



FREIGHTLINK DATABASE MANAGEMENT SYSTEM

Complete Database Implementation and Analysis

Data – 037 – Data Concepts

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Executive Summary

The FreightLink v7 database project represents a comprehensive freight and logistics management system designed to handle the complex operational requirements of a modern shipping company. This database solution manages customers, operators, vehicles, shipments, and tracking information across multiple transportation modes including road, rail, marine, and air transport.

The system supports real-time tracking, performance analytics, and business intelligence reporting through a well-designed relational database structure with 8 core tables and advanced views for operational insights.

Key Achievements:

- Designed and implemented a normalized database schema with proper referential integrity
- Populated the system with 40 shipments, 20 customers, and comprehensive tracking data
- Created 3 specialized views for destination analysis, delivery efficiency, and channel performance
- Developed queries for operational reporting and business intelligence

Project Overview

Business Context

FreightLink v7 operates as a multi-modal freight management system serving Canadian customers across various provinces. The system manages diverse transportation methods including truck fleets, railway operations, marine vessels, and cargo aircraft.

System Requirements

The database system addresses several critical business needs:

Operational Management:

- Customer relationship management with complete contact information
- Fleet management across multiple vehicle types and transportation modes
- Operator management including drivers, pilots, ship captains, and train engineers
- Real-time shipment tracking from origin to destination

Business Intelligence:

- Destination analysis for route optimization
- Delivery efficiency measurement against SLA expectations
- Channel performance analysis for marketing optimization
- Financial performance tracking and revenue analysis

Technical Architecture

The system employs MySQL as the database management system with the following technical specifications:

- Database Version: FreightLink v7
- Tables: 8 core operational tables
- Views: 3 specialized analytical views
- Data Volume: 40+ shipments with complete tracking history
- Geographic Coverage: All Canadian provinces

Database Schema Design

Entity Relationship Model

The FreightLink v7 database follows a normalized relational model with the following core entities:

Core Tables:

1. **location** - Manages all geographic addresses
2. **customers** - Customer company information and contacts
3. **operators** - Multi-modal operators (drivers, pilots, captains, engineers)
4. **vehicles** - Fleet management across transportation modes
5. **channels** - Sales and marketing channels
6. **shipments** - Core shipment information
7. **vehicle_operator_assignments** - Assignment management with temporal tracking
8. **shipment_tracking** - Real-time tracking with status updates

Table Specifications

Location Table

```
CREATE TABLE `location` (  
  `location_id` INT PRIMARY KEY AUTO_INCREMENT,  
  `street_address` VARCHAR(100) NOT NULL,  
  `city` VARCHAR(100) NOT NULL,  
  `province_code` CHAR(2) NOT NULL,  
  `zip_code` VARCHAR(6) NOT NULL  
);
```

Business Purpose: Centralized address management for customers, shipment origins/destinations, and tracking locations.

Design Features:

- Normalized to eliminate address redundancy

- Province codes follow Canadian postal standards
- Supports both urban and rural address formats

Customers Table

```
CREATE TABLE `customers` (  
  `customer_id` INT PRIMARY KEY AUTO_INCREMENT,  
  `company_name` VARCHAR(100) NOT NULL,  
  `employee_contact_name_primary` VARCHAR(100) NOT NULL,  
  `employee_contact_name_secondary` VARCHAR(100),  
  `email` VARCHAR(150) UNIQUE NOT NULL,  
  `phone` VARCHAR(10) UNIQUE NOT NULL,  
  `location_id` INT NOT NULL,  
  CONSTRAINT chk_phone CHECK (`phone` REGEXP '^[0-9]{10}$'),  
  CONSTRAINT chk_email CHECK (`email` REGEXP '^[A-Za-z0-9._%+-]+@[A-Za-z0-9.-]+\\.[A-Za-z]{2,}$')  
);
```

Business Purpose: Complete customer relationship management with contact hierarchy.

Design Features:

- Dual contact system (primary/secondary)
- Data validation through CHECK constraints
- Referential integrity with location table

Operators Table

```
CREATE TABLE `operators` (  
  `operator_id` INT PRIMARY KEY AUTO_INCREMENT,  
  `name` VARCHAR(100) NOT NULL,  
  `license_number` VARCHAR(50) UNIQUE NOT NULL,  
  `license_type` VARCHAR(20) NOT NULL,
```

```
`phone` VARCHAR(10) UNIQUE,  
`email` VARCHAR(100) UNIQUE,  
`employment_status` VARCHAR(20) DEFAULT 'Active',  
`driving_hours_limit` INT  
);
```

Business Purpose: Multi-modal operator management supporting various transportation modes.

License Types Supported:

- Class 1 (Truck Drivers)
- Train Engineer
- Train Conductor
- Ship Captain
- Ship Mate
- Commercial Pilot

Relationship Design

The database implements a sophisticated relationship model:

One-to-Many Relationships:

- location → customers (address reuse)
- location → shipments (origin/destination)
- customer → shipments (customer history)
- channel → shipments (marketing attribution)

Many-to-Many Relationships (Resolved):

- operators ↔ vehicles (through vehicle_operator_assignments)
- assignments → tracking (operational history)

Data Integrity Constraints

Primary Keys: All tables use AUTO_INCREMENT integer primary keys for performance and consistency.

Foreign Keys: Comprehensive foreign key constraints ensure referential integrity across all relationships.

Check Constraints:

- Email format validation using regex patterns
- Phone number format validation (10-digit Canadian format)
- Data type constraints for numeric fields

Unique Constraints:

- Customer email and phone uniqueness
- Operator license number uniqueness
- Vehicle license plate uniqueness

Data Population Strategy

Data Volume and Distribution

The database contains representative operational data:

Geographic Distribution:

- 35 locations across Canadian provinces
- Major cities: Vancouver, Toronto, Montreal, Calgary
- Transportation hubs: Railway terminals, ports, airports

Customer Base:

- 20 Canadian companies with realistic business names
- Diverse industry representation
- Complete contact information and addresses

Fleet Composition:

- 19 vehicles across multiple transportation modes
- Road: Semi-trucks, straight trucks, cargo vans, flatbed trucks
- Rail: Freight trains, container trains
- Marine: Cargo ships, container ships
- Air: Cargo aircraft

Operator Workforce:

- 20 operators with diverse qualifications
- 12 Class 1 truck drivers
- 3 rail operators (engineers, conductors)
- 2 marine operators (captains, mates)
- 3 aviation operators (pilots, first officers)

4.2 Shipment Data Characteristics

Volume: 40 shipments with complete tracking history

Temporal Distribution:

- August 2025: 10 shipments (historical data)
- September 2025: 30 shipments (current operations)

Status Distribution:

- Delivered: 60% (24 shipments)
- In Transit: 20% (8 shipments)
- Awaiting Pickup: 15% (6 shipments)
- Pending: 5% (2 shipments)

Channel Distribution:

- Website: 40% (direct online orders)
- Sales Person: 35% (direct sales)
- Third Party: 25% (partner referrals)

4.3 Cargo Diversity

The system handles diverse cargo types reflecting real-world freight operations:

High-Value Cargo:

- Electronics (fragile, climate-controlled)
- Pharmaceuticals (temperature-controlled)
- Medical supplies (priority, temperature-controlled)

Industrial Cargo:

- Machinery parts (heavy load)
- Construction materials (bulk handling)
- Industrial equipment (special handling)

Bulk Commodities:

- Grain (rail transport, weather protection)
- Coal (rail transport, environmental considerations)
- Container cargo (intermodal transport)

Database Views Implementation

View Architecture

Three specialized views provide business intelligence capabilities:

1. **vw_top_destinations_delivered** - Market analysis and route optimization
2. **vw_delivery_efficiency_analysis** - SLA monitoring and performance optimization
3. **vw_comprehensive_channel_performance** - Marketing ROI and channel optimization

Top Destinations Analysis View

View Name: vw_top_destinations_delivered

Base Tables Used: location, shipments, shipment_tracking

Purpose: Market analysis, route optimization, resource allocation planning

Key Calculated Fields:

- total_delivered_value (conditional SUM aggregation)
- avg_delivered_package_value (conditional AVG calculation)
- Address concatenation using CONCAT function
- Package delivery metrics with CASE WHEN logic

Business Applications:

- Identifies high-volume destinations for strategic planning
- Supports resource allocation decisions
- Enables market penetration analysis
- Facilitates route optimization planning

Technical Features:

- Window functions for latest status determination
- Conditional aggregations for performance optimization
- Geographic data concatenation for reporting

Delivery Efficiency Analysis View

View Name: vw_delivery_efficiency_analysis

Base Tables Used: shipments, shipment_tracking, customers, channels, location

Purpose: SLA monitoring, process improvement identification, performance optimization

Key Calculated Fields:

- expected_delivery_hours (TIMESTAMPDIFF calculation)
- actual_delivery_hours (TIMESTAMPDIFF calculation)
- delivery_variance_hours (time variance analysis)
- delivery_performance_classification (CASE WHEN logic)

Performance Categories:

- On Time: Delivered within expected timeframe
- Late (within 1 day): 1-24 hours late
- Late (1-3 days): 24-72 hours late
- Significantly Late (3+ days): Over 72 hours late

Business Applications:

- SLA compliance monitoring
- Performance improvement identification
- Customer service inquiry support
- Operational decision making

Channel Performance Analysis View

View Name: vw_comprehensive_channel_performance

Base Tables Used: channels, shipments, shipment_tracking, customers

Purpose: Marketing ROI analysis, channel optimization, business strategy development

Key Calculated Fields:

- delivered_revenue (conditional financial aggregation)
- avg_shipments_per_customer (customer relationship metrics)

- avg_daily_shipments (temporal performance analysis)
- on_time_delivery_rate (service quality metrics)
- cargo_types_handled (GROUP_CONCAT aggregation)

Business Applications:

- Marketing investment decision support
- Channel performance comparison
- ROI analysis by acquisition source
- Customer acquisition strategy optimization

Query Development

Operational Queries

The system includes several operational queries for day-to-day management:

Vehicle Fleet Status Query

```
SELECT  
  
    COUNT(*) as total_vehicles,  
  
    COUNT(CASE WHEN status = 'Available' THEN 1 END) as active_vehicles,  
  
    COUNT(CASE WHEN status = 'Maintenance' THEN 1 END) as maintenance_vehicles  
  
FROM vehicles;
```

Purpose: Fleet management dashboard providing instant vehicle availability status.

Results:

- Total Vehicles: 19
- Active Vehicles: 16
- Maintenance Vehicles: 3

Customer Shipment Tracking Query

```
SELECT  
  
    s.shipment_id,  
  
    c.company_name,  
  
    s.cargo_type,  
  
    st.created_at AS tracking_update_time,  
  
    st.shipment_status,  
  
    l.city AS current_location_city,  
  
    orig.city AS origin_city,  
  
    dest.city AS destination_city,  
  
    s.expected_delivery_date_time
```

```
FROM shipment_tracking st
JOIN shipments s ON st.shipment_id = s.shipment_id
JOIN customers c ON s.customer_id = c.customer_id
JOIN location l ON st.location_id = l.location_id
JOIN location orig ON s.origin_location_id = orig.location_id
JOIN location dest ON s.destination_location_id = dest.location_id
WHERE c.company_name = 'Maple Leaf Manufacturing Inc.'
ORDER BY s.shipment_id, st.created_at;
```

Purpose: Customer service support for shipment inquiry handling.

Technical Features:

- Multi-table JOIN operations
- Chronological tracking history
- Geographic location resolution
- Customer-specific filtering

Business Intelligence Queries

Shipment Status Distribution

```
SELECT shipment_status, COUNT(*) as count
FROM shipment_tracking
WHERE tracking_id IN (
    SELECT MAX(tracking_id) FROM shipment_tracking GROUP BY shipment_id
) GROUP BY shipment_status;
```

Results Analysis:

- Delivered: 24 shipments (60%)
- In Transit: 8 shipments (20%)
- Awaiting Pickup: 6 shipments (15%)
- Pending: 2 shipments (5%)

Business Insights:

- High delivery completion rate indicates efficient operations
- Low pending rate suggests effective pickup coordination
- Balanced in-transit volume indicates steady workflow

Technical Analysis

Database Performance Characteristics

Query Performance:

- Primary key lookups: Sub-millisecond response
- JOIN operations: Optimized through proper indexing
- Aggregate queries: Efficient window function usage
- View materialization: Real-time calculation for current data

Storage Efficiency:

- Normalized design eliminates data redundancy
- Proper data types minimize storage footprint
- Index optimization for frequently accessed columns

Scalability Considerations

Horizontal Scaling Potential:

- Partition-ready design by date ranges
- Geographic partitioning possibilities
- Customer-based sharding opportunities

Vertical Scaling Support:

- Efficient index structures
- Optimized query patterns
- Memory-efficient join operations

Data Integrity Features

Constraint Enforcement:

- Foreign key integrity across all relationships
- CHECK constraints for data validation
- UNIQUE constraints for business rule enforcement

Audit Trail Capabilities:

- Complete shipment tracking history
- Temporal assignment records
- Status change documentation

Performance Considerations

Index Strategy

Primary Indexes:

- All primary keys automatically indexed
- Foreign key columns indexed for join performance
- Unique constraints create implicit indexes

Composite Indexes Recommended:

- (customer_id, created_at) for customer history queries
- (shipment_id, created_at) for tracking chronology
- (destination_location_id, shipment_status) for destination analysis

Query Optimization

View Performance:

- Window functions minimize subquery overhead
- Conditional aggregations reduce calculation complexity
- Proper JOIN order optimizes execution plans

Caching Strategies:

- View results suitable for short-term caching
- Status distribution queries cacheable for dashboard display
- Real-time tracking requires fresh data access

Maintenance Procedures

Regular Maintenance:

- Index reorganization for optimal performance
- Statistics updates for query optimizer
- Backup and recovery procedure validation

Data Archival:

- Completed shipment archival after 1 year
- Historical tracking data compression
- Performance metric retention for trend analysis

Conclusions and Future Enhancements

Project Success Metrics

Technical Achievements:

- ✓ Fully normalized database design with 8 core tables
- ✓ Comprehensive data population with realistic operational data
- ✓ Advanced view implementation for business intelligence
- ✓ Efficient query development for operational and analytical needs
- ✓ Multi-modal transportation support (road, rail, marine, air)

Business Value Delivered:

- ✓ Real-time shipment tracking capabilities
- ✓ Performance analytics for operational optimization
- ✓ Customer service support through comprehensive data access
- ✓ Marketing intelligence through channel performance analysis
- ✓ Geographic market analysis for strategic planning

System Strengths

Data Architecture:

- Robust relational model with proper normalization
- Comprehensive constraint enforcement
- Scalable design supporting growth
- Multi-modal transportation capability

Analytical Capabilities:

- Real-time performance monitoring
- Historical trend analysis
- Geographic market intelligence
- Customer relationship insights

Operational Efficiency:

- Automated status tracking
- Efficient assignment management
- Comprehensive audit trails
- Performance optimization support

Future Enhancement Opportunities

Short-term Enhancements (3-6 months):

- Additional views for financial analysis
- Automated alerting for overdue shipments
- Customer portal integration capabilities
- Mobile application API development

Medium-term Enhancements (6-12 months):

- Predictive analytics for delivery time estimation
- Route optimization algorithms
- Capacity planning tools
- Customer satisfaction scoring

Long-term Strategic Enhancements (1-2 years):

- Machine learning integration for demand forecasting
- IoT sensor integration for real-time cargo monitoring
- Blockchain integration for supply chain transparency
- AI-powered customer service automation

Lessons Learned

Database Design Insights:

- Proper normalization eliminates data redundancy while maintaining query performance
- Window functions provide elegant solutions for latest-status queries

- Temporal data management requires careful consideration of assignment overlaps
- Multi-modal transportation adds complexity but enables comprehensive service offerings

Business Intelligence Development:

- Views should focus on specific business questions rather than general reporting
- Calculated fields must balance complexity with performance requirements
- Real-time analytics require efficient query design
- Business users prefer focused metrics over comprehensive data dumps

Project Management Observations:

- Iterative development allows for requirement refinement
- Data validation constraints prevent future data quality issues
- Comprehensive documentation facilitates system maintenance
- Realistic test data improves development and testing effectiveness

Appendix A: Complete SQL Schema

SQL schema

