - Easy to Build Organizationally
  - Easy to Build Technically
- Cons:
  - Business Enterprise view unavailable
  - Redundant data costs
  - High ETL costs
  - High App costs
  - High DBA and operational costs
- Leave Data Where it Lies:
  - No need for ETL
  - No need for separate platform

## Dependent Data Marts
- Pros:
  - Allows easier customization of user interfaces & reports
- Cons:
  - Business Enterprise view challenging
  - Redundant data costs
  - High DBA and operational costs
  - Data latency
- Centralized Integrated Data With Direct Access:
  - Business Enterprise view
  - Design consistency & data quality
  - Data reusability

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Which Architecture is the Best?

- Bill Inmon versus Ralph Kimball
- Enterprise DW versus Data Marts approach

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<table>
<thead>
<tr>
<th></th>
<th>Independent Data Marts</th>
<th>Bus Architecture</th>
<th>Hub-and-Spoke Architecture</th>
<th>Centralized Architecture (No Dependent Data Marts)</th>
<th>Federated Architecture</th>
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</thead>
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<td><strong>Information Quality</strong></td>
<td>4.42</td>
<td>5.16</td>
<td>5.35</td>
<td>5.23</td>
<td>4.73</td>
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<td><strong>System Quality</strong></td>
<td>4.59</td>
<td>5.60</td>
<td>5.56</td>
<td>5.41</td>
<td>4.69</td>
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<tr>
<td><strong>Individual Impacts</strong></td>
<td>5.08</td>
<td>5.80</td>
<td>5.62</td>
<td>5.64</td>
<td>5.15</td>
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<td><strong>Organizational Impacts</strong></td>
<td>4.66</td>
<td>5.34</td>
<td>5.24</td>
<td>5.30</td>
<td>4.77</td>
</tr>
</tbody>
</table>

*Empirical study by Ariyachandra and Watson (2006)*

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Data Warehousing Architectures

Ten factors that potentially affect the architecture selection decision:

1. Information interdependence between organizational units
2. Upper management’s information needs
3. Urgency of need for a data warehouse
4. Nature of end-user tasks
5. Constraints on resources
6. Strategic view of the data warehouse prior to implementation
7. Compatibility with existing systems
8. Perceived ability of the in-house IT staff
9. Technical issues
10. Social/political factors

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Enterprise Data Warehouse
(by Teradata Corporation)

Transactional Users

Transactional Data

Data Transformation

Operational Data Store (ODS)

"Enterprise" Data Warehouse

Data Replication

Data Marts

Decision Users

Strategic Users

Tactical Users

Reporting OLAP Users

Data Miners

Event-driven/Closed Loop

Middleware/Enterprise Message Bus

Physical Database Design

Logical Data Model

Enterprise, System, and Database Management

Metadata

Business and Technology - Consultation Support and Education Services

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Data Integration and the Extraction, Transformation, and Load (ETL) Process

• Data integration
  Integration that comprises three major processes: data access, data federation, and change capture.

• Enterprise application integration (EAI)
  A technology that provides a vehicle for pushing data from source systems into a data warehouse

• Enterprise information integration (EII)
  An evolving tool space that promises real-time data integration from a variety of sources

• Service-oriented architecture (SOA)
  A new way of integrating information systems

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Data Integration and the Extraction, Transformation, and Load (ETL) Process

Extraction, transformation, and load (ETL) process

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
ETL

• Issues affecting the purchase of and ETL tool
  – Data transformation tools are expensive
  – Data transformation tools may have a long learning curve

• Important criteria in selecting an ETL tool
  – Ability to read from and write to an unlimited number of data sources/architectures
  – Automatic capturing and delivery of metadata
  – A history of conforming to open standards
  – An easy-to-use interface for the developer and the functional user

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Benefits of DW

• Direct benefits of a data warehouse
  – Allows end users to perform extensive analysis
  – Allows a consolidated view of corporate data
  – Better and more timely information
  – Enhanced system performance
  – Simplification of data access

• Indirect benefits of data warehouse
  – Enhance business knowledge
  – Present competitive advantage
  – Enhance customer service and satisfaction
  – Facilitate decision making
  – Help in reforming business processes

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Data Warehouse Development

- Data warehouse development approaches
  - Inmon Model: EDW approach (top-down)
  - Kimball Model: Data mart approach (bottom-up)
  - Which model is best?
    - There is no one-size-fits-all strategy to DW
  - One alternative is the hosted warehouse

- Data warehouse structure:
  - The Star Schema vs. Relational

- Real-time data warehousing?

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
# DW Development Approaches

<table>
<thead>
<tr>
<th>Effort</th>
<th>Data Mart Approach</th>
<th>EDW Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scope</strong></td>
<td>One subject area</td>
<td>Several subject areas</td>
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<tr>
<td><strong>Development time</strong></td>
<td>Months</td>
<td>Years</td>
</tr>
<tr>
<td><strong>Development cost</strong></td>
<td>$10,000 to $100,000+</td>
<td>$1,000,000+</td>
</tr>
<tr>
<td><strong>Development difficulty</strong></td>
<td>Low to medium</td>
<td>High</td>
</tr>
<tr>
<td><strong>Data prerequisite for sharing</strong></td>
<td>Common (within business area)</td>
<td>Common (across enterprise)</td>
</tr>
<tr>
<td><strong>Sources</strong></td>
<td>Only some operational and external systems</td>
<td>Many operational and external systems</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>Megabytes to several gigabytes</td>
<td>Gigabytes to petabytes</td>
</tr>
<tr>
<td><strong>Time horizon</strong></td>
<td>Near-current and historical data</td>
<td>Historical data</td>
</tr>
<tr>
<td><strong>Data transformations</strong></td>
<td>Low to medium</td>
<td>High</td>
</tr>
<tr>
<td><strong>Update frequency</strong></td>
<td>Hourly, daily, weekly</td>
<td>Weekly, monthly</td>
</tr>
</tbody>
</table>

**Technology**

- **Hardware**: Workstations and departmental servers
- **Operating system**: Windows and Linux
- **Databases**: Workgroup or standard database servers
- Enterprise servers and mainframe computers
- Unix, Z/OS, OS/390
- Enterprise database servers

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
DW Structure: Star Schema (a.k.a. Dimensional Modeling)

Start Schema Example for an Automobile Insurance Data Warehouse

Dimensions:
How data will be sliced/diced (e.g., by location, time period, type of automobile or driver)

Facts:
Central table that contains (usually summarized) information; also contains foreign keys to access each dimension table.

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Dimensional Modeling

Data cube
A two-dimensional, three-dimensional, or higher-dimensional object in which each dimension of the data represents a measure of interest

- Grain
- Drill-down
- Slicing

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Best Practices for Implementing DW

• The project must fit with corporate strategy
• There must be complete buy-in to the project
• It is important to manage user expectations
• The data warehouse must be built incrementally
• Adaptability must be built in from the start
• The project must be managed by both IT and business professionals (a business–supplier relationship must be developed)
• Only load data that have been cleansed/high quality
• Do not overlook training requirements
• Be politically aware.

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Risks in Implementing DW

- No mission or objective
- Quality of source data unknown
- Skills not in place
- Inadequate budget
- Lack of supporting software
- Source data not understood
- Weak sponsor
- Users not computer literate
- Political problems or turf wars
- Unrealistic user expectations

(Continued ...)

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Risks in Implementing DW – Cont.

- Architectural and design risks
- Scope creep and changing requirements
- Vendors out of control
- Multiple platforms
- Key people leaving the project
- Loss of the sponsor
- Too much new technology
- Having to fix an operational system
- Geographically distributed environment
- Team geography and language culture

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Things to **Avoid** for Successful Implementation of DW

- Starting with the wrong sponsorship chain
- Setting expectations that you cannot meet
- Engaging in politically naive behavior
- Loading the warehouse with information just because it is available
- Believing that data warehousing database design is the same as transactional DB design
- Choosing a data warehouse manager who is technology oriented rather than user oriented

*Source: Turban et al. (2011), Decision Support and Business Intelligence Systems*
Real-time DW
(a.k.a. Active Data Warehousing)

• Enabling real-time data updates for real-time analysis and real-time decision making is growing rapidly
  – Push vs. Pull (of data)

• Concerns about real-time BI
  – Not all data should be updated continuously
  – Mismatch of reports generated minutes apart
  – May be cost prohibitive
  – May also be infeasible

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Evolution of DSS & DW

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Active Data Warehousing
(by Teradata Corporation)

**Active Access**
Front-Line operational decisions or services supported by near-real-time (NRT) access; Service Level Agreements of 5 seconds or less

**Active Load**
Intra-day data acquisition; Mini-batch to NRT trickle data feeds measured in minutes or seconds

**Active Events**
Proactive monitoring of business activity initiating intelligent actions based on rules and context; to systems or users supporting an operational business process

**Active Workload Management**
Dynamically manage system resources for optimum performance and resource utilization supporting a mixed-workload environment

**Active Enterprise Integration**
Integration into the Enterprise Architecture for delivery of intelligent decisioning services

**Active Availability**
Business Continuity to support the requirements of the business (up to 7x24)

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Source: Turban et al. (2011), Decision Support and Business Intelligence Systems

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## Comparing Traditional and Active DW

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<th>Traditional Data Warehouse Environment</th>
<th>Active Data Warehouse Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic decisions only</td>
<td>Strategic and tactical decisions</td>
</tr>
<tr>
<td>Results sometimes hard to measure</td>
<td>Results measured with operations</td>
</tr>
<tr>
<td>Daily, weekly, monthly data currency</td>
<td>Only comprehensive detailed data</td>
</tr>
<tr>
<td>acceptable; summaries often appropriate</td>
<td>available within minutes is acceptable</td>
</tr>
<tr>
<td>Moderate user concurrency</td>
<td>High number (1,000 or more) of users accessing and querying the system simultaneously</td>
</tr>
<tr>
<td>Highly restrictive reporting used to confirm or check existing processes and patterns; often uses predeveloped summary tables or data marts</td>
<td>Flexible ad hoc reporting, as well as machine-assisted modeling (e.g., data mining) to discover new hypotheses and relationships</td>
</tr>
<tr>
<td>Power users, knowledge workers, internal users</td>
<td>Operational staffs, call centers, external users</td>
</tr>
</tbody>
</table>

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Data Warehouse Administration

• Due to its huge size and its intrinsic nature, a DW requires especially strong monitoring in order to sustain its efficiency, productivity and security.

• The successful administration and management of a data warehouse entails skills and proficiency that go past what is required of a traditional database administrator.
  – Requires expertise in high-performance software, hardware, and networking technologies

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
DW Scalability and Security

• Scalability
  – The main issues pertaining to scalability:
    • The amount of data in the warehouse
    • How quickly the warehouse is expected to grow
    • The number of concurrent users
    • The complexity of user queries
  – Good scalability means that queries and other data-access functions will grow linearly with the size of the warehouse

• Security
  – Emphasis on security and privacy

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
Summary

• Definitions and concepts of data warehouses
• Types of data warehousing architectures
• Processes used in developing and managing data warehouses
• Data warehousing operations
• Role of data warehouses in decision support
• Data integration and the extraction, transformation, and load (ETL) processes
• Data warehouse administration and security issues

Source: Turban et al. (2011), Decision Support and Business Intelligence Systems
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