AKTU · 3RD YEAR · SEMESTER 5 · BCDS051

Business Intelligence and Analytics

Unit 1 — Business Intelligence – Introduction

- Introduction - History and Evolution
- Effective and Timely Decisions
- Data, Information, and Knowledge
- Architectural Representation
- Role of Mathematical Models
- Real Time Business Intelligent System



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Introduction to Business Intelligence

BUSINESS INTELLIGENCE (BI)

Business Intelligence is a technology-driven process for analyzing operational data and presenting actionable information to help executives, managers, and operational workers make informed business decisions.

- Combines data mining, process analytics, performance benchmarking, and descriptive analytics.
- Transforms raw operational data into structured, strategic insights for competitive advantage.
- Enables evidence-based decision-making across all organizational levels.

Evolution Timeline of Business Intelligence



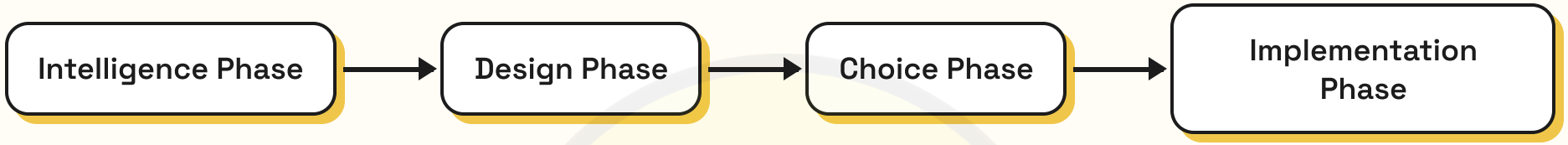
Historical evolution from mainframe batch reporting to continuous real-time analytics.

Historical Development and Drivers of BI

The evolution of BI was driven by exponential data growth and the need for organized data analysis.

- 1958: Hans Peter Luhn first coined the term Business Intelligence in an IBM journal article.
- 1989: Howard Dresner proposed BI as an umbrella term for decision support concepts and methods.
- 1970s-1980s: Relational Database Management Systems (RDBMS) provided structured data storage.
- 1990s: Ralph Kimball and Bill Inmon standardized Enterprise Data Warehousing architectures.
- Modern Era: BI integrates Artificial Intelligence, Machine Learning, and Cloud Computing platforms.

Simon’s Decision-Making Model in BI



Herbert Simon's decision-making model integrated with modern BI analytics.

Effective and Timely Decisions

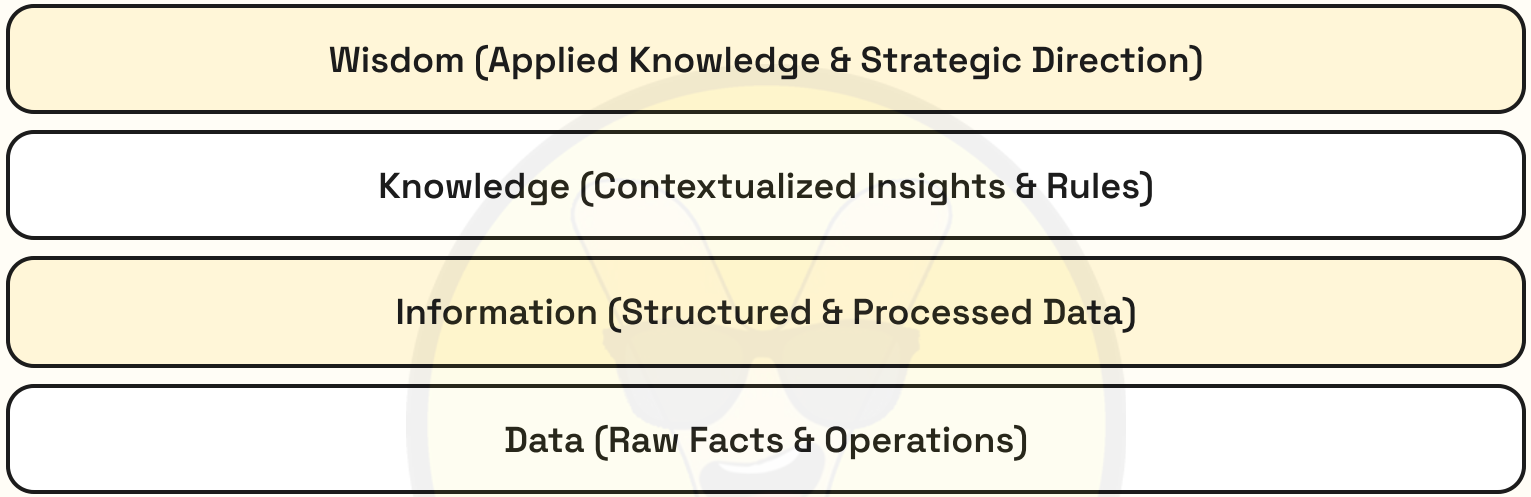
BI systems bridge the gap between operational data availability and strategic execution speed.

- Effective Decisions: Decisions grounded in objective metrics, validated data, and quantitative analysis.
- Timely Decisions: Decisions executed within the critical time window before business opportunities expire.
- Decision Latency: The total elapsed time between a business event occurring and taking corrective action.
- Automated Decision Rules: BI systems trigger predefined operations automatically when metrics breach thresholds.
- Quality-Speed Balance: BI balances decision quality with execution speed by providing organized data feeds.

Components of Decision Latency

Latency Component	Description	BI Reduction Strategy
Data Latency	Time taken to capture, collect, and load raw data	Automated ETL pipelines and event streaming
Analysis Latency	Time taken to process data and generate actionable insights	OLAP engines, pre-calculated aggregations
Decision Latency	Time taken by decision-makers to select an action	Interactive dashboards, automated alert systems
Action Latency	Time taken to execute the selected decision	Automated workflows, direct API integrations

The DIKW Hierarchy



Hierarchical transformation of raw input values into strategic organizational wisdom.

Comparison: Data, Information, and Knowledge

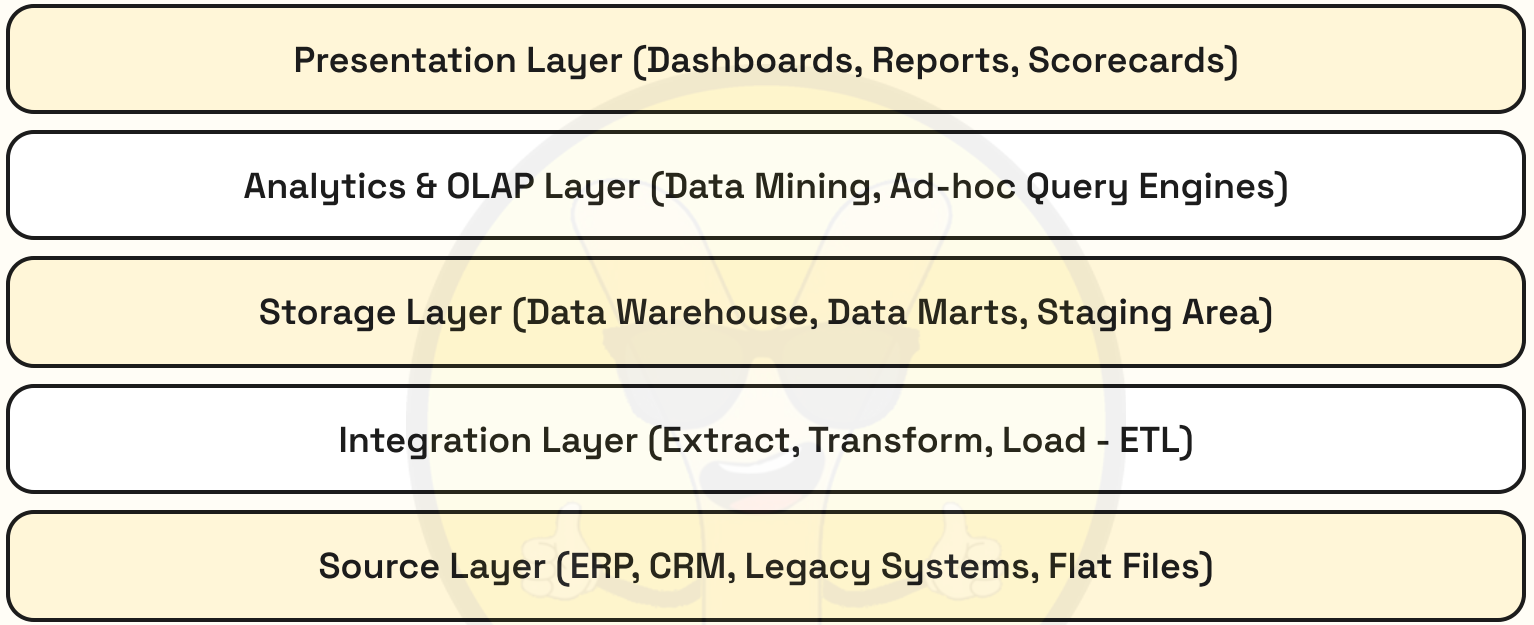
Parameter	Data	Information	Knowledge
Definition	Unprocessed, isolated facts or symbols	Processed and structured data with context	Actionable understanding derived from insights
Context	Lacks business context	Has clear purpose and context	Integrates experience, rules, and framework
Format	Raw values, numbers, strings	Reports, graphs, and formatted tables	Patterns, rules, predictive models
Example	Values: 100, 250, 400	Monthly sales chart by region	Understanding root causes of regional sales drop
BI Role	Stored in source systems / staging	Displayed in dashboards / OLAP	Drives executive decision strategies

Knowledge Management and BI Integration

Combining Business Intelligence with Knowledge Management maximizes organizational intelligence.

- Tacit Knowledge: Personal experience and intuition converted into structured rules using BI models.
- Explicit Knowledge: Documented metrics and analytics shared easily across enterprise channels.
- Knowledge Discovery in Databases (KDD): Methodological extraction of non-trivial, implicit patterns from large datasets.
- Closed-Loop Analytics: Operational results feed back into data warehouses to continually refine knowledge models.
- Competitive Edge: Systematic knowledge retrieval accelerates problem-solving and operational strategy.

Multi-Tier BI System Architecture



Standard multi-tier architectural representation of an Enterprise BI System.

Core Architectural Components of BI

Each tier in the BI architecture plays a specific role in data transformation and presentation.

- Data Sources: Operational systems (OLTP), external files, APIs, and flat transaction logs.
- ETL Engine: Extracts source data, performs cleansing and transformation, and loads into storage.
- Data Warehouse (DW): Subject-oriented, integrated, time-variant, and non-volatile data repository.
- Data Marts: Department-specific subsets of data warehouses optimized for focused business units.
- OLAP Engines: High-performance engines enabling multi-dimensional data aggregation and analysis.
- Front-End Tools: User interfaces presenting dashboards, KPIs, scorecards, and interactive reports.

Data Integration and the ETL Pipeline

ETL processes ensure high data quality, consistency, and structural integrity across the BI stack.

- Extraction: Capturing relevant delta data from operational databases without impacting system performance.
- Transformation: Cleaning noise, standardizing data types, resolving key conflicts, and calculating metrics.
- Loading: Writing structured data into target data warehouse schemas or staging repositories.
- Staging Area: Intermediate storage layer used to perform transformations before enterprise loading.
- Batch vs Real-Time ETL: Traditional architectures run batch ETL; modern systems employ continuous stream ETL.

Mathematical Models in Business Intelligence

MATHEMATICAL MODELING IN BI

Mathematical modeling in BI represents complex business scenarios through mathematical equations, parameters, constraints, and objective functions to evaluate strategies and optimize decisions.

- Transitions analytics from descriptive (what happened) to predictive and prescriptive states.
- Uses operations research, optimization theory, statistics, and probability models.
- Enables scenario evaluation, sensitivity analysis, and trade-off optimization under uncertainty.

Categories of Mathematical Models in BI

Model Type	Objective	Core Techniques	BI Application
Optimization Models	Find the best solution subject to operational constraints	Linear Programming, Integer Programming	Resource allocation, supply chain optimization
Simulation Models	Imitate real-world process behavior over time	Monte Carlo Simulation, Discrete Event	Risk analysis, financial planning
Predictive Models	Forecast future metrics from historical trend data	Regression Analysis, Time-Series Forecasting	Demand forecasting, customer churn prediction
Decision Analysis	Evaluate alternative choices under uncertainty	Decision Trees, Analytic Hierarchy Process	Capital allocation, vendor selection

Mathematical Optimization Example: Product Mix

A factory produces two products P_1 and P_2 with unit profits of \$40 and \$30. Product P_1 requires 2 hours of labor, and P_2 requires 1 hour. Total labor capacity is 100 hours. Total available material is 80 units (each product consumes 1 unit). Formulate and solve to maximize total profit Z.

1. Formulate Objective Function: Maximize $Z = 40P_1 + 30P_2$
2. Write Constraints: Labor: $2P_1 + P_2 \leq 100$; Material: $P_1 + P_2 \leq 80$; Non-negativity: $P_1, P_2 \geq 0$
3. Find Intersection Point: Subtract material constraint from labor constraint: $(2P_1 + P_2) - (P_1 + P_2) = 100 - 80 \implies P_1 = 20$
4. Calculate P_2: Substitute $P_1 = 20$ into material constraint: $20 + P_2 = 80 \implies P_2 = 60$
5. Calculate Total Profit: $Z = 40(20) + 30(60) = 800 + 1800 = 2600$

The optimal production plan is 20 units of P_1 and 60 units of P_2, generating a maximum profit of \$2,600.

Real-Time Business Intelligence (RTBI)

REAL-TIME BUSINESS INTELLIGENCE (RTBI)

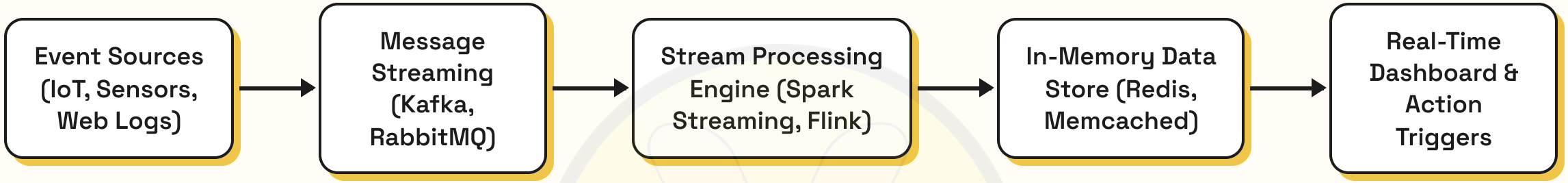
Real-Time Business Intelligence (RTBI) is an architectural approach that delivers operational analytics with zero or near-zero data latency, allowing instant analysis and immediate automated action upon event occurrence.

- Minimizes data, analysis, decision, and action latency components.
- Uses Event-Driven Architecture (EDA) and stream processing infrastructure.
- Essential for time-critical domains such as algorithmic trading, fraud prevention, and dynamic pricing.

Comparison: Traditional BI vs. Real-Time BI

Parameter	Traditional BI	Real-Time BI (RTBI)
Data Processing	Scheduled batch processing (daily/weekly)	Continuous event stream processing
System Latency	Hours to days	Milliseconds to minutes
Data Repository	Historical Data Warehouse	In-memory datastores and message streams
Decision Scope	Strategic, tactical, long-term planning	Operational, immediate, event-driven execution
Query Type	Pre-calculated OLAP cube queries	Continuous push-based streaming queries
Primary End-Users	Executives, business analysts	Operational managers, automated edge systems

Real-Time BI System Architecture



Event-driven streaming pipeline for near-zero latency analytics.

RTBI Applications and Implementation Challenges

Deploying real-time intelligence provides strategic benefits but introduces architectural complexity.

- Application - Credit Fraud Prevention: Evaluating financial transactions instantly to block fraudulent requests.
- Application - Dynamic Surge Pricing: Continuous adjustment of pricing based on real-time supply-demand shifts.
- Challenge - Financial Cost: High computational overhead and specialized in-memory computing costs.
- Challenge - Data Quality On-The-Fly: Cleansing unstructured continuous streams without introducing processing delay.
- Challenge - Complex System State: Managing stateful stream analytics and guaranteeing system fault tolerance.

AKTU Exam Corner: Unit 1 Important Questions

- **Q1** Define Business Intelligence (BI). Detail its historical evolution from early Decision Support Systems (DSS) to modern real-time platforms.
- **Q2** Differentiate between Data, Information, and Knowledge using relevant examples and the DIKW hierarchy pyramid.
- **Q3** Draw and explain the detailed multi-tier architectural representation of an Enterprise Business Intelligence system.
- **Q4** What is Decision Latency? Explain how BI systems help minimize Data, Analysis, Decision, and Action latency.
- **Q5** Discuss the role of Mathematical Models in BI. Formulate a Linear Programming Problem (LPP) for product optimization and show its solution.
- **Q6** Compare Traditional BI and Real-Time BI (RTBI) across data processing, latency, architecture, and user roles.
- **Q7** Explain the architecture of a Real-Time Business Intelligence System. Discuss the key operational challenges in streaming data analytics.

Unit 1 done. You are exam-ready.

Revise the Exam corner once more, then open Unit 2 on theycotes.com. Every AKTU subject, unit by unit, free. Notes by Chirag Jain, Ycotes.

