The Star Schema:

A Hands-On Approach to Modeling

1. Stage: Stock Market Company

1.1 Stock Market Company

We are on the data team for a fictional stock market trading firm that needs some insights into its orders data.

Users trade stocks: BUY / SELL

- **Buy Stocks**
    - Example-1: user Alex buys 1000 shares of ILMN
    - Example-2: user Jane buys 5000 shares of FB
- **Sell Stocks**
    - Example-1: user Terry sells 700 shares of APL
    - Example-2: user Betty sells 2000 shares of ILMN

1.2 Data Warehouding & Analysis

After analyzing our source data and business needs, the team has decided

that modeling the orders data as a
star schema would be the optimal choice.

1.3 Operational Database Tables

We receive data exports from our backend team. The means of this transfer isn't important as we will start our project at the point which it is loaded into our warehouse. The raw data will be normalized, comprised of three tables:

Table 1. Operational Tables

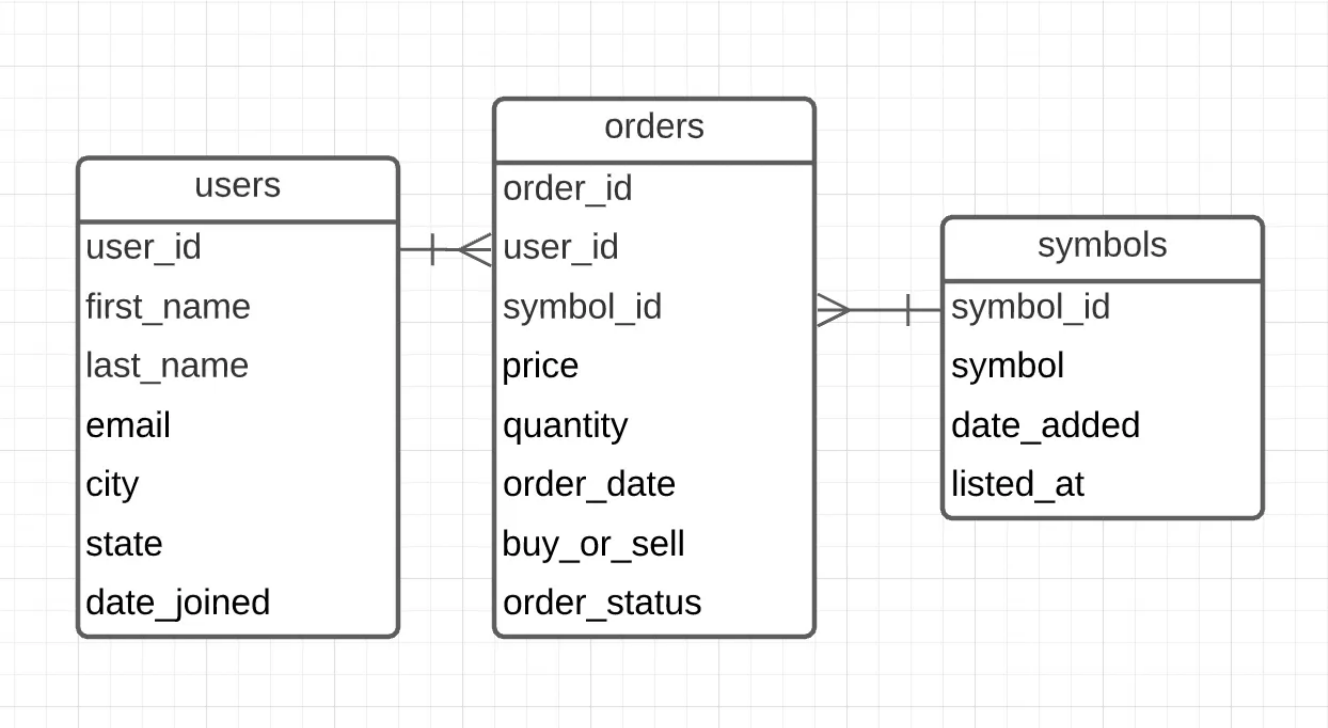
Operational Table Name	Table Description
Users	Users buying or selling stocks
Orders	Stock orders by users
Symbols	Stock symbols

2. Business Intelligence Questions:

2.1. On average, which cities are trading the highest-priced stocks

2.2. What is the daily proportion of orders that are executed (as opposed to canceled)?

3. Operational Database tables



Users table

```
CREATE TABLE users (
    user_id INTEGER,
    first_name VARCHAR(155),
    last_name VARCHAR(155),
    email VARCHAR(155),
    city VARCHAR(155),
    state VARCHAR(155),
    date_joined DATE
);
```

Users table sample records

```
+---------+-----------+----------+--------+------+-------+------------+
| user_id | first_name | last_name | email  | city |state | date_joined |
+---------+-----------+----------+--------+------+------+-------------+
| 1122001 | Alex       | Smith     |a@g.com | Ames | IA    | 2/23/2020   |
+---------+-----------+----------+--------+------+-------+------------+
| 1122002 | Bob        | Fox       |f@g.com | Tampa| FL    | 4/20/2021   |
+---------+-----------+----------+--------+------+------+-------------+
...
```

Orders table

```
CREATE TABLE orders (
```

```
    order_id INTEGER,
    user_id INTEGER,
    symbol_id INTEGER,
    price DOUBLE,
    quantity INTEGER,
    order_date DATE
    buy_or_sell VARCHAR(1),  -- { 'buy', 'sell' }
    order_status VARCHAR(1), -- { 'executed', 'cancelled' }
);
```

Orders table sample records

```
+----------+---------+---------+-------+---------+-----------+------------+
-------------+
| order_id | user_id |symbol_id| price | quantity| order_date| buy_or_sell |
order_status|
+----------+---------+---------+-------+---------+-----------+------------+
-------------+
| 999901   | 1122001 | 45      | 123.45| 12000   | 1/5/2022  | buy          | executed
|
+----------+---------+---------+-------+---------+-----------+------------+
-------------+
| 999902   | 1122001 | 46      |  65.00|  2000   | 1/6/2022  | sell         | executed
|
+----------+---------+---------+-------+---------+-----------+------------+
-------------+
| 999903   | 1122002 | 49      |   9:00|  8000   | 1/8/2022  | buy          | executed
|
+----------+---------+---------+-------+---------+-----------+------------+
-------------+
| 999904   | 1122002 | 40      |  35.00|  1000   | 1/10/2022 | sell         | executed
|
+----------+---------+---------+-------+---------+-----------+------------+
-------------+
| 999905   | 1122002 | 60      | 129:00|  5000   | 1/17/2022 | buy          | cancelled
|
+----------+---------+---------+-------+---------+-----------+------------+
-------------+
| 999906   | 1122002 | 60      | 128.00| 15000   | 1/17/2022 | sell         | cancelled
|
+----------+---------+---------+-------+---------+-----------+------------+
-------------+
...
```

Symbols table

```
CREATE TABLE symbols (
```

```
    symbol_id INTEGER,
    symbol VARCHAR(16),
    date_added DATE,
    listed_at VARCHAR(16)
)
```

Symbols table sample records:

```
+-----------+---------+-----------+-----------+
| symbol_id | symbol  | date_added| listed_at |
+-----------+---------+-----------+-----------+
| 40        | TEZ     | 1/1/2010  | Dow       |
+-----------+---------+-----------+-----------+
| 45        | MAK     | 1/1/2010  | Dow       |
+-----------+---------+-----------+-----------+
| 46        | IBT     | 1/1/2010  | Nasdaq    |
+-----------+---------+-----------+-----------+
| 49        | TEE     | 1/1/2009  | Nasdaq    |
+-----------+---------+-----------+-----------+
| 60        | AAA     | 1/1/2008  | Dow       |
+-----------+---------+-----------+-----------+
...
```

NOTE: 3 tables: operational database tables

Remember, this is not our analytical model. Data modeling optimized for operational use is very different from the one used for analytics. Transforming the former into the latter is one of the reasons why data and analytics engineers exist. ~

The Dimensional Design Process

There are 4 decisions we need to make at this stage.

1. Selecting the business process.
2. Declaring the grain.
3. Identifying the dimensions.
4. Identifying the facts.

Bsiness Process

The business process in our project is the orders placed by our users. Taking a quick look at the raw orders table, we see two numerical columns:

1. price

2. quantity

from which we can generate key metrics for the business. These will be the facts/measures in our final facts table.

Order as a FACT Table

Now that we have our business process clearly defined, we can tackle the grain. Kimball encourages targeting the atomic grain — 'the lowest level at which data is captured by a given business process' — which in our case would be defining our records at the order level.

This means we don't try to limit our business users by preemptively guessing their questions, instead, we give them the most amount of data and allow them to explore on their own.

Dimensional Tables

[6 dim modeling] | */Users/mparsian/max/github/data-warehousing/z/class_lectures/CLASS-WEEK-2-star_schema_hands_on/images/6_dim_modeling.png*

Next to grain, the most important contributor to BI users adopting our model is the dimension tables. Requests usually come in at least two parts:

- first is the measure (how much, how many, etc.),
- second is the filter/descriptor (who, what, when, etc.).

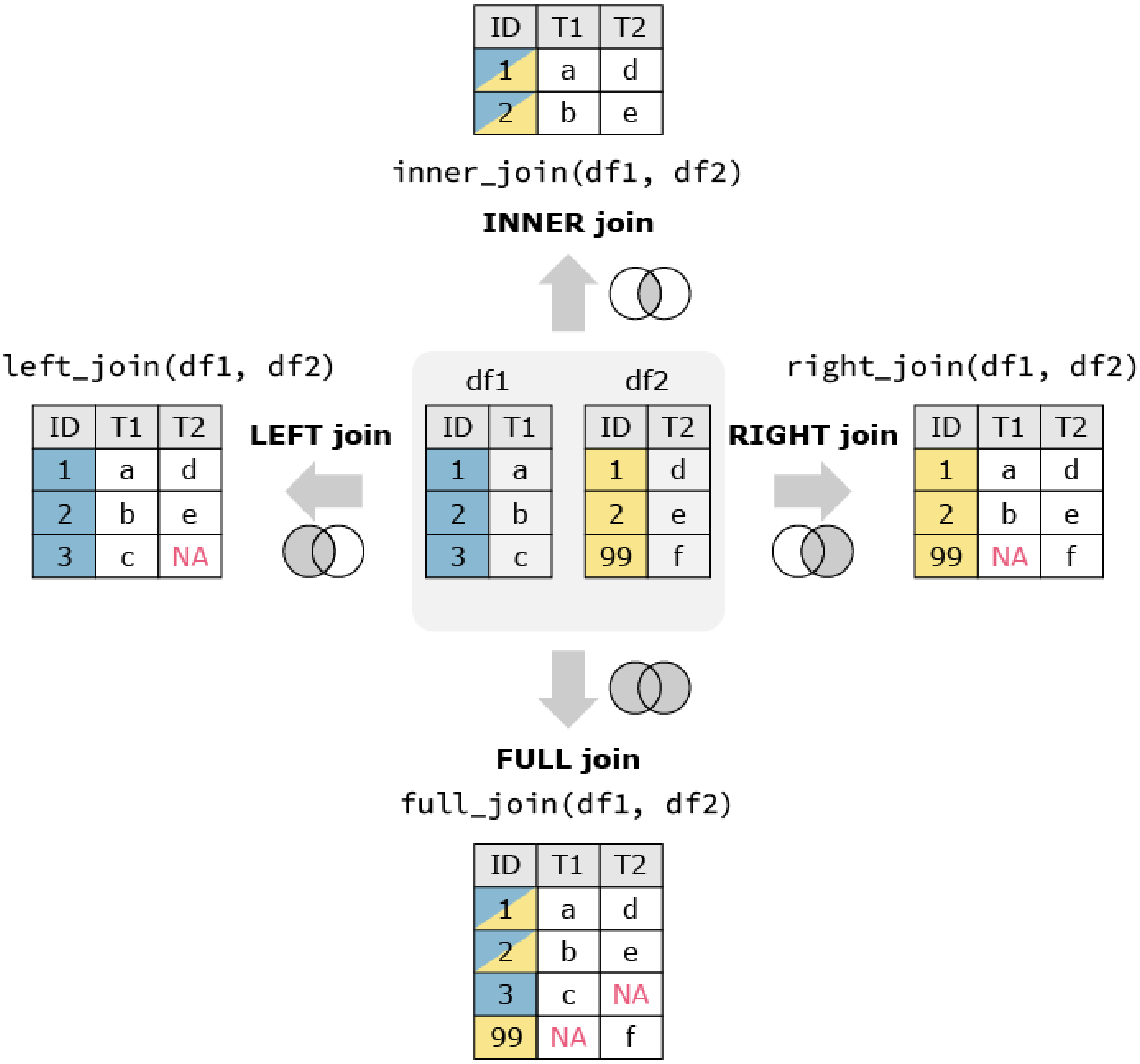
The more dimensions we make available, the more our users will be able to uncover by slicing up the data.

Finally, we move to our fact table. There are a few different types of fact tables, however, choosing one isn't really up to us. Taking a close look at our business process and its grain, and it is clear that our table is transactional. Each order is an event that only happens once at a specific point in time.

Other types of fact tables include Periodic Snapshot — each row summarizes a measurement over some period of time, Accumulating Periodic Snapshot — each row represents an instance of some business process (such as the lifecycle of an order, or claim), and Factless Tables — a table without measures.

Forming the Star Schema

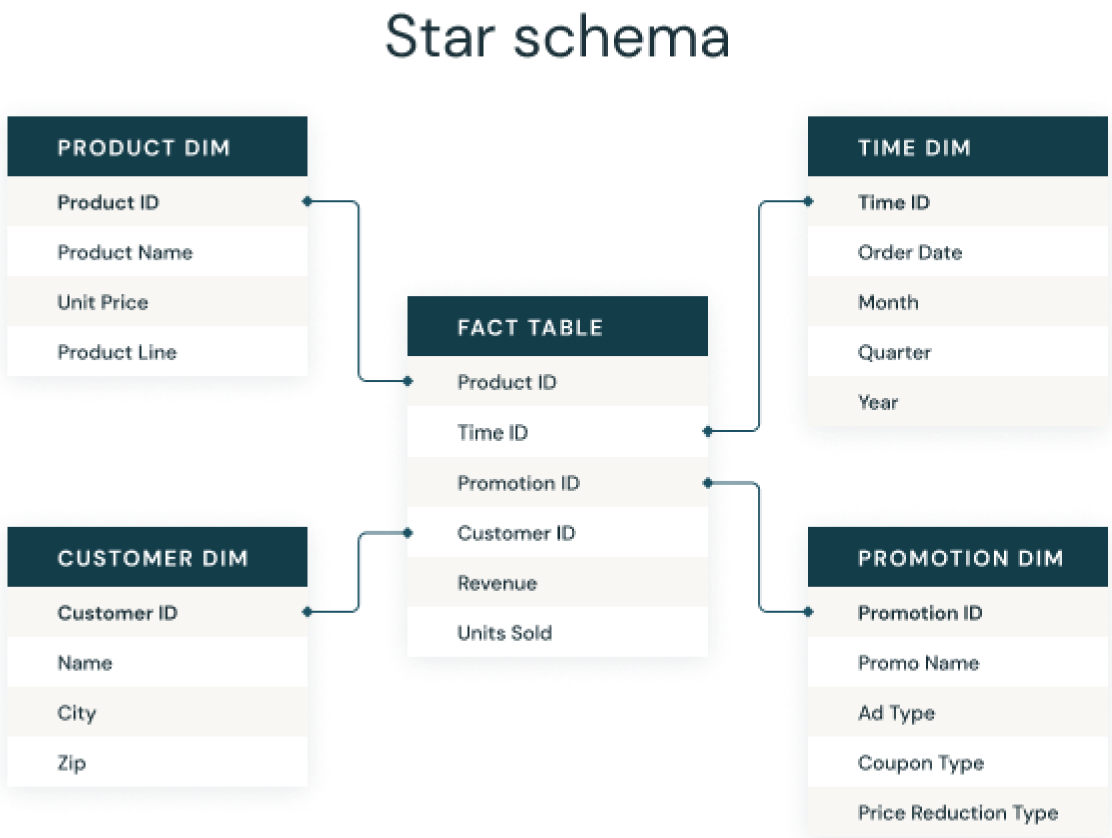
Understand Left Join



Understand Star Schema

What is a star schema?

1. A star schema is a multi-dimensional data model used to organize datain a database so that it is easy to understand and analyze.
2. Star schemas can be applied to data warehouses, databases, data marts, and other tools.
3. The star schema design is optimized for querying large data sets.
4. Introduced by Ralph Kimball in the 1990s, star schemas are efficient at storing data, maintaining history, and updating data by reducing the duplication of repetitive business definitions, making it fast to aggregate and filter data in the data warehouse.



Fact tables and Dimension tables

```
1. A star schema is used to denormalize
   business data into dimensions (like
   time and product)  and facts (like
   transactions in amounts and quantities).


2. A star schema has a single fact table
   in the center, containing business"facts"
   (like transaction amounts and quantities).

3. The fact table connects to multiple other
   dimension tables along "dimensions" like
   time, or product.

4. Star schemas enable users to slice and dice
   the data however they see fit, typically by
   joining two or more fact tables and dimension
   tables together.
```

Denormalized data

```
1. Star schemas denormalize the data, which means
```

```
   adding redundant columns to some dimension tables
   to make querying and working with the data faster
   and easier.

 2. The purpose is to trade some redundancy (duplication
    of data) in the data model for increased query speed,
    by avoiding computationally expensive join operations.
```

Designing the Star Schema

The easiest way to begin the design of the star schema is to denormalize the raw tables into one record. This will give us a wide view of our orders transaction and help us build out our dimensions.

The following query will do just that.

3 tables joined AS (denormalized table)

```sql
SELECT
  u.user_id,
  u.last_name,
  u.email,
  u.city,
  u.state,
  u.date_joined,
  o.order_id,
  o.price,
  o.quantity,
  o.order_date,
  o.buy_or_sell,
  o.order_status,
  s.symbol_id,
  s.symbol,
  s.date_added,
  s.listed_at
FROM orders AS o
LEFT JOIN symbols AS s
  ON o.symbol_id = s.symbol_id
LEFT JOIN users AS u
  ON o.user_id = u.user_id
```

Star Schema Tables

Looking a this join, we figure that Orders is the most important FACT table and the following are dimension (DIM) tables:

FACT: fct_orders

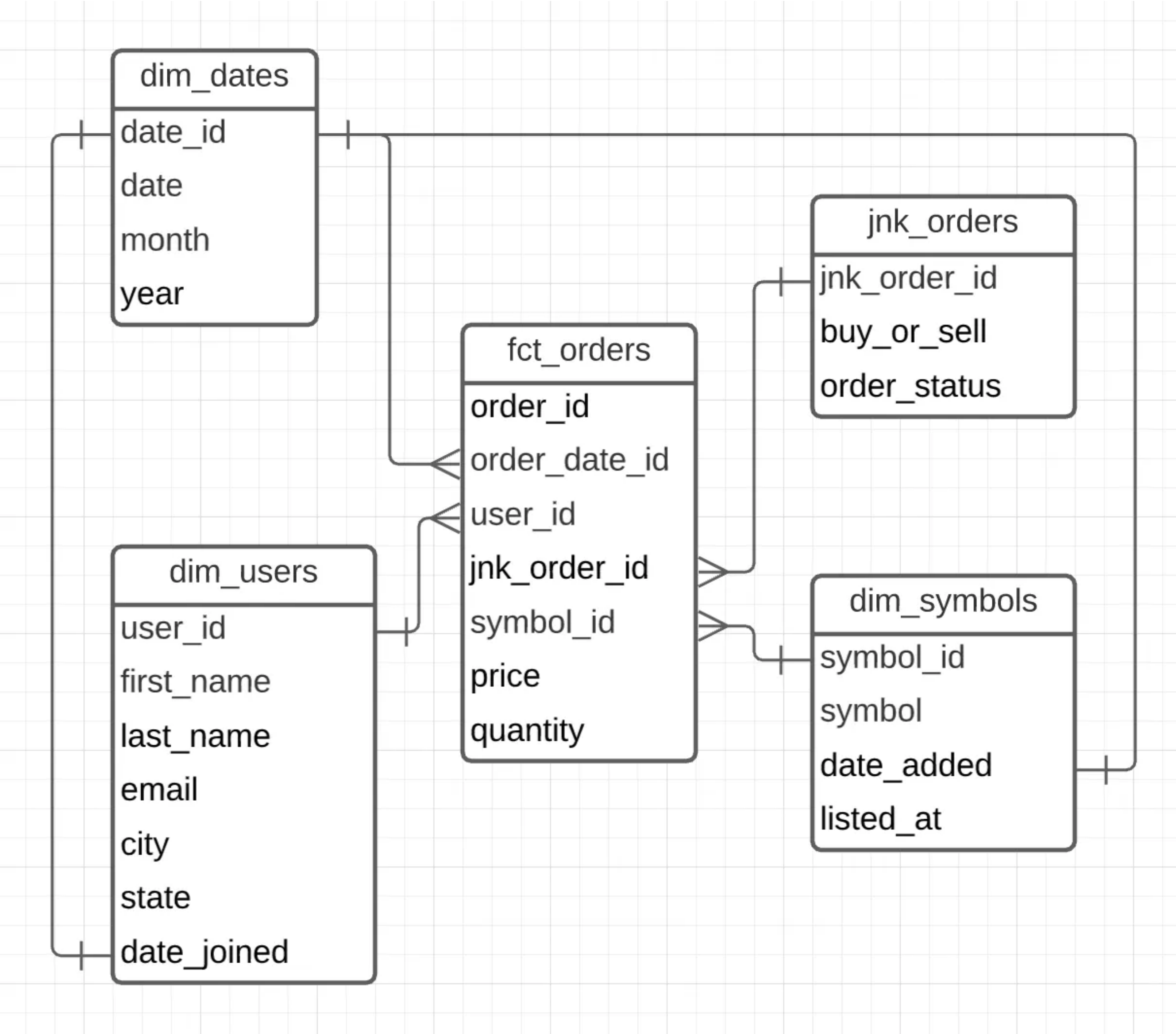
DIM tables:

dim_users

dim_symbols

dim_dates

jnk_orders



SHA-256 hash algorithm

```
SHA-256 hash algorithm is used to convert
      user passwords into a hash value before
```

```
        storing them in a database.
```

Fact Table: `fct_orders`

We build a fact table from the raw orders table

```
CREATE TABLE `fct_orders` AS (
SELECT
  order_id,
  order_date as order_date_id,
  user_id,
  SHA256(CONCAT(buy_or_sell, order_status)) as jnk_order_id,
  symbol_id,
  price,
  quantity
FROM `orders`
)
```

DIM Table: `dim_date`

For the dates dimension table, there are plenty of ways to go about generating a series of past and future dates. This really depends on the dialect your database is using

```
CREATE TABLE `dim_dates` AS (
  SELECT
    date AS date_id,
    date,
    EXTRACT(MONTH FROM date) AS month,
    EXTRACT(YEAR FROM date) AS year
  FROM UNNEST(
    GENERATE_DATE_ARRAY('2014-01-01', CURRENT_DATE('America/New_York'), INTERVAL 1
DAY)
  ) AS date
```

The query above generates a table of distinct dates, one day apart, starting from the arbitrary date ‘2014–01–01’ to the current date. Since dates are distinct, I’ve chosen to also use them for the date_id field.

DIM Table: `jnk_orders`

The "buy_or_sell" and "order_status" columns from Orders table, can be used to create what is called a junk dimension table, where the rows are simply all possible combinations of the attributes of the columns. A hash of the different combinations will also be computed and used as a surrogate key.

```
CREATE TABLE `jnk_orders` AS (
WITH values AS (
  SELECT DISTINCT buy_or_sell, order_status
  FROM `orders`
),
apply_surrogate_key AS (
  SELECT
    SHA256(CONCAT(buy_or_sell, order_status)) AS jnk_orders_id,
    buy_or_sell,
    order_status
  FROM values
)
SELECT *
FROM apply_surrogate_key
)
```

jnk_orders table

```
select * from `jnk_orders`
+--------------+------------+--------------+
| jnk_orders_id |buy_or_sell | order_status |
+--------------+------------+--------------+
| aaa45t89rdtf  | buy        | executed     |
+--------------+------------+--------------+
| bbb657rftyyg  | buy        | cancelled    |
+--------------+------------+--------------+
| xxx45t89rdtf  | sell       | executed     |
+--------------+------------+--------------+
| yyy657rftyyg  | sell       | cancelled    |
+--------------+------------+--------------+
```

Alternate solution for jnk_orders table

```
CREATE TABLE jnk_orders (
   jnk_orders_id INT PRIMARY KEY,
   buy_or_sell TEXT,
   order_status TEXT
);

INSERT INTO  jnk_orders (
   jnk_orders_id,
   buy_or_sell,
   order_status
```

```
)
VALUES
(1, 'buy', 'executed'),
(2, 'buy', 'cancelled'),
(3, 'sell', 'executed'),
(4, 'sell', 'cancelled');
```

```
select * from `jnk_orders`
+--------------+-----------+-------------+
| jnk_orders_id |buy_or_sell | order_status |
+--------------+-----------+-------------+
| 1            | buy       | executed    |
+--------------+-----------+-------------+
| 2            | buy       | cancelled   |
+--------------+-----------+-------------+
| 3            | sell      | executed    |
+--------------+-----------+-------------+
| 4            | sell      | cancelled   |
+--------------+-----------+-------------+
```

Revising the Fact Table with new `jnk_order_id`

```
CREATE TABLE `fct_orders` AS (
SELECT
  order_id,
  order_date as order_date_id,
  user_id,
  CASE
    WHEN buy_or_sell = 'buy' and order_status = 'executed'   THEN 1
    WHEN buy_or_sell = 'buy' and order_status = 'cancelled'  THEN 2
    WHEN buy_or_sell = 'sell' and order_status = 'executed'  THEN 3
    WHEN buy_or_sell = 'sell' and order_status = 'cancelled' THEN 4
    ELSE 0
  END AS jnk_orders_id,
  symbol_id,
  price,
  quantity
FROM `orders`
)
```

Business Intelligence Analysis

We now have a star schema model that can be fed into most BI tools and made available to end-users.

Let’s use our model to answer a few hypothetical questions.

1. On average, which cities are trading the highest-priced stocks?

```
SELECT
  city,
  ROUND(AVG(price),2) AS avg_price

   FROM `fct_orders` AS f
   LEFT JOIN `dim_users` as u
     ON f.user_id = u.user_id
   GROUP BY city
   ORDER BY avg_price DESC
   LIMIT 5
```

```
SELECT
  u.city,
  ROUND(AVG(f.price),2) AS avg_price

   FROM `fct_orders` AS f
   LEFT JOIN `dim_users` as u
     ON f.user_id = u.user_id
   GROUP BY u.city
   ORDER BY avg_price DESC
   LIMIT 5
```

Row	city	avg_price
1	Port Christopherside	136.3
2	South Jasmine	128.91
3	New Marvinside	126.73
4	Hawkinsport	124.47
5	Cruzfurt	120.28

2. What is the daily proportion of orders that are executed (as opposed to canceled)?

```
SELECT
  date,
  SUM(CASE WHEN order_status = 'executed' THEN 1 ELSE 0 END) /
    COUNT(*) AS proportion_executed

  FROM `fct_orders` as f
  LEFT JOIN `dim_dates` as d   ON f.order_date_id = d.date_id
  LEFT JOIN `jnk_orders` as o  ON f.jnk_order_id = o.jnk_order_id
GROUP BY date
ORDER BY date DESC
```

Row	date	proportion_executed
1	2021-01-31	1.0
2	2021-01-29	1.0
3	2021-01-28	0.0
4	2021-01-27	0.5
5	2021-01-26	0.0
6	2021-01-25	1.0
7	2021-01-23	0.0
8	2021-01-20	1.0

Source

The Star Schema: A Hands-On Approach to Modeling by Jonathan Duran