”Optimizing Logistics Through Data” - Courier Nexus

Chaitali Rajulkumar Thakkar
UB ID: 50557808
MS Engineering Science (Data Science)
thakkar6@buffalo.edu

Pranavi Chintala
UB ID: 50563997
MS Engineering Science (Data Science)
pchintal@buffalo.edu

I. Problem Statement

As the logistics company grows, managing shipment flow becomes increasingly complex. Current tools, mainly Excel, can't handle the rising volume and complexity, leading to inefficiencies in tracking shipments, managing customer feedback, and resolving claims. This results in delayed deliveries, poor customer satisfaction, and operational bottlenecks.

Additionally, Excel's basic password protection is vulnerable, and manual backups risk data loss, highlighting the need for a secure, automated, and scalable database solution.

We propose implementing a scalable logistics management system that provides real-time tracking, efficient delivery monitoring, and streamlined claims processing. The new database will handle large datasets, support multiple users, and generate reports to optimize operations, improving data accuracy, decision-making, and overall efficiency.

II. Target Users

The data-driven platform, Courier Nexus, targets four key user groups for logistics optimization.

Logistics Operations Team: They manage shipments by adding details, selecting shipment methods, and updating delivery statuses. For example, Sarah, a coordinator, inputs package info and tracks its progress.

Customer Service Representatives: They resolve inquiries and issues, using the system to track shipments and initiate claims. John, a representative, checks shipment status in real-time to assist customers.

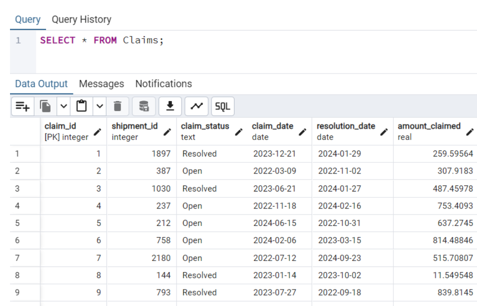
Warehouse and Delivery Teams: They log delivery attempts and update package statuses. Mike, a delivery person, records failed delivery attempts, helping the logistics team reschedule.

Administrators and IT Team: They ensure security, performance, and system upkeep, managing permissions and backups. Maria, a database admin, protects sensitive data and ensures system compliance.

III. Entity - Relationship Diagram

A. Entities

*1) **Claims**:* `claim_id` (Primary Key, INTEGER): Unique identifier for each claim. This cannot be NULL.
`claim_status` (TEXT): Represents the status of the claim (e.g., ”Pending”, ”Resolved”). Can be NULL.
`claim_date` (DATE): The date when the claim was filed. Can be NULL.
`resolution_date` (DATE): The date when the claim was resolved. Can be NULL.
`amount_claimed` (REAL): The amount claimed in the process. Default value is 0.0.
`shipment_id` (Foreign Key, INTEGER): References the `shipment_id` in the Shipments table to associate a claim with a specific shipment. Cannot be NULL.
Primary Key Justification: The `claim_id` serves as the primary key to ensure that each claim is uniquely identifiable within the system. No duplicate claims are allowed, and every claim needs a distinct ID for traceability.
Foreign Key Action: When a shipment (referenced by `shipment_id`) is deleted, a cascade delete action can be applied, meaning the associated claims would also be deleted.


Query Query History

```
1 SELECT * FROM Claims;
```

Data Output Messages Notifications

	claim_id [PK] integer	shipment_id integer	claim_status text	claim_date date	resolution_date date	amount_claimed real
1	1	1897	Resolved	2023-12-21	2024-01-29	259.59564
2	2	387	Open	2022-03-09	2022-11-02	307.9183
3	3	1030	Resolved	2023-06-21	2024-01-27	487.45978
4	4	237	Open	2022-11-18	2024-02-16	753.4093
5	5	212	Open	2024-06-15	2022-10-31	637.2745
6	6	758	Open	2024-02-06	2023-03-15	814.48846
7	7	2180	Open	2022-07-12	2024-09-23	515.70807
8	8	144	Resolved	2023-01-14	2023-10-02	11.549548
9	9	793	Resolved	2023-07-27	2022-09-18	839.8145
10	10	148	Open	2023-02-21	2023-07-30	496.20346

Fig. 1. Table Claims

*2) **Customer Feedback** :* `feedback_id` (Primary Key, INTEGER): Unique identifier for customer feedback. Cannot be NULL.
`customer_id` (INTEGER): Represents the customer providing feedback. Can be NULL.
`rating` (INTEGER): The rating given by the customer (e.g., 1–5). Can be NULL.
`comments` (TEXT): Feedback or comments from the customer. Can be NULL.
`feedback_date` (DATE): The date when the feedback was provided. Can be NULL.
`shipment_id` (Foreign Key, INTEGER): References the `shipment_id` in the Shipments table to tie feedback to a

specific shipment. Cannot be NULL.
Primary Key Justification: The `feedback_id` uniquely identifies each feedback entry, ensuring no duplicates and allowing feedback to be tracked individually.
Foreign Key Action: On deletion of a referenced shipment, the associated customer feedback can be set to NULL to maintain feedback records without shipment information.

Query Query History

```
1 SELECT * FROM CustomerFeedback;
```

Data Output Messages Notifications

	feedback_id [PK] integer	shipment_id integer	customer_id integer	rating integer	comments text	feedback_date date
1	1	44	401	1	Quick delivery but t...	2021-10-11
2	2	573	303	2	The delivery person ...	2023-08-10
3	3	2080	321	1	Excellent service! W...	2023-12-20
4	4	1506	551	3	The packaging was ...	2022-05-05
5	5	606	750	4	The package arrive...	2024-06-25
6	6	2371	729	5	Delivery was delaye...	2024-02-09
7	7	1067	787	1	The package arrive...	2022-02-13
8	8	1820	291	2	Received the packa...	2023-06-12
9	9	1804	523	2	Had a minor issue ...	2023-02-21
10	10	1316	1178	1	The delivery person ...	2023-07-18

Fig. 2. Table Customer Feedback

*3) **Delivery Attempts** :* `attempt_id` (Primary Key, INTEGER): Unique identifier for each delivery attempt. Cannot be NULL.
`attempt_date` (DATE): The date of the delivery attempt. Can be NULL.
`attempt_status` (TEXT): The result or status of the delivery attempt (e.g., "Failed", "Successful"). Can be NULL.
`notes` (TEXT): Additional information about the attempt. Can be NULL.
`shipment_id` (Foreign Key, INTEGER): References `shipment_id` in the Shipments table. Cannot be NULL.
Primary Key Justification: The `attempt_id` is necessary to uniquely identify each attempt made to deliver a shipment, ensuring that all records are traceable.
Foreign Key Action: On deletion of a shipment, a cascade delete can be applied, removing all associated delivery attempts for that shipment.

Query Query History

```
1 SELECT * FROM DeliveryAttempts;
```

Data Output Messages Notifications

	attempt_id [PK] integer	shipment_id integer	attempt_date date	attempt_status text	notes text
1	1	1228	2022-07-14	Success	Receiver una...
2	2	1733	2022-03-01	Failed	Address not ...
3	3	498	2024-07-01	Failed	Unable to del...
4	4	2089	2023-05-06	Failed	Package han...
5	5	1179	2022-10-23	Success	Unable to del...
6	6	1777	2022-10-14	Success	Delivery succ...
7	7	887	2023-01-29	Failed	Address not ...
8	8	1813	2022-10-24	Success	Package han...
9	9	565	2023-01-27	Failed	Delivery succ...
10	10	592	2024-03-10	Success	Delivery succ...

Fig. 3. Table Delivery Attempts

*4) **Delivery Locations**:* `location_id` (Primary Key, INTEGER): Unique identifier for each delivery location. Cannot be NULL.
`longitude` (REAL): The longitude of the delivery location. Can be NULL.
`latitude` (REAL): The latitude of the delivery location. Can be NULL.
`delivery_date` (DATE): The date of delivery at this location. Can be NULL.
`shipment_id` (Foreign Key, INTEGER): References `shipment_id` in the Shipments table. Cannot be NULL.
Primary Key Justification: The `location_id` is used to ensure that every delivery location is unique, which is crucial for tracking where shipments were delivered.
Foreign Key Action: On deletion of a shipment, all associated delivery locations should also be deleted, enforcing a cascade delete policy.

Query Query History

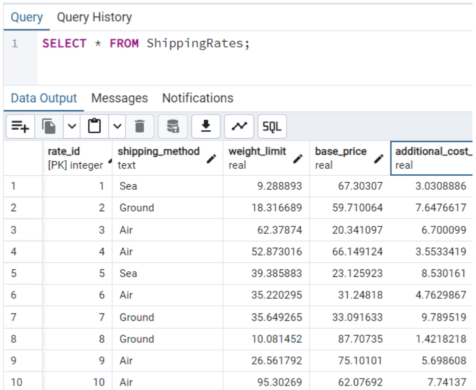
```
1 SELECT * FROM DeliveryLocations;
```

Data Output Messages Notifications

	location_id [PK] integer	shipment_id integer	longitude real	latitude real	delivery_date date
1	1	1373	-99.89181	34.38017	2023-08-15
2	2	1476	-41.30496	24.38021	2023-03-24
3	3	1178	82.0588	-3.6846325	2023-02-13
4	4	754	56.149853	43.25911	2022-12-05
5	5	1630	97.22757	56.849693	2022-06-01
6	6	1782	160.31514	-86.59653	2022-01-08
7	7	1210	111.70607	-66.451126	2022-01-13
8	8	941	-109.08024	4.1975765	2021-11-01
9	9	2023	116.70572	-59.936333	2023-04-08
10	10	1915	119.57497	82.997406	2023-06-27

Fig. 4. Table Delivery Locations

*5) **Shipping Rates** :* `rate_id` (Primary Key, INTEGER): Unique identifier for each shipping rate. Cannot be NULL.
`shipping_method` (TEXT): The shipping method used (e.g., "Air", "Ground"). Can be NULL.
`weight_limit` (REAL): The maximum weight allowed for this rate. Default value is 0.0.
`base_price` (REAL): The base price for this shipping rate. Default value is 0.0.
`additional_cost_per_kg` (REAL): Additional cost per kilogram over the weight limit. Default value is 0.0.
Primary Key Justification: The `rate_id` ensures each shipping rate is unique, as different rates may apply based on method and weight.
Foreign Key Action: No foreign keys are present, so no specific action is required for deletions.



Query Query History

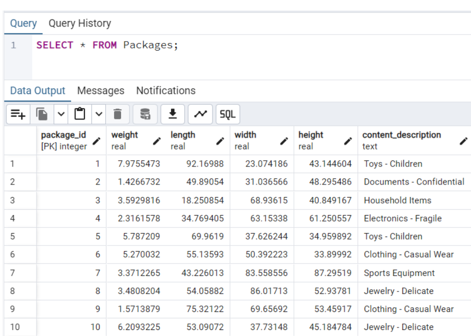
```
1 SELECT * FROM ShippingRates;
```

Data Output Messages Notifications

	rate_id [PK] integer	shipping_method text	weight_limit real	base_price real	additional_cost_ real
1	1	Sea	9.288893	67.30307	3.0308886
2	2	Ground	18.316689	59.710064	7.6476617
3	3	Air	62.37874	20.341097	6.700099
4	4	Air	52.873016	66.149124	3.5533419
5	5	Sea	39.385883	23.125923	8.530161
6	6	Air	35.220295	31.24818	4.7629867
7	7	Ground	35.649265	33.091633	9.789519
8	8	Ground	10.081452	87.70735	1.4218218
9	9	Air	26.561792	75.10101	5.698608
10	10	Air	95.30269	62.07692	7.74137

Fig. 5. Table Shipping Rates

*6) **Packages** :* `package_id` (Primary Key, INTEGER): Unique identifier for each package. Cannot be NULL.
`weight` (REAL): Weight of the package. Default value is 0.0.
`length` (REAL): Length of the package. Default value is 0.0.
`width` (REAL): Width of the package. Default value is 0.0.
`height` (REAL): Height of the package. Default value is 0.0.
`content_description` (TEXT): Description of the contents of the package. Can be NULL.
Primary Key Justification: The `package_id` uniquely identifies each physical package, allowing shipments to be tied to specific packages.
Foreign Key Action: No foreign keys are present, so no specific action is required for deletions.



Query Query History

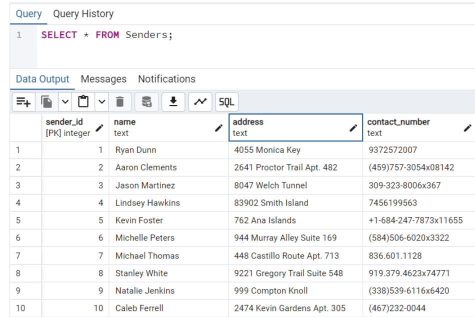
```
1 SELECT * FROM Packages;
```

Data Output Messages Notifications

	package_id [PK] integer	weight real	length real	width real	height real	content_description text
1	1	7.9755473	92.16988	23.074186	43.144604	Toys - Children
2	2	1.4266732	49.89054	31.036566	48.295486	Documents - Confidential
3	3	3.5929816	18.250854	68.93615	40.849167	Household Items
4	4	2.3161578	34.769405	63.15338	61.250557	Electronics - Fragile
5	5	5.787209	69.9619	37.626244	34.959892	Toys - Children
6	6	5.270032	55.13593	50.392223	33.89992	Clothing - Casual Wear
7	7	3.3712265	43.226013	83.558556	87.29519	Sports Equipment
8	8	3.4808204	54.05882	86.01713	52.93781	Jewelry - Delicate
9	9	1.5713879	75.32122	69.65692	53.45917	Clothing - Casual Wear
10	10	6.2093225	53.09072	37.73148	45.184784	Jewelry - Delicate

Fig. 6. Table Packages

*7) **Senders** :* `sender_id` (Primary Key, INTEGER): Unique identifier for each sender. Cannot be NULL.
`name` (TEXT): Name of the sender. Can be NULL.
`address` (TEXT): Address of the sender. Can be NULL.
`contact` (TEXT): Contact information for the sender. Can be NULL.
Primary Key Justification: The `sender_id` uniquely identifies each sender, allowing packages to be tracked by who sent them.
Foreign Key Action: No foreign keys are present, so no specific action is required for deletions.



Query Query History

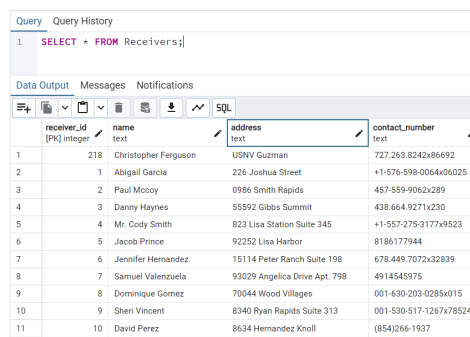
```
1 SELECT * FROM Senders;
```

Data Output Messages Notifications

	sender_id [PK] integer	name text	address text	contact_number text
1	1	Ryan Dunn	4055 Monica Key	9372572007
2	2	Aaron Clements	2641 Proctor Trail Apt. 482	(459)757-3054x08142
3	3	Jason Martinez	8047 Welch Tunnel	309-323-8006x367
4	4	Lindsey Hawkins	83902 Smith Island	7456199563
5	5	Kevin Foster	762 Ana Islands	+1-684-247-7873x11655
6	6	Michelle Peters	944 Murray Alley Suite 169	(584)506-6020x3322
7	7	Michael Thomas	448 Castillo Route Apt. 713	836.601.1128
8	8	Stanley White	9221 Gregory Trail Suite 548	919.379.4623x74771
9	9	Natalie Jenkins	999 Compton Knoll	(338)539-6116x6420
10	10	Caleb Ferrell	2474 Kevin Gardens Apt. 305	(467)232-0044

Fig. 7. Table Senders

*8) **Receivers** :* `receiver_id` (Primary Key, INTEGER): Unique identifier for each receiver. Cannot be NULL.
`name` (TEXT): Name of the receiver. Can be NULL.
`address` (TEXT): Address of the receiver. Can be NULL.
`contact` (TEXT): Contact information for the receiver. Can be NULL.
Primary Key Justification: The `receiver_id` ensures that each receiver is unique, allowing the system to track who receives which shipment.
Foreign Key Action: No foreign keys are present, so no specific action is required for deletions.



Query Query History

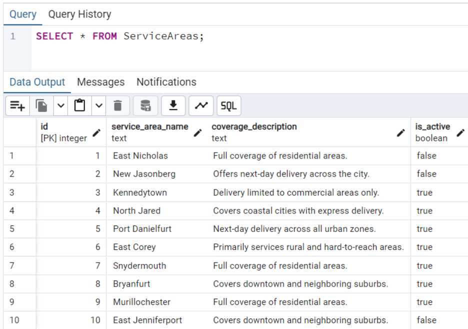
```
1 SELECT * FROM Receivers;
```

Data Output Messages Notifications

	receiver_id [PK] integer	name text	address text	contact_number text
1	218	Christopher Ferguson	USNV Guzman	727.263.8242x86692
2	1	Abigail Garcia	226 Joshua Street	+1-576-598-0064x06025
3	2	Paul Mccoy	0986 Smith Rapids	457-559-9062x289
4	3	Danny Haynes	55592 Gibbs Summit	438.664.9271x230
5	4	Mr. Cody Smith	823 Lisa Station Suite 345	+1-557-275-3177x9523
6	5	Jacob Prince	92252 Lisa Harbor	8186177944
7	6	Jennifer Hernandez	15114 Peter Ranch Suite 198	678.449.7072x32839
8	7	Samuel Valenzuela	93029 Angelica Drive Apt. 798	4914545975
9	8	Dominique Gomez	70044 Wood Villages	001-630-203-0285x015
10	9	Sheri Vincent	8340 Ryan Rapids Suite 313	001-530-517-1267x78524
11	10	David Perez	8634 Hernandez Knoll	(854)266-1937

Fig. 8. Table Receivers

*9) **Service Areas** :* `area_id` (Primary Key, INTEGER): Unique identifier for each service area. Cannot be NULL.
`service_area_name` (TEXT): Name of the service area. Can be NULL.
`coverage_description` (TEXT): Description of the area covered by the service. Can be NULL.
`is_active` (BOOLEAN): Indicates whether the service area is active. Default value is TRUE.
Primary Key Justification: The `area_id` uniquely identifies each service area, ensuring distinct coverage zones.
Foreign Key Action: No foreign keys are present, so no specific action is required for deletions.


Query Query History

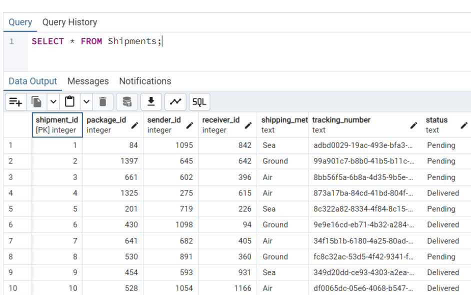
```
1 SELECT * FROM ServiceAreas;
```

Data Output Messages Notifications

	id [PK] integer	service_area_name text	coverage_description text	is_active boolean
1	1	East Nicholas	Full coverage of residential areas.	false
2	2	New Jasonberg	Offers next-day delivery across the city.	false
3	3	Kennedytown	Delivery limited to commercial areas only.	true
4	4	North Jared	Covers coastal cities with express delivery.	true
5	5	Port Danielfurt	Next-day delivery across all urban zones.	true
6	6	East Corey	Primarily services rural and hard-to-reach areas.	true
7	7	Snydermouth	Full coverage of residential areas.	true
8	8	Bryanfurt	Covers downtown and neighboring suburbs.	true
9	9	Murillochester	Full coverage of residential areas.	true
10	10	East Jenniferport	Covers downtown and neighboring suburbs.	false

Fig. 9. Table Service Areas

*10) **Shipments** :* `shipment_id` (Primary Key, INTEGER): Unique identifier for each shipment. Cannot be NULL.
`package_id` (Foreign Key, INTEGER): References `package_id` in the Packages table. Cannot be NULL.
`sender_id` (Foreign Key, INTEGER): References `sender_id` in the Senders table. Cannot be NULL.
`receiver_id` (Foreign Key, INTEGER): References `receiver_id` in the Receivers table. Cannot be NULL.
`shipment_method` (TEXT): The method used for shipment. Can be NULL.
`tracking_number` (TEXT): Tracking number for the shipment. Can be NULL.
`status` (TEXT): The status of the shipment (e.g., "In Transit", "Delivered"). Can be NULL.
Primary Key Justification: The `shipment_id` ensures that each shipment is uniquely identified, allowing detailed tracking of every shipment in the system.
Foreign Key Action: For `package_id`, `sender_id`, and `receiver_id`, when the primary key is deleted, all associated shipments should be deleted using cascade delete.


Query Query History

```
1 SELECT * FROM Shipments;
```

Data Output Messages Notifications

	shipment_id [PK] integer	package_id integer	sender_id integer	receiver_id integer	shipping_met text	tracking_number text	status text
1	1	84	1095	842	Sea	adbd0029-19ac-493e-bfa3-...	Pending
2	2	1397	645	642	Ground	99a901c7-b8b0-41b5-b11c-...	Pending
3	3	661	602	396	Air	8bb56f5a-6b8a-4d35-9b5e-...	Pending
4	4	1325	275	615	Air	873a17ba-84cd-41bd-804f-...	Delivered
5	5	201	719	226	Sea	8c322a82-8334-4f84-8c15-...	Pending
6	6	430	1098	94	Ground	9e9e16cd-eb71-4b32-a284-...	Delivered
7	7	641	682	405	Air	34f15b1b-6180-4a25-80ad-...	Delivered
8	8	530	891	360	Ground	fc8c32ac-53d5-4f42-9341-f...	Pending
9	9	454	593	931	Sea	349d20dd-ce93-4303-a2ea-...	Delivered
10	10	528	1054	1166	Air	df0065dc-05e6-4068-b547-...	Delivered

Fig. 10. Table Shipments

B. Relations and Attributes

Table I below gives an overview of some of the important entities that describe the relationships and attributes of the logistics enterprise, including claims, shipments, and customer feedback. It provides full elaboration, featuring specific details for each entity on its main attributes and how those entities relate to one another through foreign keys. The following table shows the structure of this system.

TABLE I
ENTITY RELATIONS AND ATTRIBUTES

Entity	Attributes
Claims	`claim_id` (primary key), `claim_status`, `claim_date`, `resolution_date`, `amount_claimed`, `shipment_id` (foreign key)
Customer Feedback	`feedback_id` (primary key), `customer_id`, `rating`, `comments`, `feedback_date`, `shipment_id` (foreign key)
Delivery Attempts	`attempt_id` (primary key), `attempt_date`, `attempt_status`, `notes`, `shipment_id` (foreign key)
Delivery Locations	`location_id` (primary key), `longitude`, `latitude`, `delivery_date`, `shipment_id` (foreign key)
Shipping Rates	`rate_id` (primary key), `shipping_method`, `weight_limit`, `base_price`, `additional_cost_per_kg`
Packages	`package_id` (primary key), `weight`, `length`, `width`, `height`, `content_description`
Senders	`sender_id` (primary key), `name`, `address`, `contact`
Receivers	`receiver_id` (primary key), `name`, `address`, `contact`
Service Areas	`area_id` (primary key), `service_area_name`, `coverage_description`, `is_active` (Boolean)
Shipments	`shipment_id` (primary key), `package_id` (foreign key), `sender_id` (foreign key), `receiver_id` (foreign key), `shipment_method`, `tracking_number`, `status`

C. Relationships Between Entities

Fig. 11 illustrates the relationships among the logistics system entities. Key relationships include:

- **Shipments** → **Packages**: A one-to-one relationship where each shipment corresponds to a single package.
- **Shipments** → **Senders / Receivers**: A many-to-one relationship; one sender or receiver can be linked to multiple shipments.
- **Shipments** → **Claims**: A one-to-one relationship; each shipment is associated with at most one claim.
- **Shipments** → **Customer Feedback**: A one-to-many relationship; a shipment can receive multiple feedback entries.
- **Shipments** → **Delivery Attempts**: A one-to-many relationship; multiple delivery attempts may be logged for a shipment.
- **Shipments** → **Delivery Locations**: A one-to-many relationship; several delivery locations may be recorded for a shipment.
- **Service Areas** → **Shipments**: Service Areas define zones for shipment deliveries, influencing shipping rates based on package weight and delivery method.

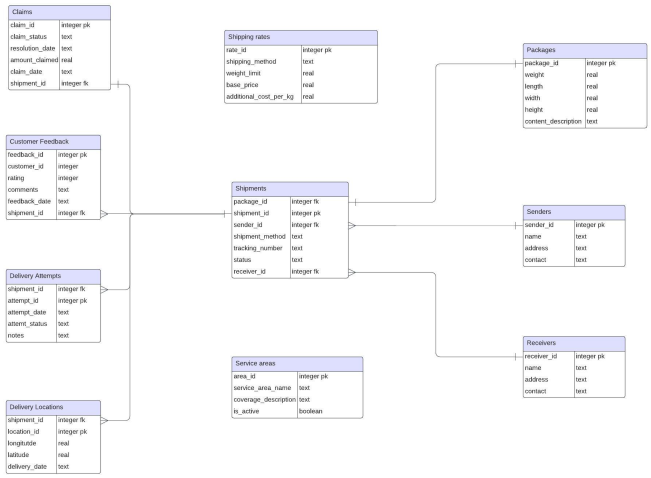


Fig. 11. Entity Relationship Diagram for Logistics Enterprise

IV. Database Generation

In this project, Python scripts generated a synthetic dataset tailored to an imaginary domain. This flexible dataset supports SQL-based applications, enabling queries, trend analysis, and updates to meet specific project needs effectively.

A. *Generating the table Packages*

```
import sqlite3
from faker import Faker
import random

# Initialize Faker
fake = Faker()

# Connect to SQLite database (or create it)
conn = sqlite3.connect('courier_services5.db')
cursor = conn.cursor()

# Create Tables
cursor.execute('''CREATE TABLE IF NOT
EXISTS Packages (
    package_id INTEGER PRIMARY KEY,
    weight REAL,
    length REAL,
    width REAL,
    height REAL,
    content_description TEXT
)''')

# Commit table creation
conn.commit()

# Helper functions to generate random data
def create_packages(n):
    for _ in range(n):
        cursor.execute('''INSERT INTO Packages
        (weight, length, width, height,
        content_description)
             VALUES (?, ?, ?, ?, ?)''',
            (random.uniform(1, 10),
            random.uniform(10, 100),
            random.uniform(10, 100),
            random.uniform(10, 100),
            fake.text(max_nb_chars=50)))
    conn.commit()

# Generate Data for a larger set
num_packages = 1500

create_packages(num_packages)

# Close the connection
conn.close()
```

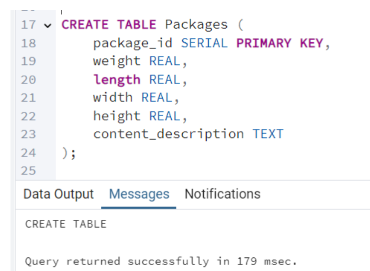


Fig. 12. Creating the table Packages

B. *Generating the table Shipments*

```
import sqlite3
from faker import Faker
import random

# Initialize Faker
fake = Faker()

# Connect to SQLite database
conn = sqlite3.connect('courier_services5.db')
cursor = conn.cursor()

# Create Tables
cursor.execute('''CREATE TABLE IF NOT
EXISTS Shipments (
    shipment_id INTEGER PRIMARY KEY,
    package_id INTEGER,
    sender_id INTEGER,
    receiver_id INTEGER,
    shipping_method TEXT,
    tracking_number TEXT,
    status TEXT,
    FOREIGN KEY (package_id) REFERENCES
    Packages(package_id),
    FOREIGN KEY (sender_id) REFERENCES
    Senders(sender_id),
```

```
    FOREIGN KEY (receiver_id) REFERENCES
    Receivers(receiver_id)
)''')

# Helper functions to generate random data
def create_shipments(n):
    for _ in range(n):
        cursor.execute('''INSERT INTO Shipments
        (package_id, sender_id, receiver_id,
        shipping_method, tracking_number, status)
            VALUES (?, ?, ?, ?, ?, ?)''',
            (random.randint(1, num_packages),
            random.randint(1, num_senders),
            random.randint(1, num_receivers),
            random.choice(['Air', 'Ground',
            'Sea'])
            ,fake.uuid4(),
            random.choice(['Pending',
            'Delivered'])))
    conn.commit()

# Generate Data for a larger set
num_shipments = 2500

create_shipments(num_shipments)

# Close the connection
conn.close()
```

```sql
CREATE TABLE Shipments (
    shipment_id SERIAL PRIMARY KEY,
    package_id INTEGER,
    sender_id INTEGER,
    receiver_id INTEGER,
    shipping_method TEXT,
    tracking_number TEXT,
    status TEXT,
    FOREIGN KEY (package_id) REFERENCES Packages(package_id) ON DELETE CASCADE,
    FOREIGN KEY (sender_id) REFERENCES Senders(sender_id) ON DELETE CASCADE,
    FOREIGN KEY (receiver_id) REFERENCES Receivers(receiver_id) ON DELETE CASCADE
);
```

Data Output Messages Notifications

```
CREATE TABLE

Query returned successfully in 179 msec.
```

Fig. 13. Creating the table Shipments

As generated above, we have created the remaining tables in the database.

V. Query Execution

SQL queries on the logistics database enable efficient analysis of shipments, claims, feedback, and delivery attempts using commands like GROUP BY, JOIN, sub-queries, and aggregate functions. These queries answer key questions, such as shipment counts by status or identifying claims. Below are examples:

A. Using GROUP BY to Get the Count of Shipments by Status

```sql
/*This query counts how many shipments are in each status
(e.g., "Pending", "Shipped", "Delivered").*/
SELECT status, COUNT(*) AS shipment_count
FROM Shipments
GROUP BY status;
```

Fig. 14. Using Group by function

Below is the output to the query in Fig. 14:

	status text	shipment_count bigint
1	Delivered	1212
2	Pending	1288

Fig. 15. Output of the Group by function

B. Using a Sub-query to Find Shipments with Claims

```sql
/*This query retrieves details of all shipments,
that have had claims filed against them using a sub-query to filter shipments.*/
SELECT shipment_id, package_id, sender_id, receiver_id, status
FROM Shipments
WHERE shipment_id IN (
    SELECT shipment_id FROM Claims
);
```

Fig. 16. Using Sub-query

Below is the output to the above query in Fig. 16:

	shipment_id [PK] integer	package_id integer	sender_id integer	receiver_id integer	status text
1	12	460	632	267	Pending
2	19	1476	157	734	Pending
3	21	654	932	1082	Pending
4	22	941	280	428	Delivered
5	33	413	660	763	Delivered
6	37	110	97	889	Delivered
7	38	1024	483	19	Delivered
8	42	1412	589	330	Pending
9	43	675	519	995	Pending
10	57	1471	7	763	Delivered

Total rows: 459 of 459 Query complete 00:00:00.057 Ln 9735, Col 3

Fig. 17. Output of the Sub-query

C. Using JOIN to Get Detailed Information About Shipments

```sql
/*This query uses an inner JOIN to get a detailed view of the shipments,
including the sender's name and receiver's name.*/
SELECT s.shipment_id, p.package_id, s.status, se.name AS sender_name, r.name AS receiver_name
FROM Shipments s
JOIN Packages p ON s.package_id = p.package_id
JOIN Senders se ON s.sender_id = se.sender_id
JOIN Receivers r ON s.receiver_id = r.receiver_id;
```

Fig. 18. Using Join function

Below is the output to the above query in Fig. 18:

	shipment_id integer	package_id integer	status text	sender_name text	receiver_name text
1	1	84	Pending	Joseph Pennington	Shane Williams
2	2	1397	Pending	Christopher Nash Jr.	Kimberly Reynolds
3	3	661	Pending	Brian Alvarez	Scott Booth
4	4	1325	Delivered	Michael Leon	Michael Smith
5	5	201	Pending	Brianna Cooper	Robert Soto
6	6	430	Delivered	Omar Donovan	Brandon Schwartz
7	7	641	Delivered	Ashlee Hamilton	Krista Jackson
8	8	530	Pending	Crystal Blake	Nicole Bailey
9	9	454	Delivered	Heather Mcgee	Vanessa Campbell
10	10	528	Delivered	Seth Rivera	Mr. Corey Smith

Total rows: 1000 of 2500 Query complete 00:00:00.047 Ln 9745, Col 51

Fig. 19. Output of the Join function

D. Using Aggregate Functions with a Sub-query to get Total Claims to specified Status

```sql
/*This query calculates the total value of all claims for shipments that have a specific status
(e.g., "Delivered") using an aggregate function and sub-query.*/
SELECT SUM(c.amount_claimed) AS total_claimed
FROM Claims c
WHERE c.shipment_id IN (
    SELECT shipment_id FROM Shipments WHERE status = 'Delivered'
);
```

Fig. 20. Using Aggregate function on Sub-query

Below is the output to the above query in Fig. 20:

	total_claimed real
1	124772.97

Fig. 21. Output of the Aggregate function on Sub-query

VI. Decompositions

Decomposition ensures compliance with Boyce-Codd Normal Form (BCNF). After evaluating functional dependencies and applying the Chase Test, the schema was confirmed to already satisfy BCNF, with every determinant being a candidate key. This compliance applies to all relations, including packages, senders, recipients, and delivery-related entities.

VII. Functional Dependencies

Each table was evaluated to ensure that all determinants are a candidate key, thus satisfying the BCNF criteria. The following is the list of Functional Dependencies (FDs) identified for all tables:

package_id → {weight, length, width, height, content_description}

receiver_id → {name, address, contact_number}

sender_id → {name, address, contact_number}

area_id → {service_area_name, coverage_description, is_active}

shipment_id → {package_id, sender_id, receiver_id, shipping_method, tracking_number, status}

tracking_number → {shipment_id, package_id, sender_id, receiver_id, shipping_method, status}

claim_id → {shipment_id, claim_status, claim_date, resolution_date, amount_claimed}

feedback_id → {shipment_id, customer_id, rating, comments, feedback_date}

attempt_id → {shipment_id, attempt_date, attempt_status, notes}

location_id → {shipment_id, longitude, latitude, delivery_date}

Each of these dependencies was analyzed for compliance with BCNF, ensuring that there are no partial or transitive dependencies. In every relation, the determinant is a superkey, making all tables BCNF-compliant. Below is the analysis of each table in terms of its superkeys:

A. Packages

The **Packages** table contains the attributes {package_id, weight, length, width, height, content_description}. The functional dependency package_id → {weight, length, width, height, content_description} shows that package_id is a superkey, as it uniquely identifies all attributes in the table. Thus, the table satisfies BCNF.

B. Receivers

The **Receivers** table contains the attributes {receiver_id, name, address, contact_number}. The functional dependency receiver_id → {name, address, contact_number} demonstrates that receiver_id is a superkey, as it uniquely identifies all attributes in the table. Therefore, this table is BCNF-compliant.

C. Senders

The **Senders** table contains the attributes {sender_id, name, address, contact_number}. The functional dependency sender_id → {name, address, contact_number} ensures that sender_id is a superkey. This guarantees that the table is in BCNF.

D. Service Areas

The **Service Areas** table contains the attributes {area_id, service_area_name, coverage_description, is_active}. The functional dependency area_id $\rightarrow$ {service_area_name, coverage_description, is_active} ensures that area_id is a superkey. As a result, the table satisfies BCNF.

E. Shipments

The **Shipments** table contains the attributes {`shipment_id, package_id, sender_id, receiver_id, shipping_method, tracking_number, status`}.
The functional dependency `shipment_id` $\rightarrow$ `all_fields` and `tracking_number` $\rightarrow$ `all_fields`, where `all_fields` represents all other attributes in the table, confirm that both `shipment_id` and `tracking_number` are superkeys.
Since all dependencies involve superkeys, the table satisfies BCNF.

F. Claims

The **Claims** table contains the attributes {`claim_id, shipment_id, claim_status, claim_date, resolution_date, amount_claimed`}.
The functional dependency `claim_id` $\rightarrow$ `all_fields`, where `all_fields` represents all other attributes in the table, confirms that `claim_id` is a superkey.
Thus, this table satisfies BCNF.

G. Customer Feedback

The **Customer Feedback** table contains the attributes {feedback_id, shipment_id, customer_id, rating, comments, feedback_date}.
The functional dependency feedback_id $\rightarrow$ {shipment_id, customer_id, rating, comments, feedback_date} confirms that feedback_id is a superkey.
This makes the table compliant with BCNF.

H. Delivery Attempts

The **Delivery Attempts** table contains the attributes {attempt_id, shipment_id, attempt_date, attempt_status, notes}. The functional dependency attempt_id $\rightarrow$ {shipment_id, attempt_date, attempt_status, notes} confirms that attempt_id is a superkey. Therefore, this table satisfies BCNF.

I. Delivery Locations

The **Delivery Locations** table contains the attributes {location_id, shipment_id, longitude, latitude, delivery_date}. The functional dependency location_id $\rightarrow$ {shipment_id, longitude, latitude, delivery_date} ensures that location_id is a superkey. As such, this table satisfies BCNF.

VIII. Chase Test

The Chase test was applied to verify whether the decomposition of each table ensures lossless joins and preserves functional dependencies. Below is the detailed analysis for all 10 tables.

A. Packages

The **Packages** table has the schema {package_id, weight, length, width, height,content_description} and the functional dependency

$$\text{package\_id} \rightarrow \begin{cases} \text{weight, length, width,} \\ \text{height, content\_description} \end{cases}$$

Starting with:

$$t_1[\text{package\_id}] = a,\ t_1[\text{weight}] = b,$$
$$t_1[\text{length}] = c,\ t_1[\text{width}] = d,$$
$$t_1[\text{height}] = e,\ t_1[\text{content\_description}] = f.$$

Applying the functional dependency unifies b, c, d, e, f with a, resulting in one row.
Lossless Join: Yes.
Dependency Preservation: Yes.

B. Receivers

The **Receivers** table has the schema {receiver_id, name, address, contact_number} and the functional dependency receiver_id $\rightarrow$ {name, address, contact_number}. Starting with

$$t_2[\text{receiver\_id}] = a,\ t_2[\text{name}] = b,\ t_2[\text{address}] = c,$$
$$t_2[\text{contact\_number}] = d.$$

Applying the functional dependency unifies b, c, d with a, resulting in one row.
Lossless Join: Yes. **Dependency Preservation**: Yes.

C. Senders

The **Senders** table has the schema {sender_id, name, address, contact_number} and the functional dependency sender_id $\rightarrow$ {name, address, contact_number}. Starting with

$$t_3[\text{sender\_id}] = a,\ t_3[\text{name}] = b,\ t_3[\text{address}] = c,$$
$$t_3[\text{contact\_number}] = d.$$

Applying the functional dependency unifies b, c, d with a, resulting in one row.
Lossless Join: Yes. **Dependency Preservation**: Yes.

D. Service Areas

The **Service Areas** table schema is {`area_id, service_area_name, coverage_description, is_active`}, with the functional dependency: `area_id` $\rightarrow$ {`other_fields`}, where `other_fields` includes `service_area_name`, `coverage_description`, and `is_active`.
Given: noitemsep

- t_4[area_id] $= a$
- Other fields unify with a: $b, c, d \rightarrow a$

This results in a single row for each unique area_id.
Lossless Join: Yes. **Dependency Preservation**: Yes.

E. Shipments

The **Shipments** table schema is {shipment_id, package_id, sender_id, receiver_id, shipping_method, tracking_number, status}, with simplified functional dependencies: noitemsep

- shipment_id $\rightarrow$ {tracking_number, other_fields}
- tracking_number $\rightarrow$ {shipment_id, other_fields}

Given: noitemsep

- t_5[shipment_id] $= a$, t_5[package_id] $= b$, t_5[sender_id] $= c$, t_5[receiver_id] $= d$, t_5[shipping_method] $= e$, t_5[tracking_number] $= f$, t_5[status] $= g$.

Applying FD1 unifies b, c, d, e, f, g with a, and FD2 unifies a, b, c, d, e, g with f.
Lossless Join: Yes. **Dependency Preservation**: Yes.

IX. Summary of 3NF and BCNF Evaluation

Third Normal Form (3NF) and Boyce-Codd Normal Form (BCNF) are designed to reduce redundancy and dependency anomalies, but BCNF imposes stricter rules by requiring all determinants to be superkeys. Each relation in the schema was evaluated and found to satisfy both BCNF and 3NF. Key examples include the **Packages**, **Receivers**, **Senders**, and **Service Areas** tables, where the functional dependencies have superkeys as determinants, ensuring compliance with BCNF. Similarly, the **Shipments** table, with candidate keys shipment_id and tracking_number, and the **Claims** table, with claim_id as a superkey, satisfy BCNF. The **Customer Feedback**, **Delivery Attempts**, and **Delivery Locations** tables also exhibit superkey-based dependencies. As all relations meet BCNF, the stricter form ensures no redundancy or dependency anomalies, making it unnecessary to relax the schema to 3NF.

X. Revised Entity - Relationship Diagram

A. Entities

The schema meets BCNF requirements, requiring no further decomposition. Key entities—Packages, Receivers, Senders, Service Areas, Shipments, Claims, Customer Feedback, Delivery Attempts, and Delivery Locations—are robust and efficient, free of partial or transitive dependencies.

B. Relations and Attributes

The relations and their attributes also remain consistent with the previous schema, as the design meets BCNF requirements. Each table is normalized with its respective primary keys and attributes. These relations are mentioned in Table I.

C. Relationship Between Entities

Relationships remain intact, with Shipments linking Packages, Senders, and Receivers. Claims, Feedback, Delivery Attempts, and Locations are tied to Shipments via foreign keys, ensuring consistency and referential integrity.

D. Constraints

1) Primary Keys: Primary key constraints are defined in the table(s) to ensure unique identification of each record.
2) Foreign Keys: Foreign key constraints are defined to enforce relationships between table(s), ensuring referential integrity.
3) Not Null Constraints: Not null constraints are applied to specific fields to ensure data completeness and maintain data integrity.

Fig. 22. Indexing

E. Redundancy Analysis

The BCNF-compliant schema minimizes redundancy, avoids data anomalies, and optimizes storage efficiency and consistency by ensuring functional dependencies depend only on superkeys.

XI. Challenges and Optimization Techniques for Managing Large Datasets

Handling larger datasets led to performance issues, particularly slower query execution times due to the table size and complex queries. Operations involving joins and filters on non-indexed attributes, like tracking$_{n}umber,$ status$, and$

To optimize performance, indexes were added on frequently queried fields, such as a unique index on tracking$_{n}umberandnon-clusteredindexeson$

Indexing reduced query execution time from seconds to milliseconds, minimized full table scans, and optimized resource usage, improving system responsiveness. Indexing increased storage requirements and slightly slowed write operations, but the benefits in read-heavy operations outweighed these trade-offs. This experience highlighted the importance of optimizing query patterns, selecting appropriate indexes, and periodic index maintenance.

XII. SQL Operations and Query Execution Results

A. Insertion Queries

For the Insert Query - I, we inserted a row in the Packages table as seen in Fig . 22.

```sql
INSERT INTO Packages (id, weight, length, width, height, content_description)
VALUES (1501, 5.0, 10.0, 8.0, 4.0, 'Books');
```

Data Output Messages Notifications

```
INSERT 0 1

Query returned successfully in 75 msec.
```

Fig. 23. Insert Query - I

For the Insert Query - II, we inserted a row in the Senders table as seen in Fig . 23.

```sql
INSERT INTO Senders (id, name, address, contact_number)
VALUES (1201, 'Alice Johnson', '123 Elm Street', '123-456-7890');
```

Data Output Messages Notifications

```
INSERT 0 1

Query returned successfully in 84 msec.
```

Fig. 24. Insert Query - II

B. Update Queries

For the first update query, we updated the content description of the package id '125' to 'Electronics' from 'Books - Hardcover'.

```sql
SELECT * FROM Packages WHERE id=125
```

Data Output Messages Notifications

	id [PK] integer	weight real	length real	width real	height real	content_description text
1	125	4.147967	83.21519	90.161194	85.46919	Books - Hardcover

Fig. 25. Update Query - I (Pre update)

```sql
UPDATE Packages
SET content_description = 'Electronics'
WHERE id = 125;

SELECT * FROM Packages WHERE id=125
```

Data Output Messages Notifications

	id [PK] integer	weight real	length real	width real	height real	content_description text
1	125	4.147967	83.21519	90.161194	85.46919	Electronics

Fig. 26. Update Query - I (Post update)

For the second update query, we increased the base price present in the table 'ShippingRates' by 10% for all the rows where the given weight limit was more than the average weight limit of all the shipping methods.

```sql
--Increase the base_price in the ShippingRates table by 10% for all rows
--where the weight_limit exceeds the average weight limit of all shipping
--methods.

UPDATE ShippingRates
SET base_price = base_price * 1.10
WHERE weight_limit > (
    SELECT AVG(weight_limit)
    FROM ShippingRates
);
```

Data Output Messages Notifications

```
UPDATE 5

Query returned successfully in 79 msec.
```

Fig. 27. Update Query - II

C. Select Queries

In query 1, we retrieve detailed information about shipments, including sender and receiver details, where the shipment status is not "Delivered."

Query Query History

```sql
SELECT
    Shipments.id AS ShipmentID,
    Packages.content_description AS PackageContent,
    Senders.name AS SenderName,
    Receivers.name AS ReceiverName,
    Shipments.shipping_method,
    Shipments.tracking_number,
    Shipments.status
FROM Shipments
JOIN Packages ON Shipments.package_id = Packages.id
JOIN Senders ON Shipments.sender_id = Senders.id
JOIN Receivers ON Shipments.receiver_id = Receivers.id
WHERE Shipments.status != 'Delivered';
```

Data Output Messages Notifications

	shipmentid integer	packagecontent text	sendername text	receivername text	shipping_method text	tracking_number text	status text
1	1	Electronics - Fragile	Timothy Ward	Ashley Davis	Sea	80409eb2-8d9d-4944-8805-6c30577d62...	Pending
2	2	Documents - Confidential	Anita Barnes	Rebecca Rose	Ground	c9fa464e-d9eb-4622-a461-e99280680bfe	Pending
3	4	Clothing - Casual Wear	Timothy Phillips	Katie Morgan	Ground	f1eaeacc-e996-4d1e-8caf-3cd881062200	Pending
4	5	Toys - Children	Jessica Rhodes	Brandon Huang	Sea	cecd0046-1793-4337-98fe-140ee9148c...	Pending
5	10	Documents - Confidential	Joe Sanford	Kimberly Miller	Ground	c80dde8d-0d60-4ab2-b469-613d29d0f2...	Pending
6	13	Toys - Children	Maureen Mendoza	Paul Montgomery	Ground	b304dcf1-42c9-4fb1-83d4-307eb15eb2a4	Pending
7	15	Documents - Confidential	Shannon Beasley	Joshua Elliott	Ground	b24590b2-593b-4884-b65e-015b81c88a...	Pending
8	16	Sports Equipment	Jaime Roberts	Patrick Solomon	Sea	e42dbbea-4434-45d5-9a3a-dc58afbf0794	Pending
9	17	Toys - Children	Sarah Craig	Tracy Wilson	Sea	a8c5bd16-0068-4335-82e6-b856d4347a...	Pending

Total rows: 1000 of 1271 Query complete 00:00:00.313 Ln 14, Col 1

Fig. 28. Query - I

In query 2, we get the total number of shipments delivered and pending, grouped by shipping method.

Query Query History

```sql
SELECT
    shipping_method,
    COUNT(CASE WHEN status = 'Delivered' THEN 1 ELSE NULL END) AS DeliveredCount,
    COUNT(CASE WHEN status = 'Pending' THEN 1 ELSE NULL END) AS PendingCount
FROM Shipments
GROUP BY shipping_method;
```

Data Output Messages Notifications

	shipping_method text	deliveredcount bigint	pendingcount bigint
1	Air	437	436
2	Ground	393	435
3	Sea	399	400

Fig. 29. Query - II

In query 3, we get the top 5 highest-rated feedback comments for shipments, including sender names and feedback details.

Query Query History

```sql
SELECT
    CustomerFeedback.id AS FeedbackID,
    Senders.name AS SenderName,
    CustomerFeedback.rating,
    CustomerFeedback.comments
FROM CustomerFeedback
JOIN Senders ON CustomerFeedback.customer_id = Senders.id
JOIN Shipments ON CustomerFeedback.shipment_id = Shipments.id
ORDER BY CustomerFeedback.rating DESC
LIMIT 5;
```

Data Output Messages Notifications

	feedbackid integer	sendername text	rating integer	comments text
1	8	Leslie Day	5	The package arrived on time and in great condition.
2	3	Carla Taylor MD	5	The delivery person was very polite and professional.
3	2	Daniel Curry	5	The package arrived on time and in great condition.
4	1	James Sullivan	5	The package arrived on time and in great condition.
5	19	John Berry	5	The delivery person was very polite and professional.

Fig. 30. Query - III

In query 4, we find the two most recent claims filed for each shipment and rank them by claim date.

```sql
WITH RankedClaims AS (
    SELECT
        c.shipment_id,
        c.id AS claim_id,
        c.claim_status,
        c.claim_date,
        c.amount_claimed,
        RANK() OVER (
            PARTITION BY c.shipment_id
            ORDER BY c.claim_date DESC
        ) AS rank_position
    FROM Claims c
)
SELECT
    shipment_id,
    claim_id,
    claim_status,
    claim_date,
    amount_claimed
FROM RankedClaims
WHERE rank_position <= 2
ORDER BY shipment_id, rank_position
LIMIT 20;
```

	shipment_id integer	claim_id integer	claim_status text	claim_date date	amount_claimed real
1	1	242	Open	2023-09-22	493.3209
2	6	27	Resolved	2024-05-11	707.30774
3	10	357	Resolved	2024-02-18	885.921
4	18	229	Open	2023-11-23	699.79095
5	29	177	Open	2024-09-17	990.67206
6	35	13	Open	2022-02-21	927.9941
7	42	180	Resolved	2024-08-17	668.5279
8	45	276	Resolved	2023-08-29	417.74557
9	64	157	Resolved	2024-06-06	784.66425
10	74	396	Resolved	2024-02-27	790.14307
11	79	190	Open	2022-05-22	483.8005

Total rows: 20 of 20 Query complete 00:00:00.236 Ln 24, Col 1

Fig. 31. Query - IV

D. Deletion Queries

In the first deletion query, we removed entries from the Claims table for claims that are older than one year and have been resolved.

```sql
DELETE FROM Claims
WHERE claim_status = 'Resolved'
  AND claim_date < CURRENT_DATE - INTERVAL '1 year';
```

```
DELETE 177

Query returned successfully in 130 msec.
```

Fig. 32. Deletion Query - I

In the second deletion query, we delete claims where the claimed amount exceeds the shipment's base price.

```sql
DELETE FROM Claims
WHERE shipment_id IN (
    SELECT Shipments.id
    FROM Shipments
    JOIN ShippingRates ON Shipments.shipping_method = ShippingRates.shipping_method
    WHERE Claims.amount_claimed > ShippingRates.base_price
);
```

```
DELETE 318

Query returned successfully in 615 msec.
```

Fig. 33. Deletion Query - II

XIII. Query Execution Analysis

Targeted Indexing: Indexes were added to key columns like sender_id, receiver_id, and shipment_id in the Shipments table, and claim_status and feedback_date in Claims and CustomerFeedback tables.

Faster Queries: Indexes reduced table scans, speeding up data retrieval and cutting execution time.

Smoother Joins: Indexes on foreign keys improved join efficiency between tables like Shipments, Claims, and CustomerFeedback.

Better Filtering and Aggregations: Indexes on claim_status and feedback_date sped up filtering and aggregation queries.

Less System Strain: Faster queries reduced system load, enabling better performance as data scales.

A. Query 1

```sql
SELECT
    s.tracking_number,
    COUNT(d.id) AS delivery_attempts,
    AVG(cf.rating) AS average_feedback_rating,
    r.name AS receiver_name
FROM Shipments s
JOIN DeliveryAttempts d ON s.id = d.shipment_id
JOIN CustomerFeedback cf ON s.id = cf.shipment_id
JOIN Receivers r ON s.receiver_id = r.id
WHERE s.status = 'Shipped'
  AND d.attempt_date > '2024-01-01'
  AND cf.feedback_date > '2024-01-01'
GROUP BY s.tracking_number, r.name
ORDER BY average_feedback_rating DESC;
```

Statistics per Node Type

Node type	Count
Aggregate	1
Hash	2
Hash Inner Join	2
Index Scan	1
Nested Loop Inner Join	1
Seq Scan	3
Sort	2

Statistics per Relation

Relation name	Scan count
Node type	Count
customerfeedback	1
Seq Scan	1
deliveryattempts	1
Seq Scan	1
receivers	1
Index Scan	1
shipments	1
Seq Scan	1

Fig. 34. Query - I (Pre Improvement)

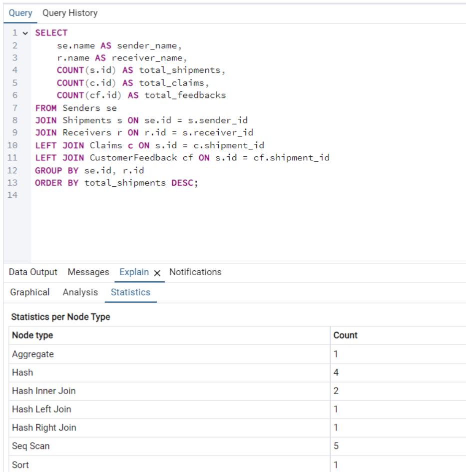
```sql
SELECT
    s.tracking_number,
    COUNT(d.id) AS delivery_attempts,
    AVG(cf.rating) AS average_feedback_rating,
    r.name AS receiver_name
FROM
    Shipments s
JOIN
    DeliveryAttempts d ON s.id = d.shipment_id
JOIN
    CustomerFeedback cf ON s.id = cf.shipment_id
JOIN
    Receivers r ON s.receiver_id = r.id
WHERE
    s.status = 'Shipped'
    AND d.attempt_date > '2024-01-01'
    AND cf.feedback_date > '2024-01-01'
GROUP BY
    s.tracking_number, r.name
ORDER BY
    average_feedback_rating DESC;
```

Statistics per Node Type

Node type	Count
Aggregate	1
Index Scan	4
Nested Loop Inner Join	3
Sort	2

Fig. 35. Query - I (Post Improvement)

B. Query 2



Query Query History

```sql
SELECT
    se.name AS sender_name,
    r.name AS receiver_name,
    COUNT(s.id) AS total_shipments,
    COUNT(c.id) AS total_claims,
    COUNT(cf.id) AS total_feedbacks
FROM Senders se
JOIN Shipments s ON se.id = s.sender_id
JOIN Receivers r ON r.id = s.receiver_id
LEFT JOIN Claims c ON s.id = c.shipment_id
LEFT JOIN CustomerFeedback cf ON s.id = cf.shipment_id
GROUP BY se.id, r.id
ORDER BY total_shipments DESC;
```

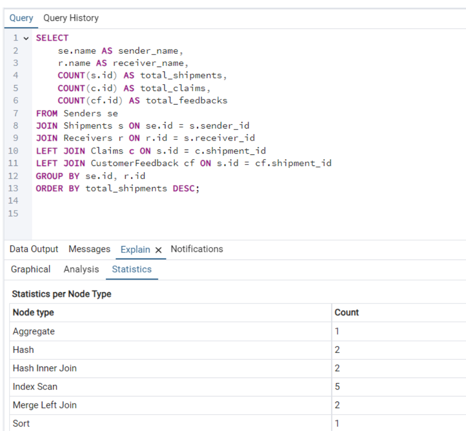
Data Output Messages Explain Notifications

Graphical Analysis Statistics

Statistics per Node Type

Node type	Count
Aggregate	1
Hash	4
Hash Inner Join	2
Hash Left Join	1
Hash Right Join	1
Seq Scan	5
Sort	1

Fig. 36. Query - II (Pre Improvement)



Query Query History

```sql
SELECT
    se.name AS sender_name,
    r.name AS receiver_name,
    COUNT(s.id) AS total_shipments,
    COUNT(c.id) AS total_claims,
    COUNT(cf.id) AS total_feedbacks
FROM Senders se
JOIN Shipments s ON se.id = s.sender_id
JOIN Receivers r ON r.id = s.receiver_id
LEFT JOIN Claims c ON s.id = c.shipment_id
LEFT JOIN CustomerFeedback cf ON s.id = cf.shipment_id
GROUP BY se.id, r.id
ORDER BY total_shipments DESC;
```

Data Output Messages Explain Notifications

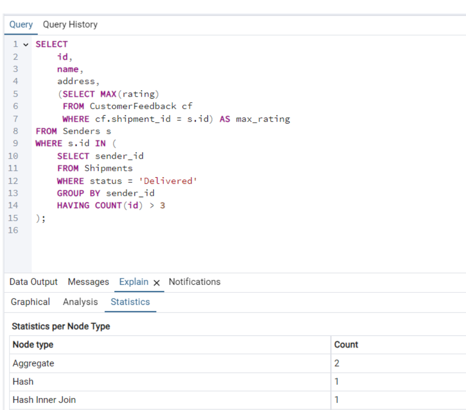
Graphical Analysis Statistics

Statistics per Node Type

Node type	Count
Aggregate	1
Hash	2
Hash Inner Join	2
Index Scan	5
Merge Left Join	2
Sort	1

Fig. 37. Query - II (Post Improvement)

C. Query 3



Query Query History

```sql
SELECT
    id,
    name,
    address,
    (SELECT MAX(rating)
     FROM CustomerFeedback cf
     WHERE cf.shipment_id = s.id) AS max_rating
FROM Senders s
WHERE s.id IN (
    SELECT sender_id
    FROM Shipments
    WHERE status = 'Delivered'
    GROUP BY sender_id
    HAVING COUNT(id) > 3
);
```

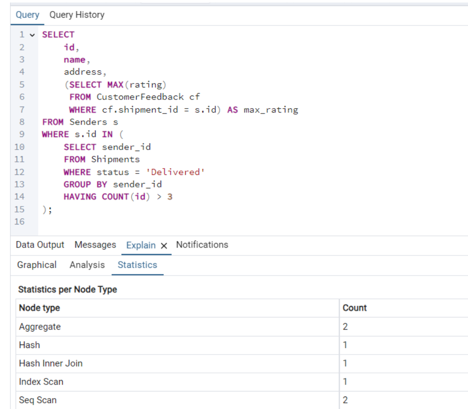
Data Output Messages Explain Notifications

Graphical Analysis Statistics

Statistics per Node Type

Node type	Count
Aggregate	2
Hash	1
Hash Inner Join	1
Seq Scan	3

Fig. 38. Deletion Query - III (Pre Improvement



Query Query History

```sql
SELECT
    id,
    name,
    address,
    (SELECT MAX(rating)
     FROM CustomerFeedback cf
     WHERE cf.shipment_id = s.id) AS max_rating
FROM Senders s
WHERE s.id IN (
    SELECT sender_id
    FROM Shipments
    WHERE status = 'Delivered'
    GROUP BY sender_id
    HAVING COUNT(id) > 3
);
```

Data Output Messages Explain Notifications

Graphical Analysis Statistics

Statistics per Node Type

Node type	Count
Aggregate	2
Hash	1
Hash Inner Join	1
Index Scan	1
Seq Scan	2

Fig. 39. Deletion Query - III (Post Improvement

XIV. Bonus Task: Web Application for Database Query Visualization

Below are a few screenshots of the running website required for the bonus task.

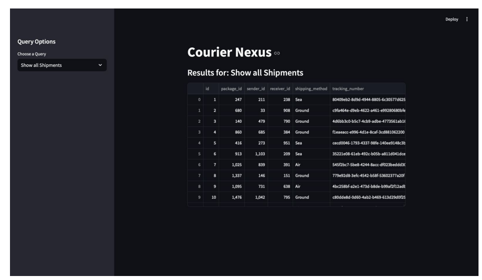


Fig. 40.

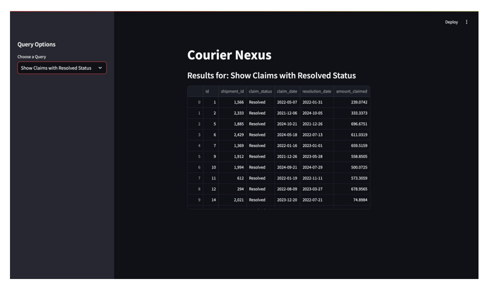


Fig. 41.

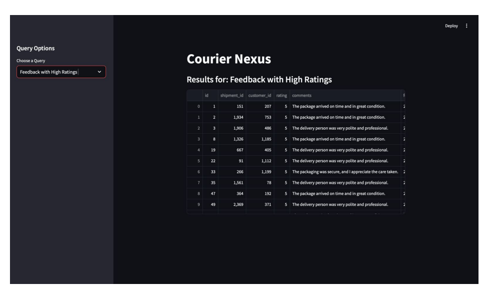


Fig. 42.

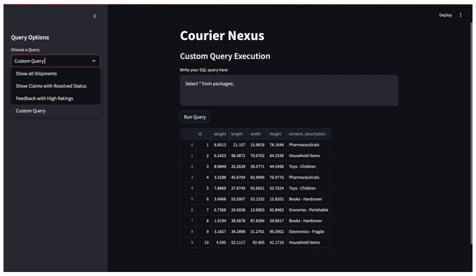


Fig. 43.

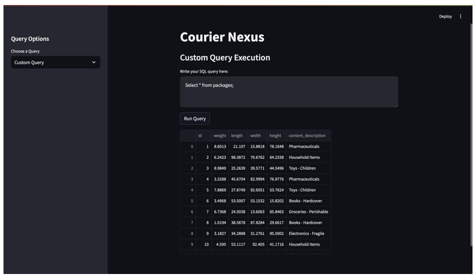


Fig. 44.