Designing a Data Warehouse on the Microsoft SQL Server Platform

UNDERSTANDING THE FUNDAMENTAL CONCEPTS OF A DATA WAREHOUSE

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Overview

Goals and purpose of a data warehouse

Introducing dimensional modeling

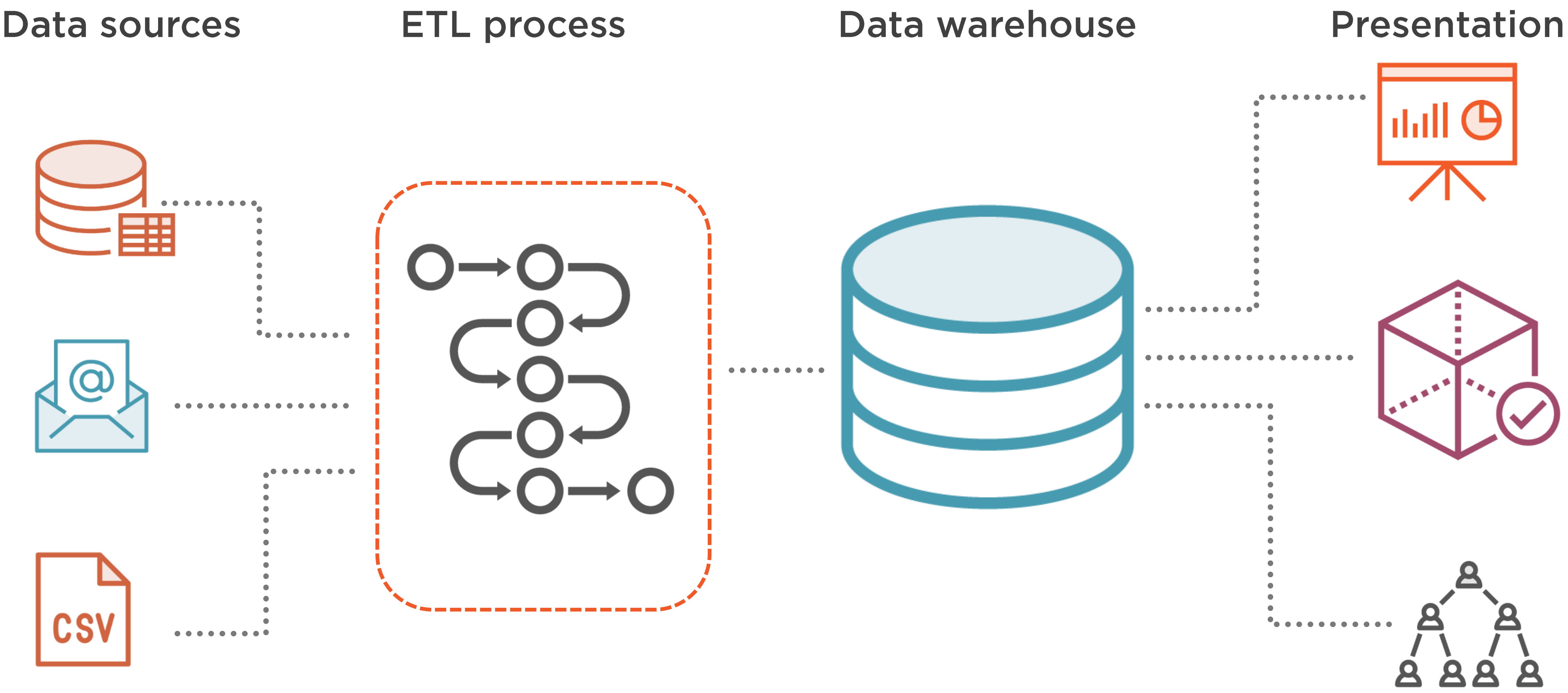
- What are facts and fact tables?
- What are dimensions and dimension tables?
- Star schemas

Putting it all together

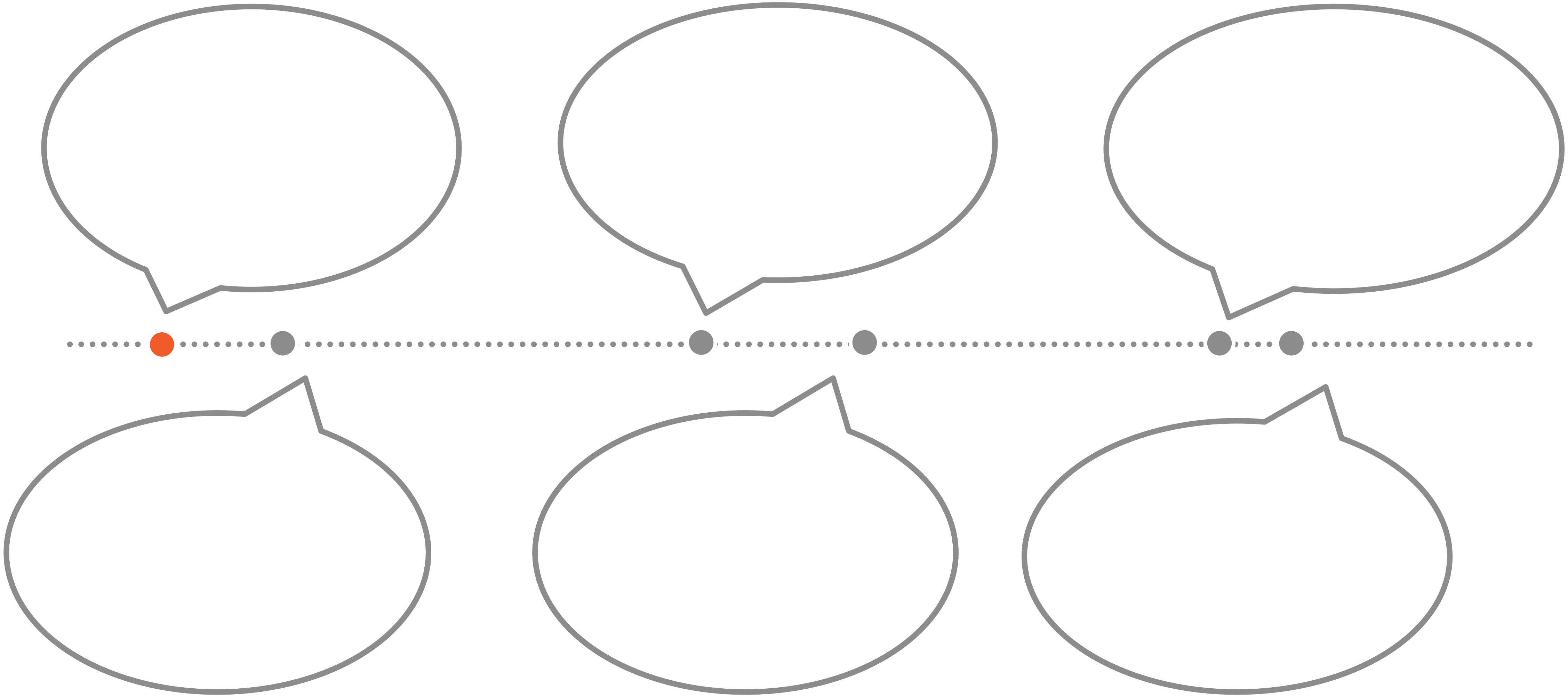
- The 4-step dimensional design process

Goals of a Data Warehouse Solution

What Is a Data Warehouse?



Problems a Data Warehouse Can Solve



Requirements of a Data Warehouse Solution

Easily accessible	Fast	Consistent
Flexible	Secure	Foundation for decision-making

Responsibilities of a Data Warehouse Designer

Understand the business users

Deliver high-quality, relevant, and accessible information

Sustain the DW environment

Introduction to Dimensional Modeling

Dimensional Modeling

Database design method optimized for data warehouse solutions

Popular technique because it addresses two important requirements:

- Deliver data in an understandable format
- Deliver fast query performance

Key word is “simplicity”

Elements of a Dimensional Model

Facts (the measurements/metrics or facts from your business process)

Dimensions (for providing the context of a business process event)

Attributes (the various characteristics of a dimension)

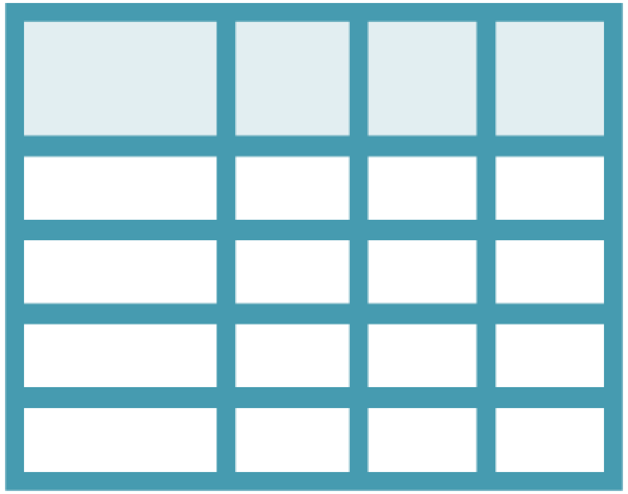
Star schema (and/or OLAP cubes)

"We sell ice-cream and other products in various locations and measure our achievements over time."

Jane Poppins

Happy Scoopers CEO

Fact Tables and Facts



Fact table = table that stores the performance measurements resulting from an organization's business process events

Fact = a business measure

- Sales
- Profit
- Volume
- Number of transactions

Fact Tables and Facts

Facts answer questions like:

- "What are we doing?" (sell, buy, count)
- "What do we want to achieve?" (more sales, bigger profit)

1 row in the fact table is 1 measurement in real life

Fact columns in a fact table should be additive

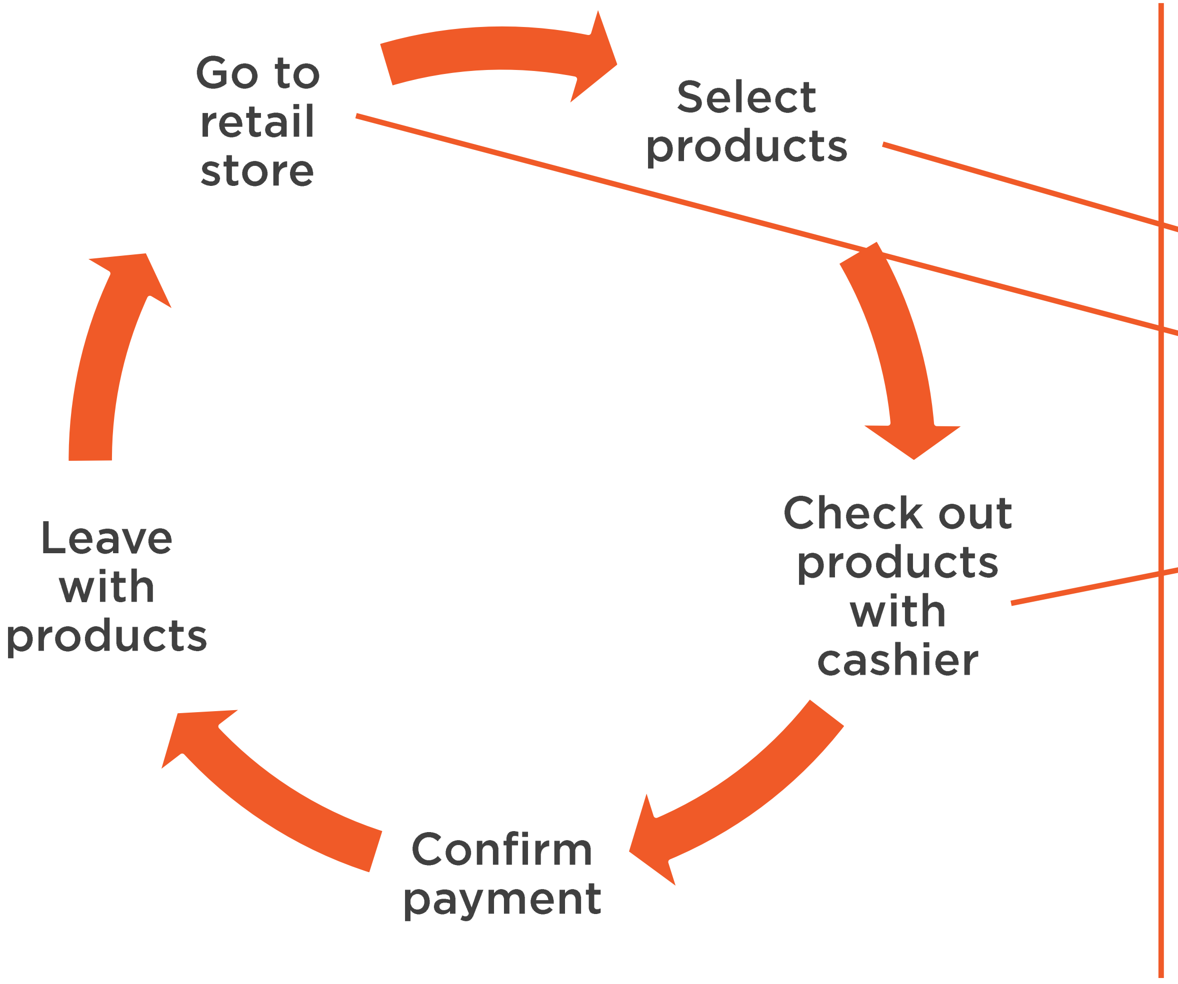
Facts make sense in combination with dimensions

- Linked with foreign keys
- Date/Time dimension is present in most data warehouses

Example of a Fact Table

Sales fact
Date key
Product key
Store key
Employee key
Transaction #
Unit price
Quantity

Example of a Fact Table



Sales fact
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Example of a Fact Table

Sales Fact
Date key
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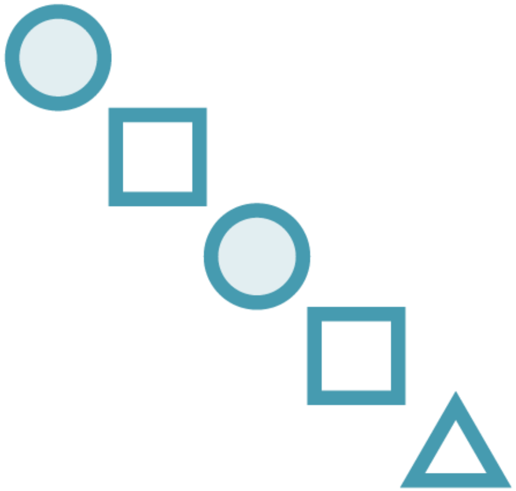
COMPOSITE KEY

Characteristics of Fact Tables

1:1 relationship between fact table row and real-world event

Most facts should be additive

Foreign keys to dimension tables



Composite key as PK for fact table

What Are Dimensions?

Companions to a fact table

Textual context associated with a business process measurement event

Questions Answered by Dimension Tables

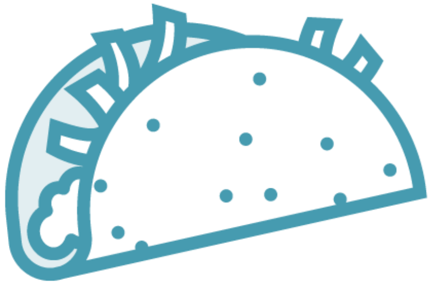
Who

What

Where

When

How

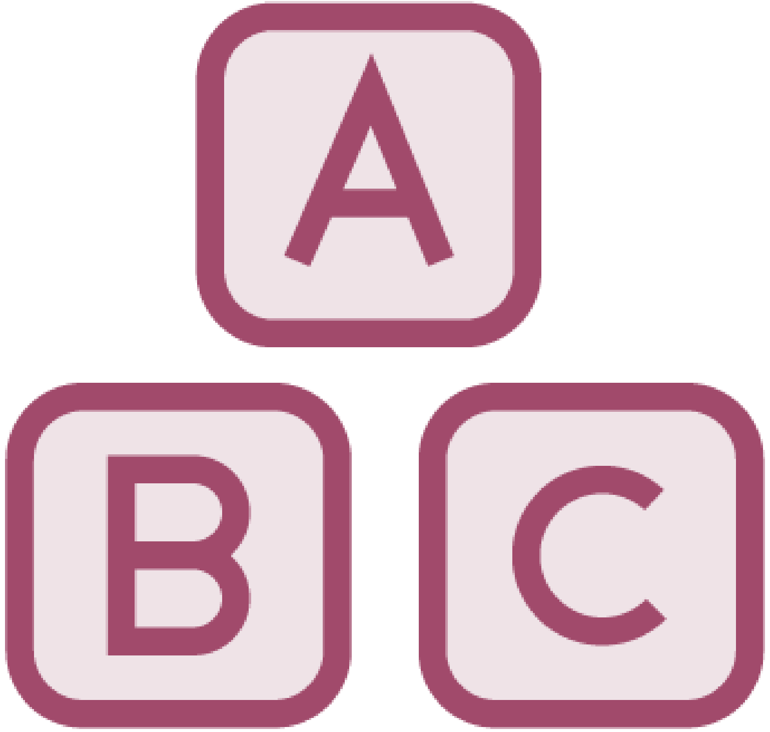


Why

Example of a Dimension Table

Product Dimension
Product key
Product name
Brand name
Category name
Subcategory name
Package type
Package size
Weight
Weight unit of measure

Characteristics of Dimension Tables



No limit for the number of attributes in a dimension table

- Common to have tables with 50 to 100 attributes
- Some dimension tables have only a handful of attributes

Have fewer rows than fact tables

- But can be much wider

Defined by a single primary key

- Basis for the referential integrity with the fact table

Denormalized

- Flattened many-to-one relationships within a single dimension table

The primary source of

- Query constraints
- Groupings
- Report labels

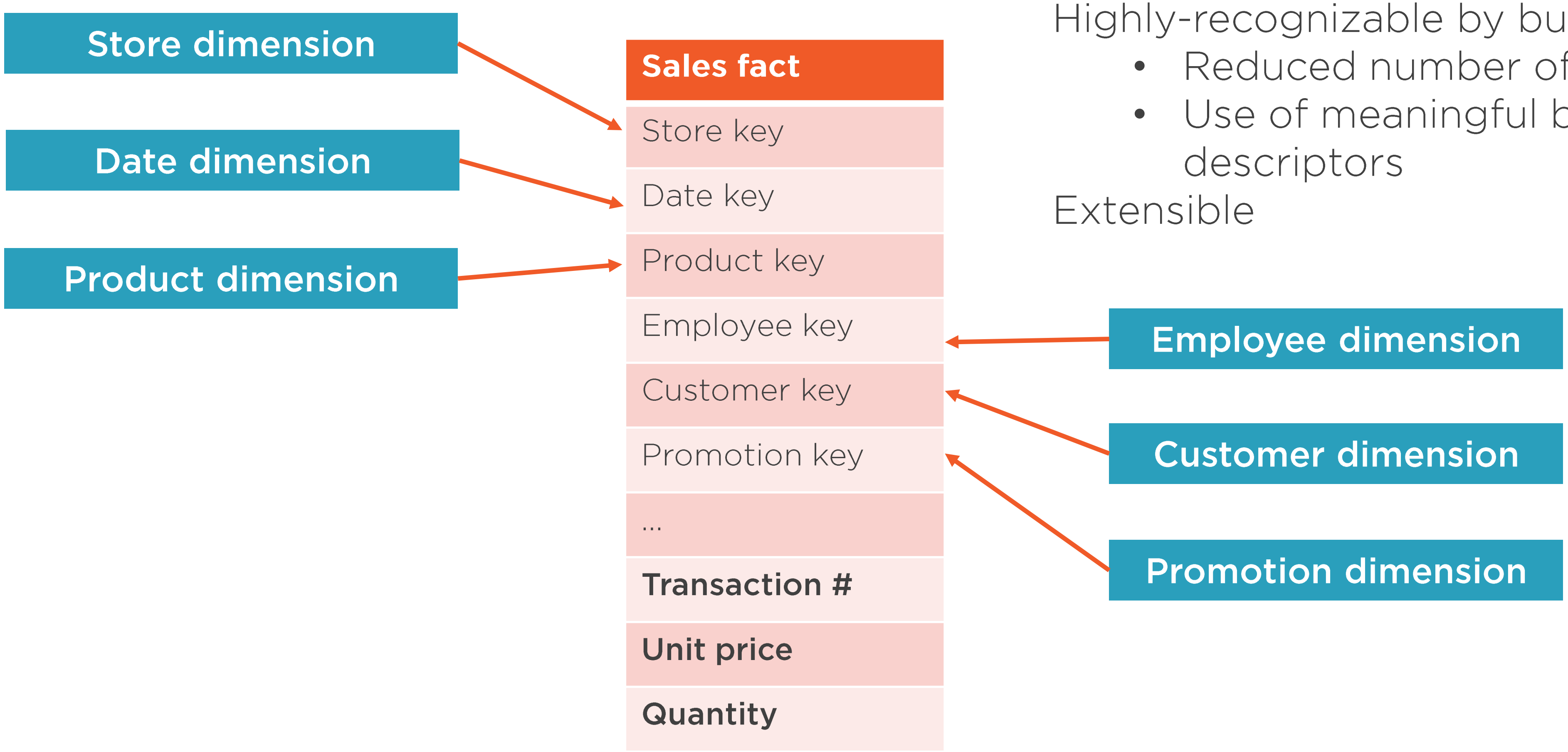
Quality of attributes ∝ quality of the system

- Use real words vs. cryptic abbreviations
- Minimize codes in the dimension tables

Dimension Attributes

Product Key	Name	Category name	Subcategory name
1	Beery cotton candy	Candy	French candy
2	Cotton candy	Candy	French candy
3	Peppermint candy (seasonal)	Candy	Fudge
4	Green tea ice cream	Ice-cream	Reduced fat
5	Chocolate chip cookie dough ice cream	Ice-cream	Fat-free frozen dairy
6	Neapolitan ice cream	Ice-cream	Lactose-free
7	Cantuccini	Cookie	Biscotti
8	Chocolate mint cookie	Cookie	Retro snacks
9	Lemon cookie	Cookie	Fruity cookies

Dimensional Model



Characteristics:

Simple

Symmetric

Highly-recognizable by business users

- Reduced number of tables
- Use of meaningful business descriptors

Extensible

Dimensional Model

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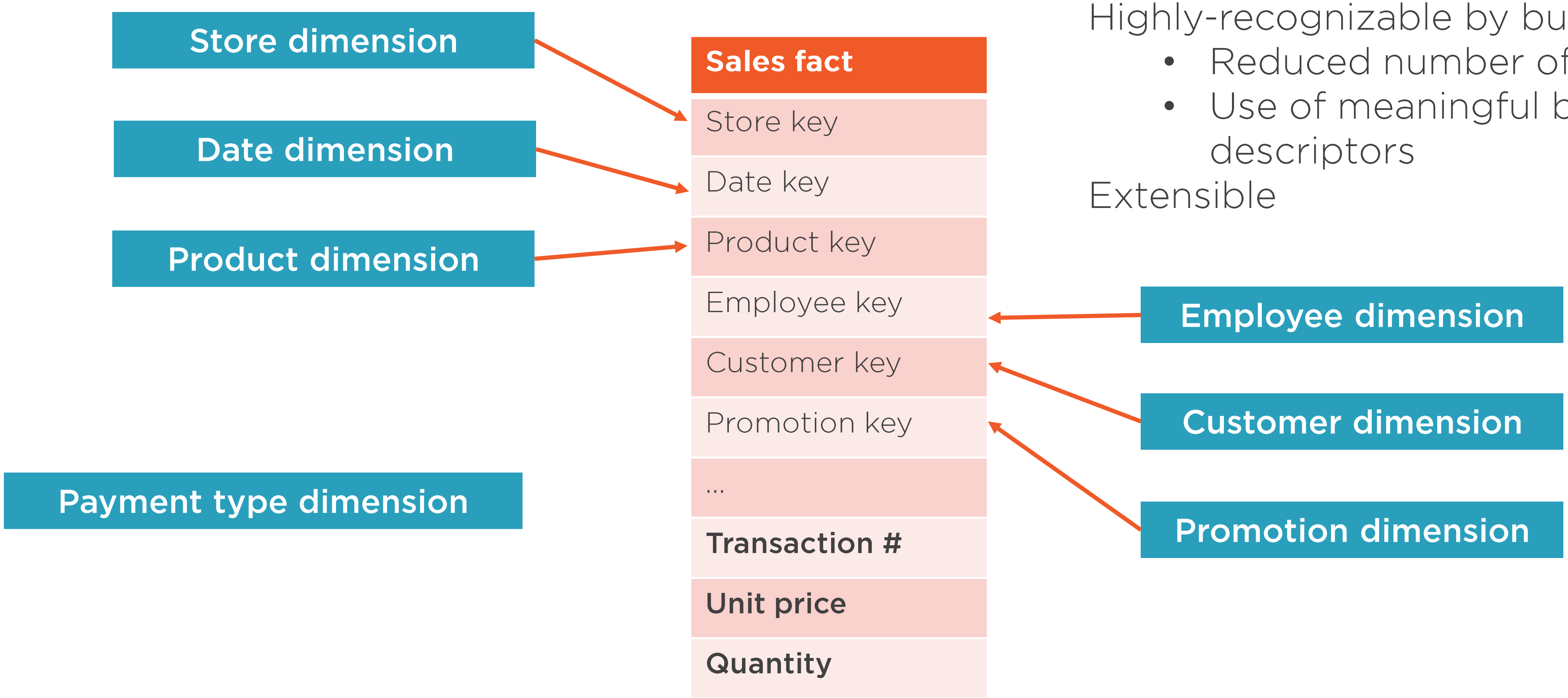
Extensible



Dimensional Model

Characteristics:

Simple

Symmetric

Highly-recognizable by business users

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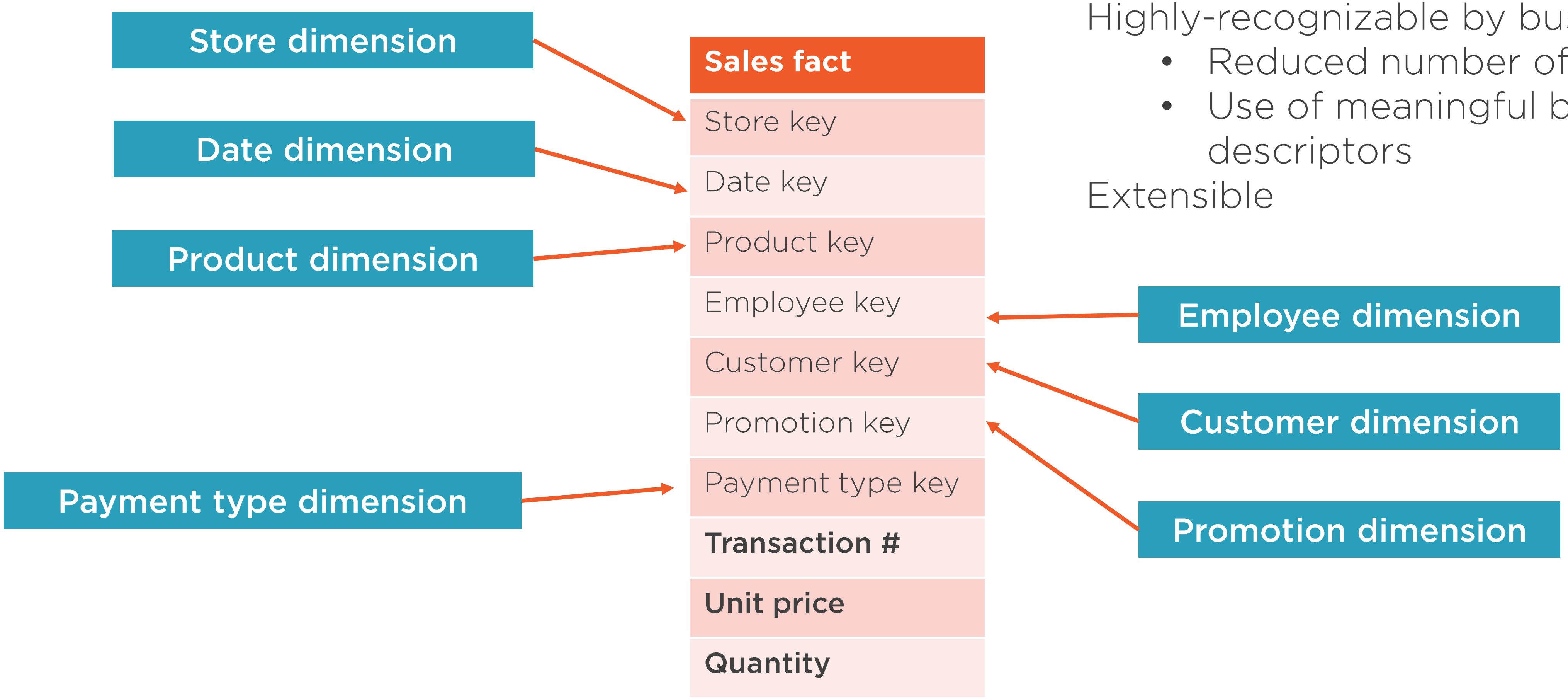
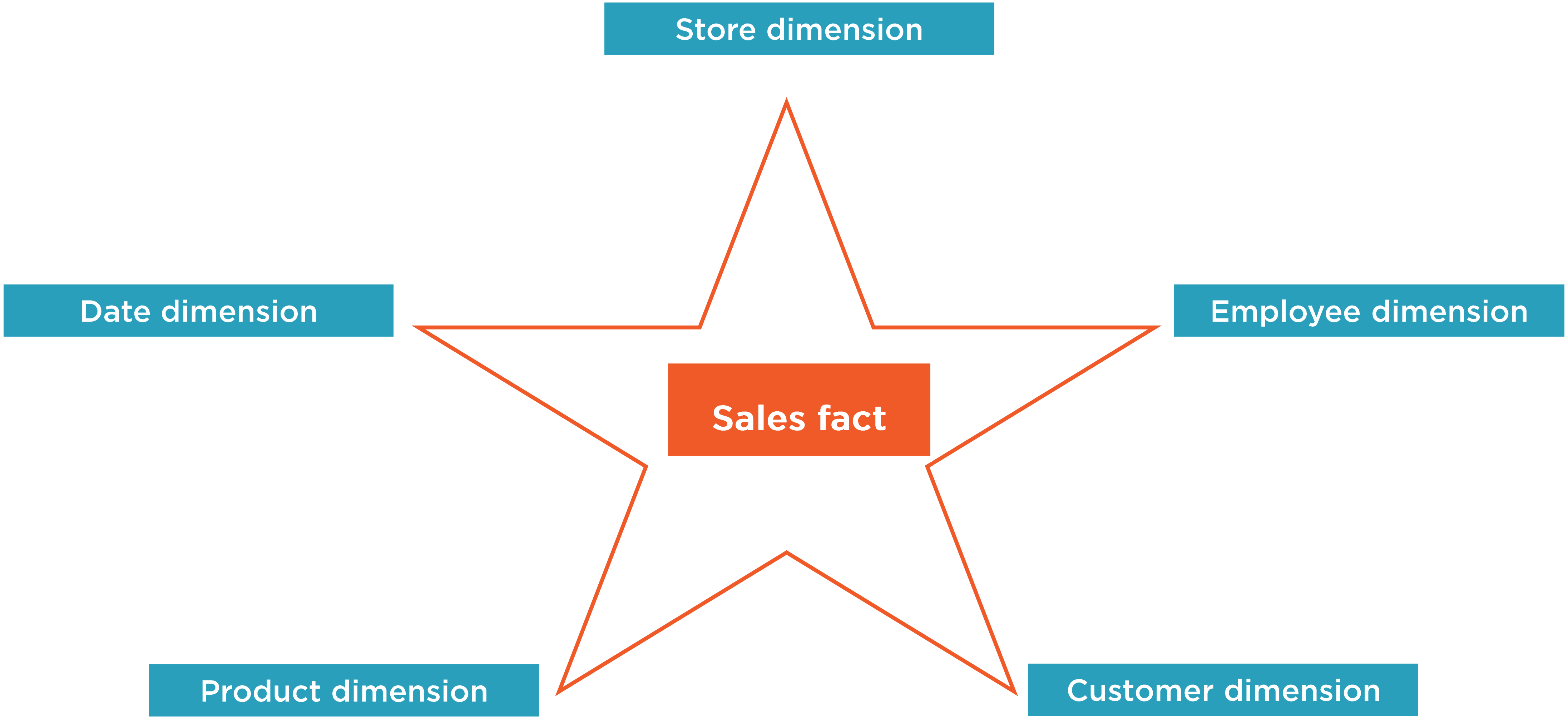
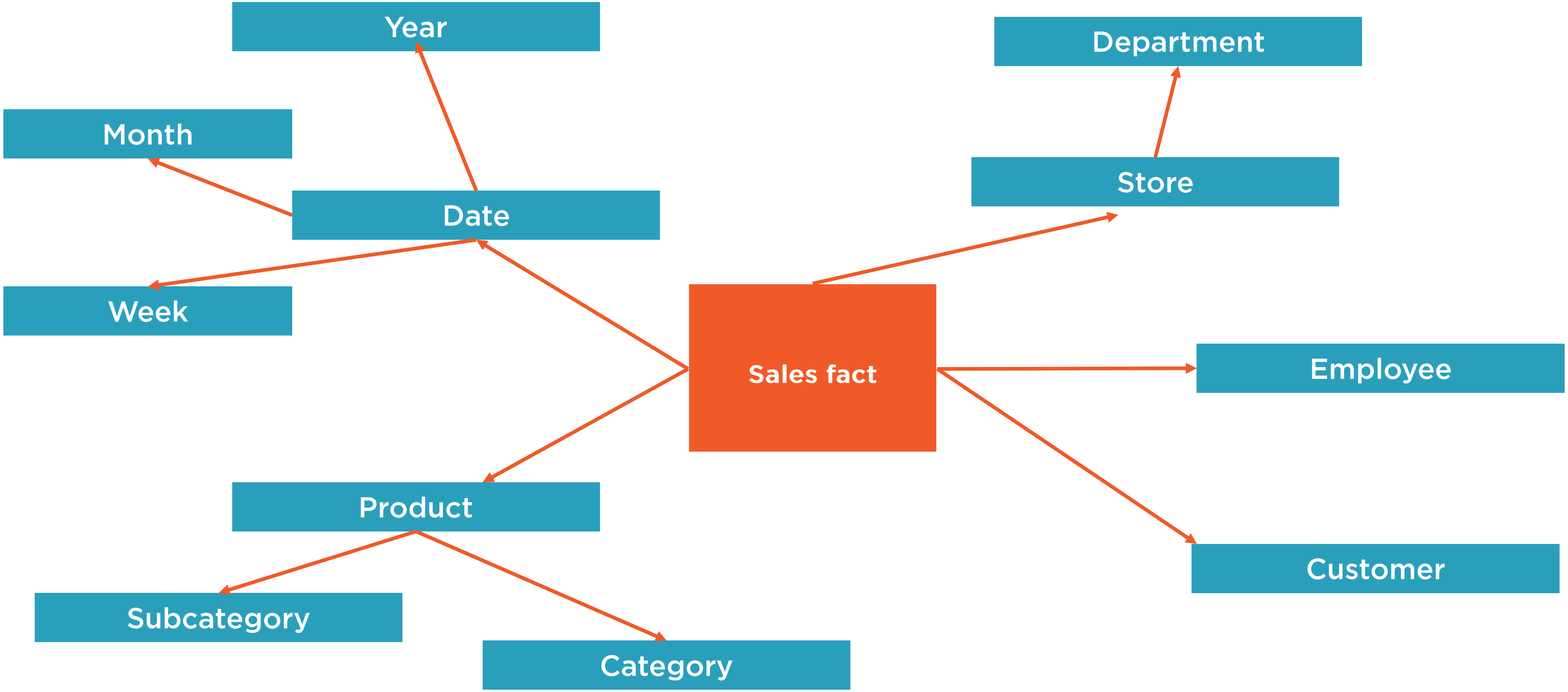
Extensible



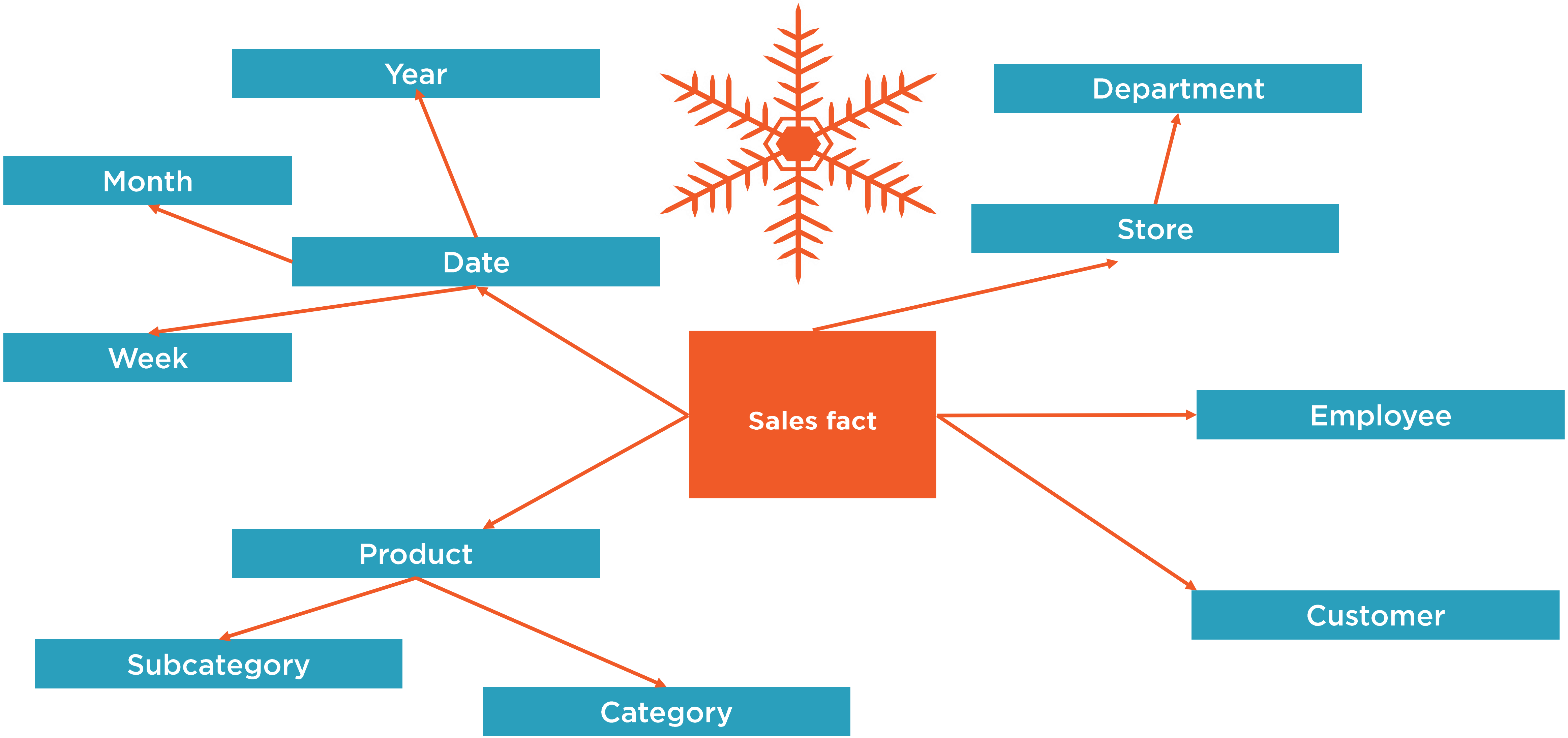
Dimensional Model as a Star Schema



Dimensional Model as a Snowflake



Dimensional Model as a Snowflake



The Four-step Dimensional Design Process

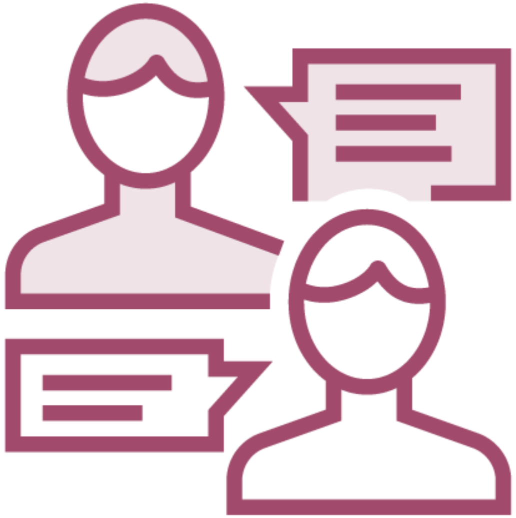
Dimensional Design

Is done "with pen and paper"

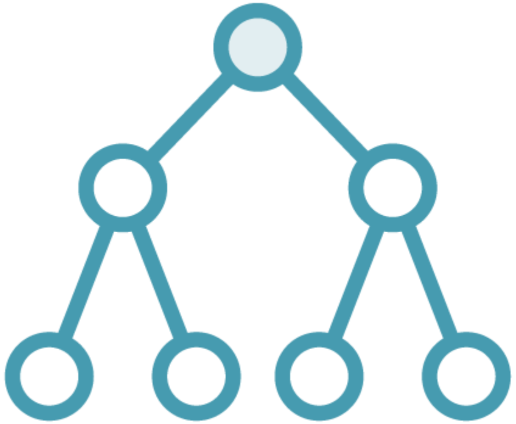
Focuses on understanding the deliverables of the project

Consists of four steps

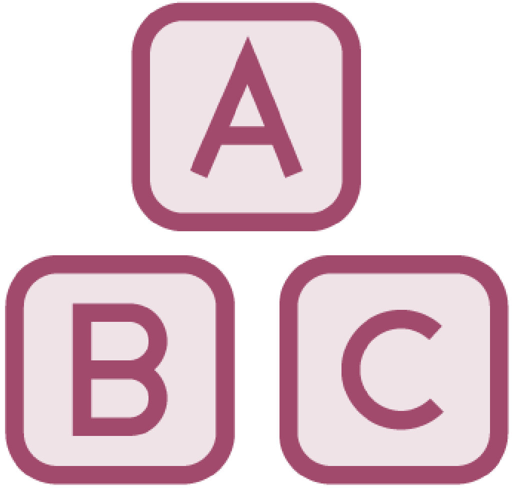
Steps of Dimensional Design



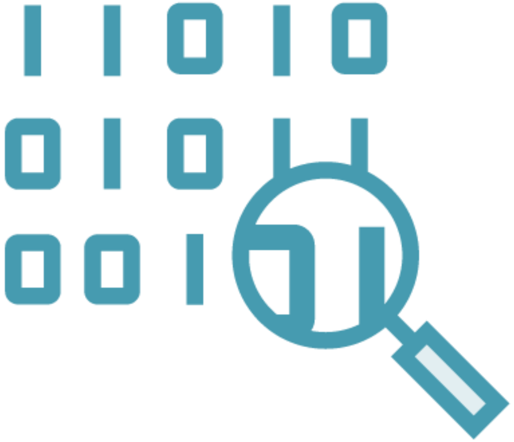
Select the business process



Declare the grain

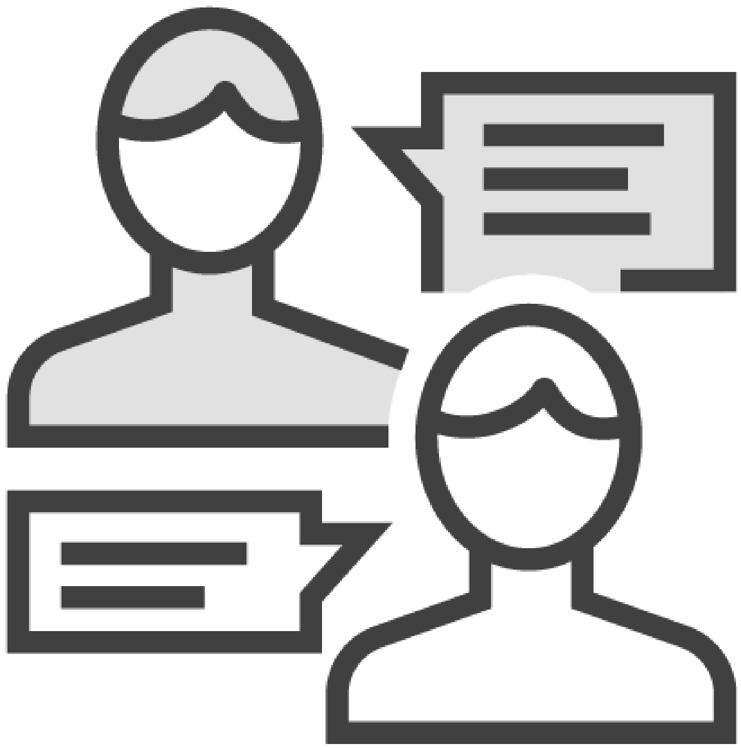


Identify the dimensions



Identify the facts

Step 1: Select the Business Process

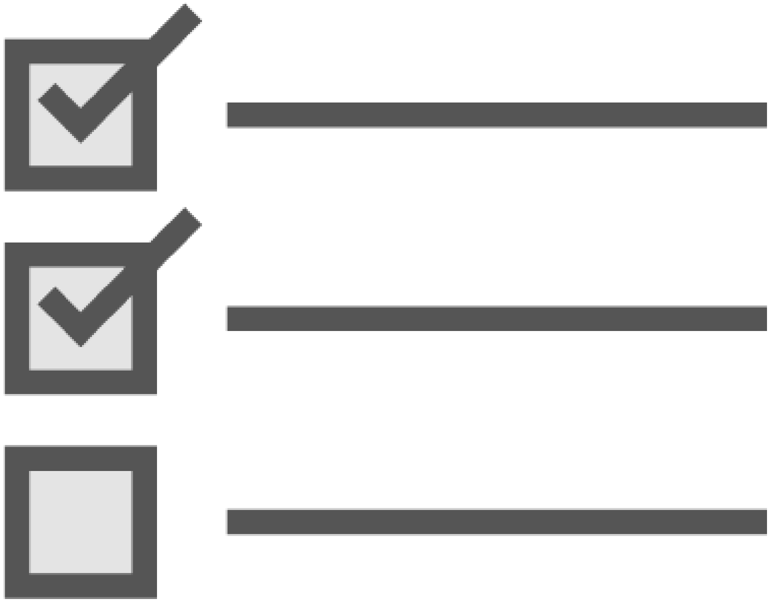


Low-level activities performed by an organization

Are identified by listening carefully to the business users

Characteristics:

- Expressed as verbs
- Are supported by an operational system
- Generate KPIs

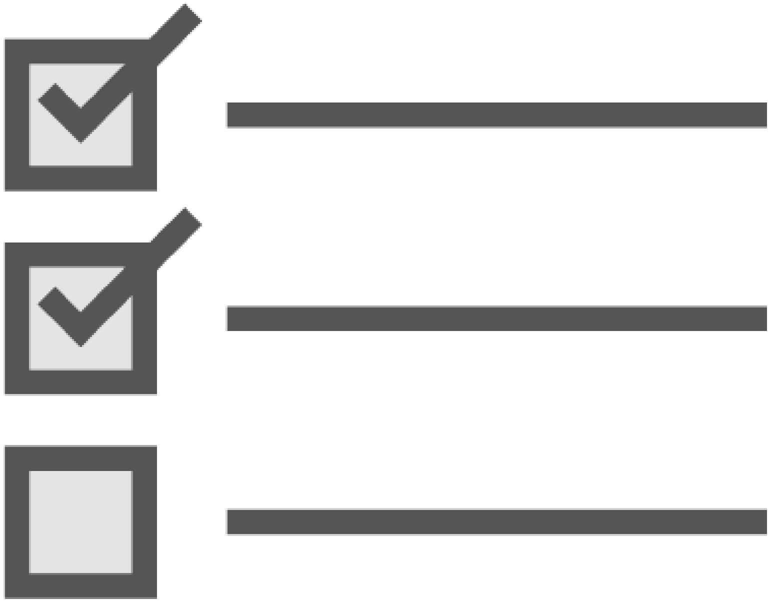


Step 2: Identify the Grain

Specify the detail level of a business process we want to measure

Example	Grain	Questions to ask
Sales/day	One row at the end of the day	How much was payed by each customer? Is this important information?
Sales/day/order	One row for every finished order	What was the most sold product? Is this important information?
Sales/day/order/ product	One row for every product sold within an order	Is this enough information?

Step 2: Identify the Grain



Specify the detail level of a business process we want to measure

"How do you describe a single row in the fact table?"

Grain declarations are expressed in business terms

Steps 3 and 4

Identify the dimensions

"How do business users describe the data resulting from the process?"

"who, what, where, when, why, how"

Examples:

- Date
- Product
- Customer
- Employee

Identify the facts

"What is the process measuring?"

All candidate facts must be true to the grain for that fact table

Facts with different grains are split in separate tables

Examples:

- Sales price
- Sales quantity (or Units sold)

Both business requirements and the realities of the source data should be considered when designing the dimensional model

Dimension Table Design Techniques

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Dimension Table Techniques

What is specific to a dimension table?

Technical guidelines for designing a table

- Working with keys
  - Surrogate key
  - Business key
- Populating the dimension's attributes with data

Examples of common dimensions

- Date dimension
- Product dimension

What Is Specific to a Dimension Table?

Example: Sources for the Product Dimension

Administration system

Inventory changes

- Normalized model
- Products, departments, categories, subcategories

Software product for storing recipes

Used by the cook for daily recipes

POS used by staff

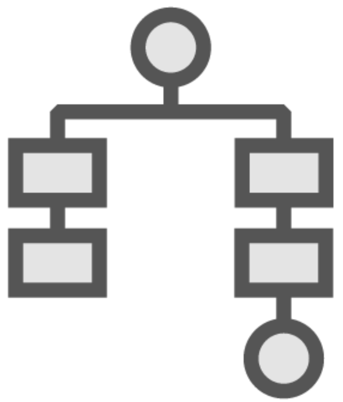
Take and fulfill orders

Flat file with information from an old accounting system

The system is not in use anymore

- But kept for historic information

Product dimension



Requirements of a Dimension Table

Administration system

Software product for storing recipes

POS used by staff

Flat file with information from an old accounting system

How will you build a table meeting these requirements?

- Dimension table can be linked to fact tables
- Keep track of the source system for data
- Data is consistent and readable
- Keep history of data changes from the operational system

What Is Specific to a Dimension Table?

A dimension table is different than a relational table

- The normalization rules don’t apply
- Not optimized for data modification aspects
- Integrates in a consistent way multiple source data
- Data is easy to read by the user

Surrogate Keys

Relationship between Fact and Dimension

One-to-many relationship

Dim Product
PK
Attribute1
Attribute2
Attribute3
Attribute4
Attribute5
…

Fact Sales
PK
FK product
FK date
…
Fact1
Fact2
…

Relationship components

- 1:M example
  - 1 product (chocolate chip cookie)
  - 2 sales (transactions)
- Keys involved
  - Primary key of dimension table
  - Foreign key from fact table
- It's important to create it correctly
  - Plays an important role in the BI solution
  - Should be unique across all data sources for the dimension

Creating the Primary Key

Bad practice

Use the PK from the source systems

Can lead to overlapping rows

Source system 1

Id	Name	...
3	Chocolate chip cookie	...

Source system 2

Id	Name	...
3	Potato	...

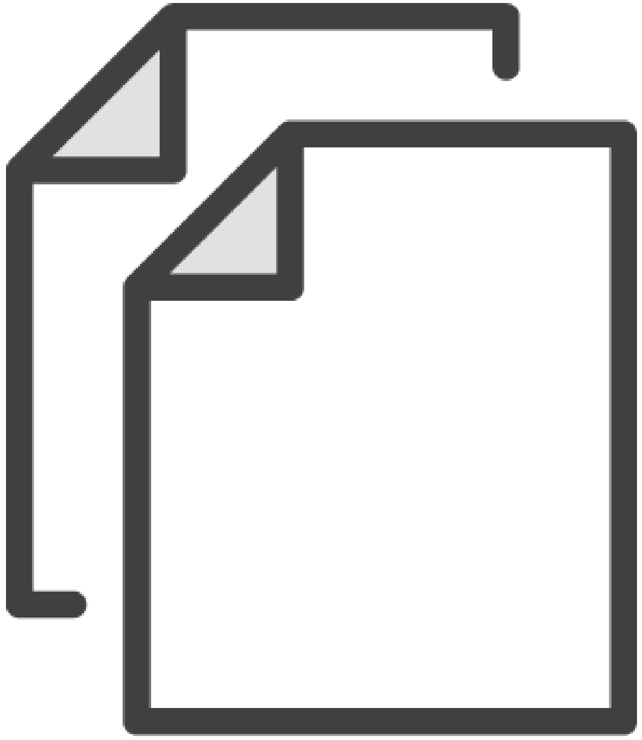
Good practice

Generate an artificial key

- Simple integer column
- Automatically incremented
- Doesn't require careful maintenance

In DW terminology, this is the surrogate key

Synonyms for Surrogate Key



Meaningless key

Integer key

Non-natural key

Artificial key

Synthetic key

Advantages of Using a Surrogate Key

Advantages of Using a Surrogate Key

Integrate multiple source systems

Advantages of Using a Surrogate Key

Integrate multiple source systems

- Example: gathering data for the Product dimension in a restaurant or store

Integrate Data from Multiple Sources

Integrate Data from Multiple Sources

Source system 1

ID	Name	Description	UM	Color
123	Milk	Non-fat	L	White
776	Sugar	Brown sugar	KG	Brown

Integrate Data from Multiple Sources

Source system 1

ID	Name	Description	UM	Color
123	Milk	Non-fat	L	White
776	Sugar	Brown sugar	KG	Brown

Source system 2

ID	Name	Description	UM	Color
776	Butter	Non-fat	G	Yellow
778	Sugar	Normal sugar	KG	White

Integrate Data from Multiple Sources

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123	Milk	Non-fat	L	White
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Source system 2

ID	Name	Description	UM	Color
776	Butter	Non-fat	G	Yellow
778	Sugar	Normal sugar	KG	White

Data warehouse – Product dimension

Dim Key	Original Key	Name	Description	UM	Color
1	123	Milk	Non-fat	L	White
2	776	Sugar	Brown sugar	KG	Brown
3	776	Butter	Non-fat	G	Yellow
4	778	Sugar	Normal sugar	KG	White

Advantages of Using a Surrogate Key

Integrate multiple source systems

Keep track of attribute changes over time

Advantages of Using a Surrogate Key

Integrate multiple source systems

Keep track of attribute changes over time

- Use surrogate keys to handle multiple versions of a row

Keep Track of Attribute Changes over Time

Keep Track of Attribute Changes over Time

Before 09-16-2018

Key	Name	Description	UM	Color
387	Cherry toffee	Great cherry taste, sticky, chewy consistency	Piece	Pink

Keep Track of Attribute Changes over Time

Before 09-16-2018

Key	Name	Description	UM	Color
387	Cherry toffee	Great cherry taste, sticky, chewy consistency	Piece	Pink

After 09-16-2018

Key	Name	Description	UM	Color
387	Super cherry toffee	Great cherry taste, sticky, chewy consistency	Piece	Pink

Keep Track of Attribute Changes over Time

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After 09-16-2018

Key	Name	Description	UM	Color
387	Super cherry toffee	Great cherry taste, sticky, chewy consistency	Piece	Pink

Data warehouse – Product dimension

Dim Key	Orig. Key	Name	Description	UM	Color
112	387	Cherry toffee	Great cherry taste, sticky, chewy consistency	Piece	Pink
244	387	Super cherry toffee	Great cherry taste, sticky, chewy consistency	Piece	Pink

Keep Track of Attribute Changes over Time

Before 09-16-2018

Key	Name	Description	UM	Color
387	Cherry toffee	Great cherry taste, sticky, chewy consistency	Piece	Pink

After 09-16-2018

Key	Name	Description	UM	Color
387	Super cherry toffee	Great cherry taste, sticky, chewy consistency	Piece	Pink

Data warehouse – Product dimension

Dim Key	Orig. Key	Name	Description	UM	Color	Valid From	Valid To
112	387	Cherry toffee	Great cherry taste, sticky, chewy consistency	Piece	Pink	01-01-2017	09-16-2018
244	387	Super cherry toffee	Great cherry taste, sticky, chewy consistency	Piece	Pink	09-17-2018	12-31-9999

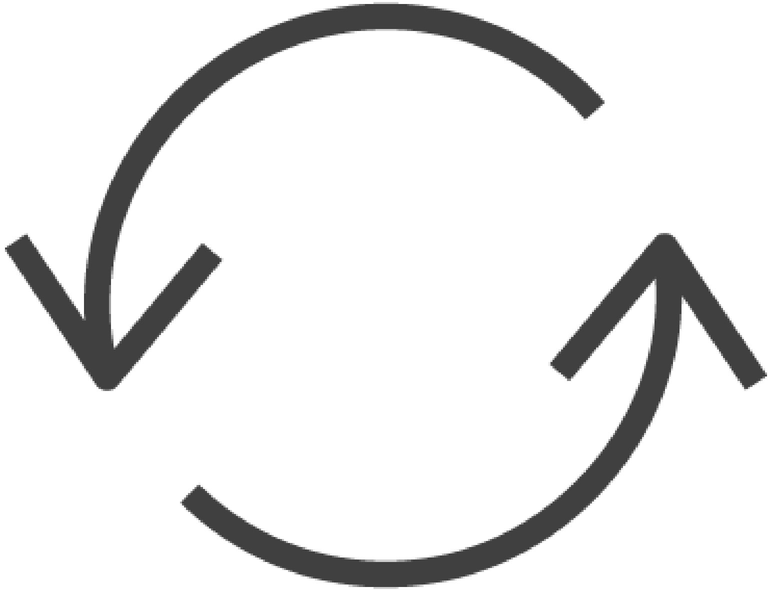
Advantages of Using a Surrogate Key

Integrate multiple source systems

Keep track of attribute changes over time

Protect the data warehouse from operational changes

Protect the Data Warehouse from Operational Changes



Characteristics of an operational system:

- Logs and processes daily activities/current actions
- Some data history is preserved
- Obsolete data is deleted after a period of time
- Codes/IDs can be reassigned to new data

Protect the Data Warehouse from Operational Changes

Protect the Data Warehouse from Operational Changes

Before 01-01-2018

Key	Name	Description	UM	Color
432	Chocolate chip cookie	Grandma's cookie recipe	Piece	Brown
776	Sugar	Brown sugar	KG	Brown

Protect the Data Warehouse from Operational Changes

Before 01-01-2018

Key	Name	Description	UM	Color
432	Chocolate chip cookie	Grandma’s cookie recipe	Piece	Brown
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After 01-01-2018

Key	Name	Description	UM	Color
776	Sugar	Brown sugar	KG	Brown

Protect the Data Warehouse from Operational Changes

Before 01-01-2018

Key	Name	Description	UM	Color
432	Chocolate chip cookie	Grandma's cookie recipe	Piece	Brown
776	Sugar	Brown sugar	KG	Brown

After 01-01-2018

Key	Name	Description	UM	Color
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Protect the Data Warehouse from Operational Changes

Before 01-01-2018

Key	Name	Description	UM	Color
432	Chocolate chip cookie	Grandma's cookie recipe	Piece	Brown
776	Sugar	Brown sugar	KG	Brown

After 01-01-2018

Key	Name	Description	UM	Color
776	Sugar	Brown sugar	KG	Brown

Data warehouse – Product dimension

Dim Key	Orig. Key	Name	Description	UM	Color	Valid From	Valid To
83	432	Chocolate chip cookie	Grandma's cookie recipe	Piece	Brown	01-01-1753	01-01-2018
2	776	Sugar	Normal sugar	KG	Brown	01-01-1753	12-31-9999

Advantages of Using a Surrogate Key

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Keep track of attribute changes over time

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Handle null or unknown conditions

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- Empty row technique

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Handle null or unknown conditions

- Empty row technique
- Handle situations when a link does not exist between fact and dimensions

Advantages of Using a Surrogate Key

Integrate multiple source systems

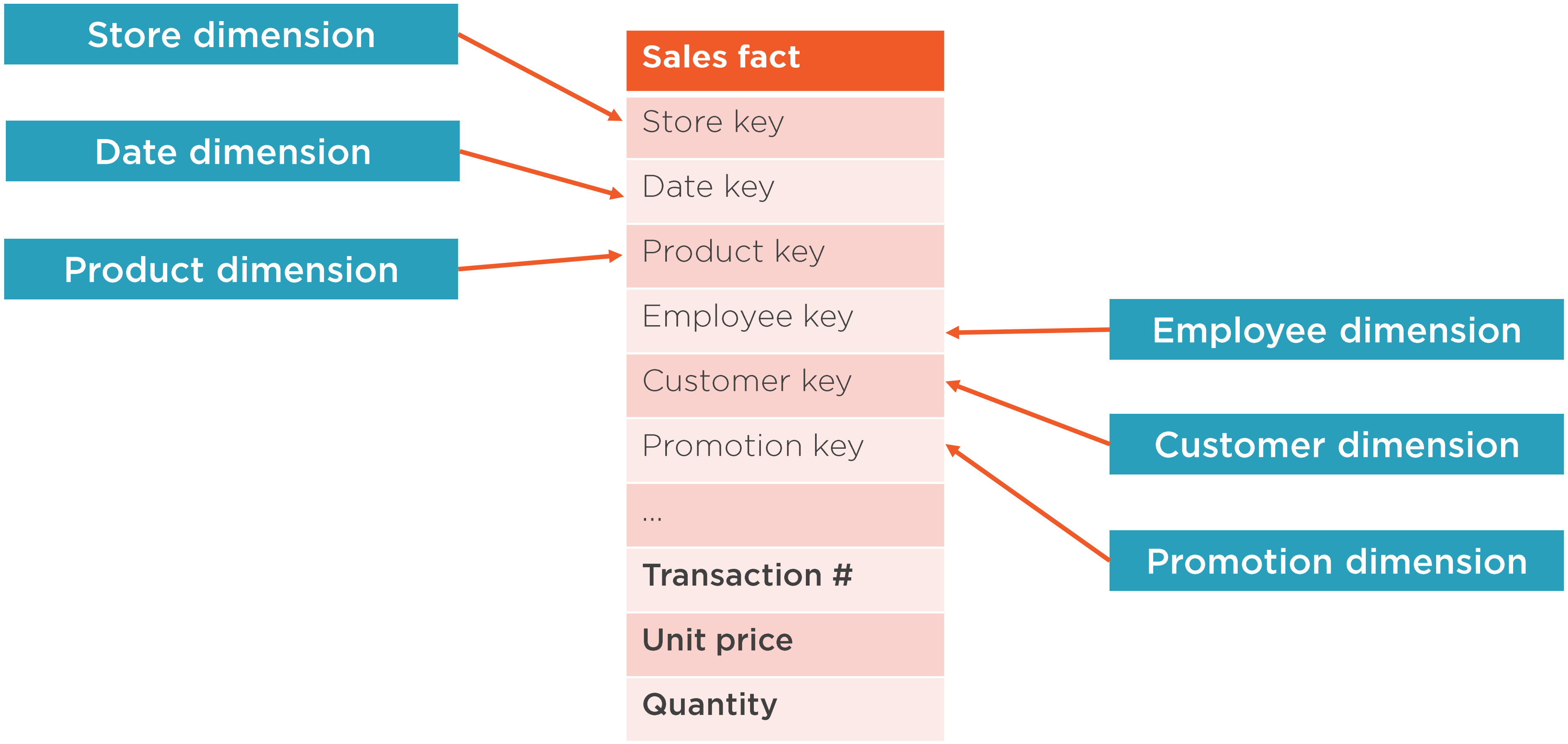
Keep track of attribute changes over time

Protect the data warehouse from operational changes

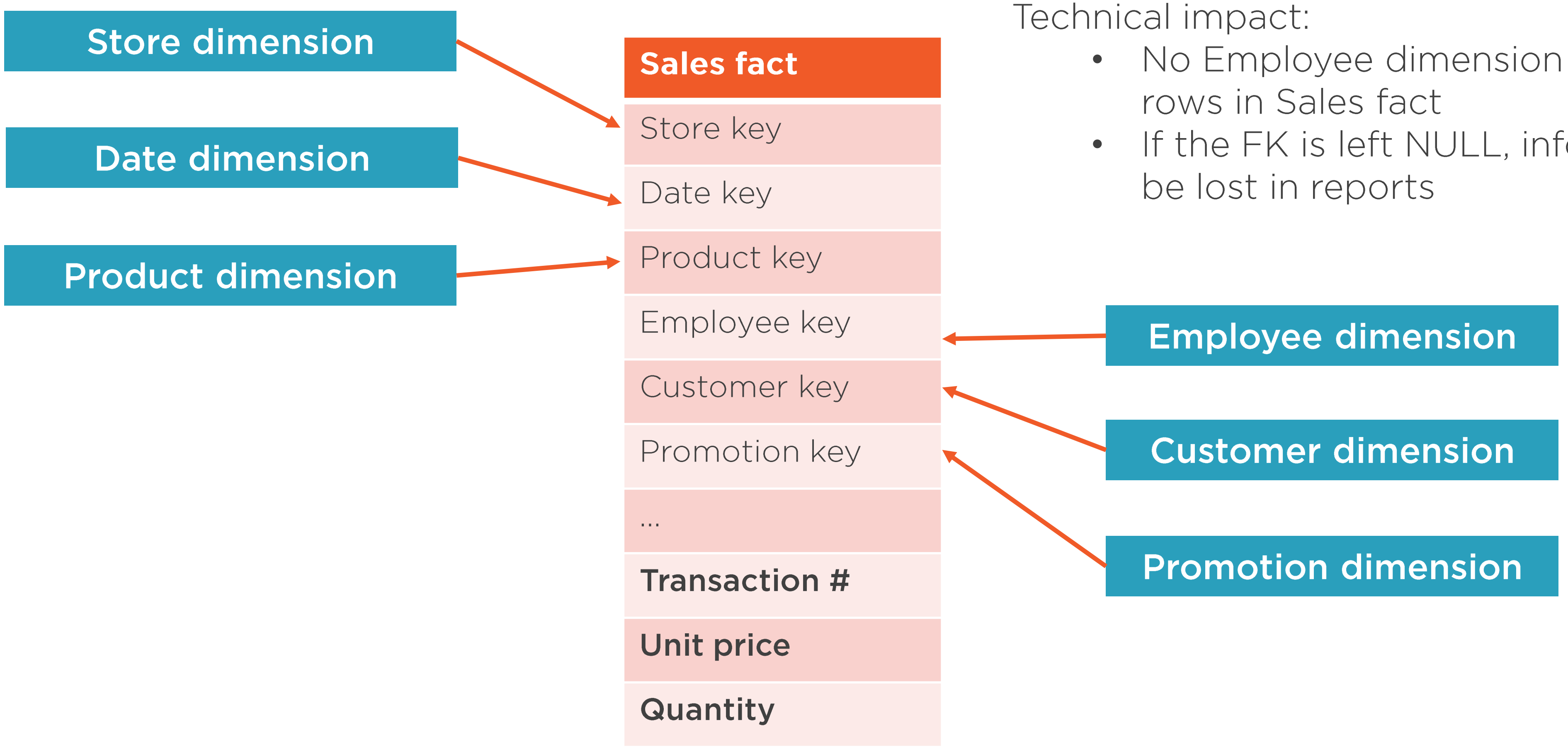
Handle null or unknown conditions

- Empty row technique
- Handle situations when a link does not exist between fact and dimensions

Scenario for Null or Unknown Conditions



Scenario for Null or Unknown Conditions



Self-checkout kiosks were introduced
Customers pay by themselves
Employees are not involved for this transaction
Technical impact:

- No Employee dimension key for these rows in Sales fact
- If the FK is left NULL, information may be lost in reports

Handle Null or Unknown Conditions

Adding the “empty row” to each dimension table

Key	Name	Birthday	Gender	PhoneNr.
1	Unknown	01-01-1753	Unknown	Unknown
32	Alice Cohen	03-05-1989	Female	Unknown

Handle Null or Unknown Conditions

Adding the "empty row" to each dimension table

Key	Name	Birthday	Gender	PhoneNr.
1	Unknown	01-01-1753	Unknown	Unknown
32	Alice Cohen	03-05-1989	Female	Unknown

Data warehouse – Sales fact table

Fact Key	Product Key	Customer Key	Employee Key	Transaction Nr	Amt.
...	432	10	32	#1050	$5
...	776	12	1	#2367	$3

Advantages of Using a Surrogate Key

Integrate multiple source systems

Keep track of attribute changes over time

Protect the data warehouse from operational changes

Handle null or unknown conditions

Improve performance

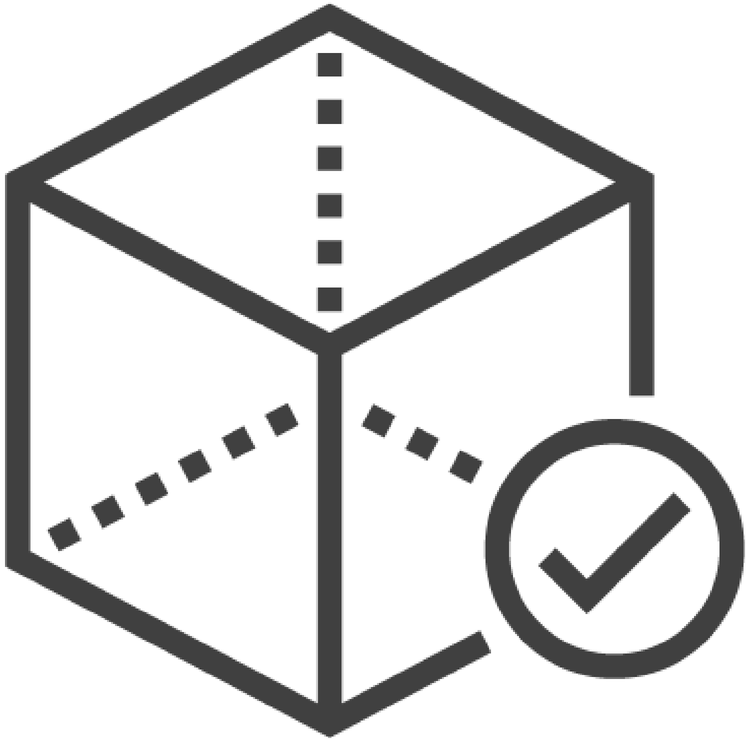
Improve Performance

The surrogate key should be a small number, preferably an integer

You need to anticipate the growth of your dimension table (a 4-byte int can handle ~2 billion positive values and ~4 billion values in total)

The smaller the surrogate key, the smaller the fact table

Dimensions of a Fact Table



Fact tables

- Have FKs to a lot of dimension tables
- Grow very fast
- Every byte counts!

FK length	Fact table growth	Fact table storage
X bytes	1 billion rows	Y GB
X + 1 bytes	1 billion rows	Y + 1 GB

Advantages of Using a Surrogate Key

- Integrate multiple source systems
- Keep track of attribute changes over time
- Protect the data warehouse from operational changes
- Handle null or unknown conditions
- Improve performance

Business Keys

Business Keys

The primary key of the source system

Also known as

- Natural keys
- Production keys
- Operational keys

Business Keys Properties

Attribute in the dimension table

Business Keys Properties

Attribute in the dimension table

Can be prefixed with a source system's code

(POS|432 or CSV|635)

Business Keys Properties

Attribute in the dimension table

Can be prefixed with a source system’s code

(POS|432 or CSV|635)

Can cause duplicated items in the dimensions

Business Keys Properties

Attribute in the dimension table

Can be prefixed with a source system's code

(POS|432 or CSV|635)

Can cause duplicated items in the dimensions

If the BK is composed of meaningful codes, it should be split and each code stored in separate columns

Keys in a Dimension Table

Surrogate key

- Primary key, no business value

Business key

- Original primary from the source system

Other Dimensional Design Considerations

Characteristics of a Dimension Table

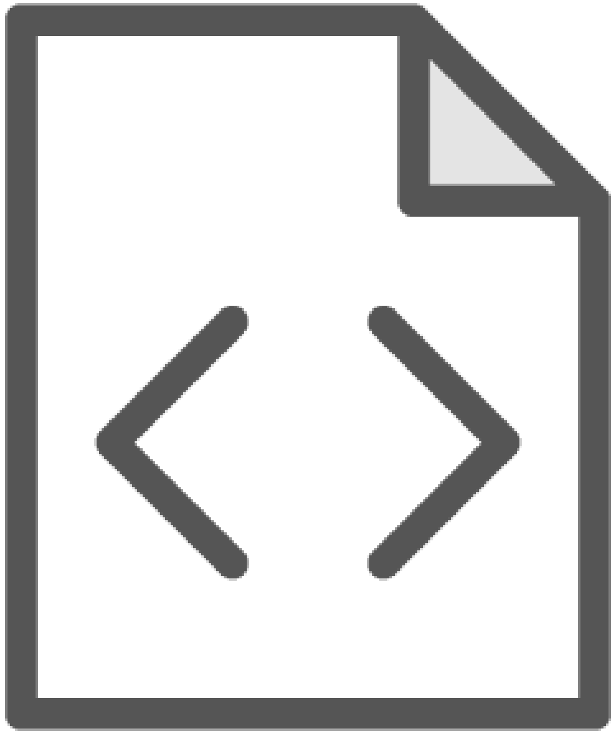
Companion of a fact table

Used to describe the business in clear terms

Design implications

- Store descriptive words instead of codes
- Replace flags or indicators with descriptions
- Replace null values with meaningful words

Use Descriptions Instead of Codes



Each code stored should be accompanied by a descriptive decode

Each attribute should be easy to interpret by people

Example of Using Descriptions Instead of Codes

Country of import for the most sold products

# Sold products	Name	Imported from
5000	Zywiec Beer	PL
4856	Pan Beer	HR
3991	Ursus Beer	RO
2674	Mort Subite Beer	BE

Codes are not easy to interpret by everyone

Id	Name	Imported from
5000	Zywiec Beer	Poland
4856	Pan Beer	Croatia
3991	Ursus Beer	Romania
2674	Mort Subite Beer	Belgium

Decodes can be retrieved from the operational system as well

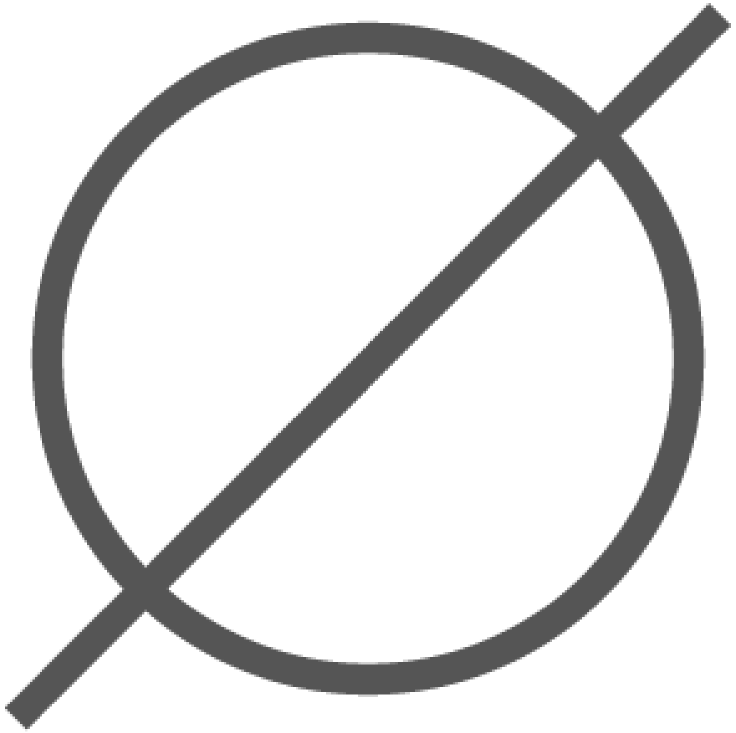
Use Textual Attributes Instead of Flags and Indicators

Flags and operational indicators should be supplemented with meaningful text words

Examples from the Date dimension:

Column	Meaningful name	Indicator
Weekday indicator	Weekday/Weekend	1/0
Holiday indicator	Holiday/Non-holiday	true/false

Replace Null Values in Dimensions



Replace null values with meaningful words, like

- Unknown
- Not applicable

Null values in data warehouse tables have unexpected behaviors

Nulls are not present in drop-down menus, so data may be missing from reports

Demo

Creating the Date dimension

- What is a Date dimension?
- Why is it important?

What Is a Date Dimension?

A table that stores dates

Is populated with a large number of dates (10 years, 100 years)

As a dimension table, it is not large

It is loaded once, not periodically

Why Is It Important?

Is present in almost all data warehouses

Helps performing time analysis

- Products sold this year vs. last year
- Products sold per month compared to last year
- Per week, per weekend, per holiday..

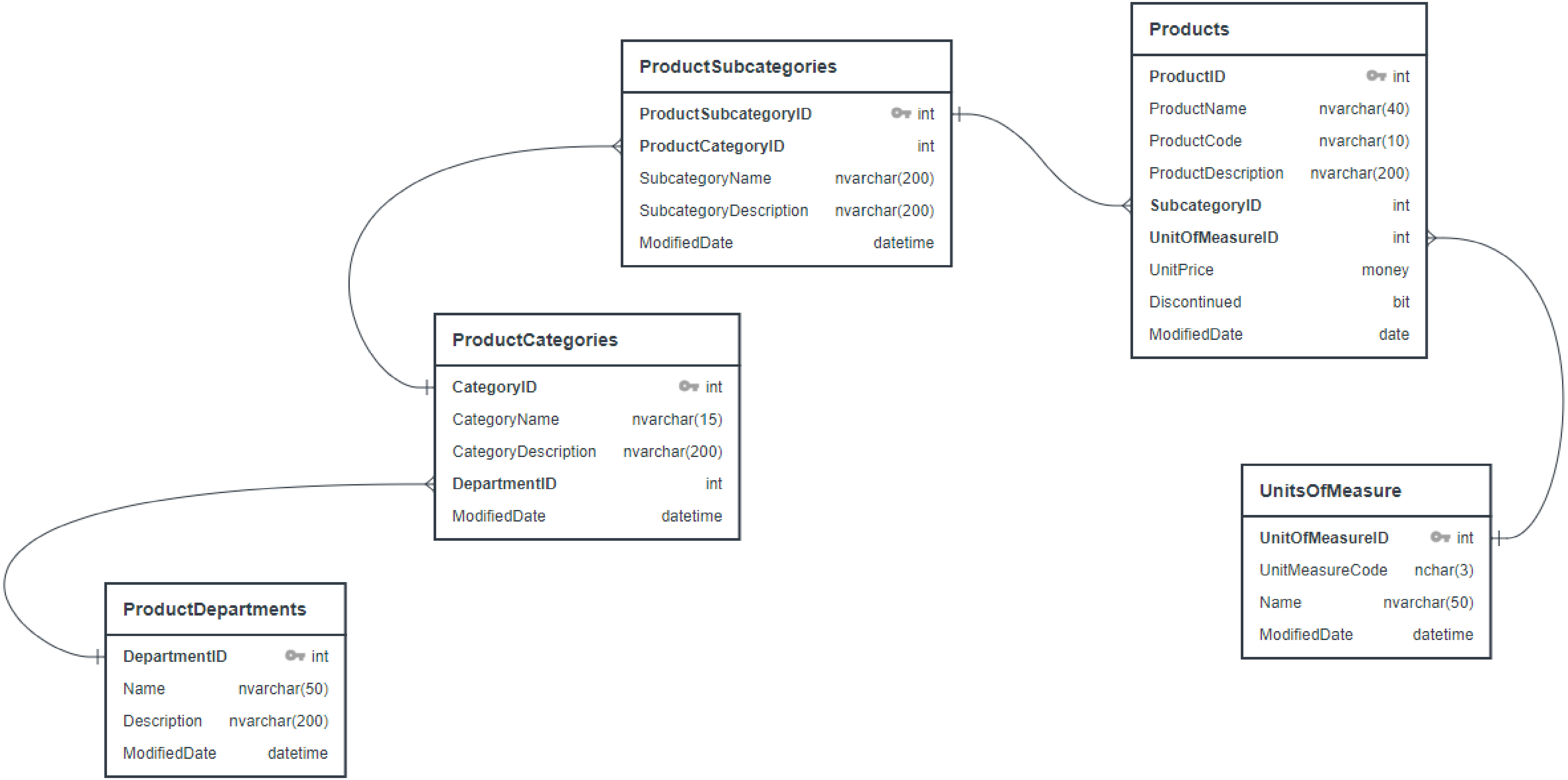
Contains pre-calculated information about dates

Demo

Creating the Product dimension

- Product dimension is present in many data warehouse projects
- It doesn't have a standard set of attributes

Product-related Tables



Summary

Characteristics of a dimension table

- Is different than a relational table
- Integrates data from multiple sources
- Data is easy to read by the user

Keys in a dimension table

- Surrogate key
- Business key

Guidelines for implementing a dimension table

- Store descriptive words instead of codes
- Replace flags or indicators with descriptions
- Replace null values with meaningful words

Creating and Working with Hierarchies

Ana Voicu
@ana_voicu

Overview

In short, a hierarchy is:

- A data structure
- Created with attributes from a dimension
- Used for data aggregation

Topics elaborated in this chapter:

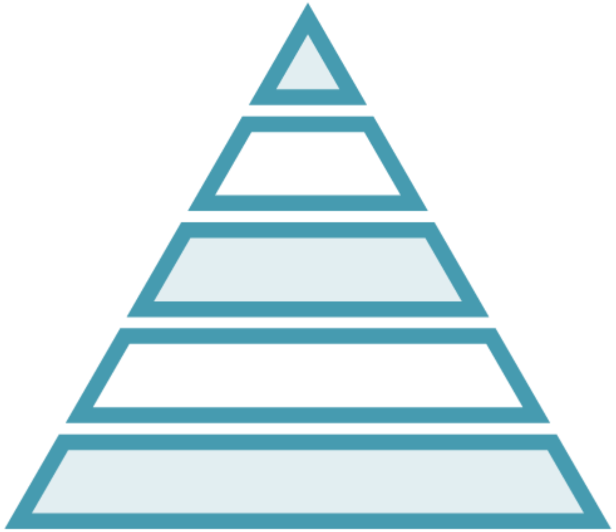
- What is a hierarchy?
- Why is it useful?
- What does drilling-down mean?
- Implementing a hierarchy in a data warehouse

What Is a Hierarchy?

What Is a Hierarchy?

Data structure with multiple levels

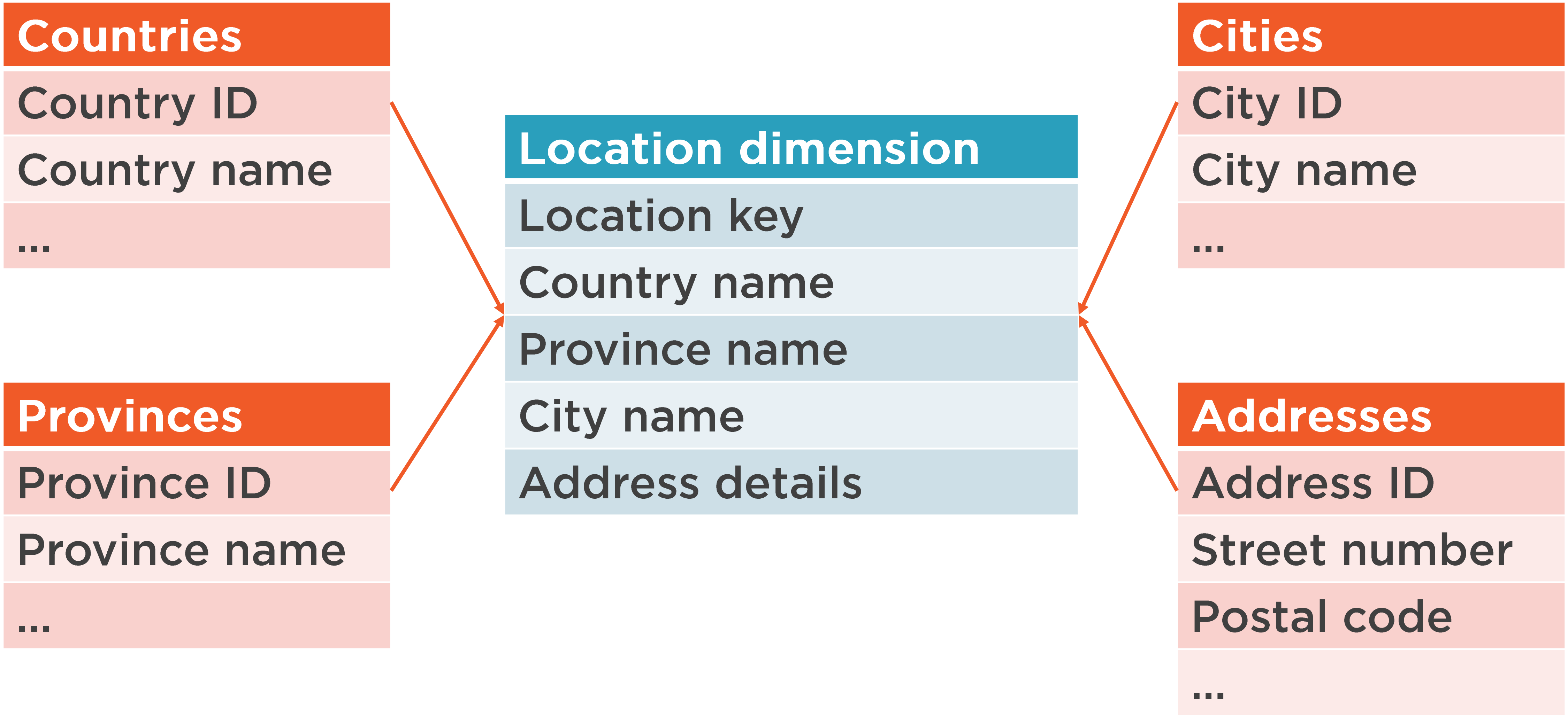
- The levels are dimension attributes
- The elements on each level are called nodes



Similar to a pyramid

- Bottom level is the weakest
- Highest level is at the top

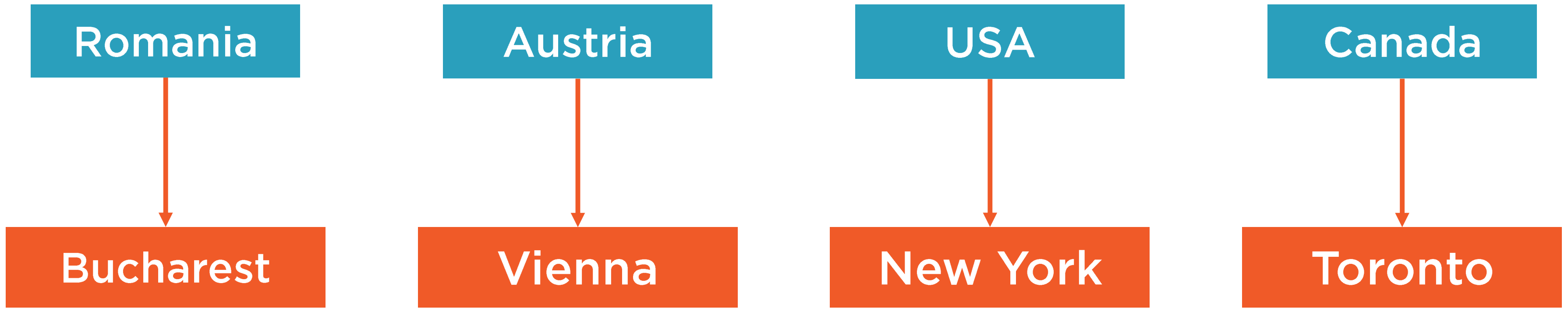
A Hierarchy in the Location Dimension



A Hierarchy in the Location Dimension

Bucharest | Vienna | New York | Toronto

A Hierarchy in the Location Dimension



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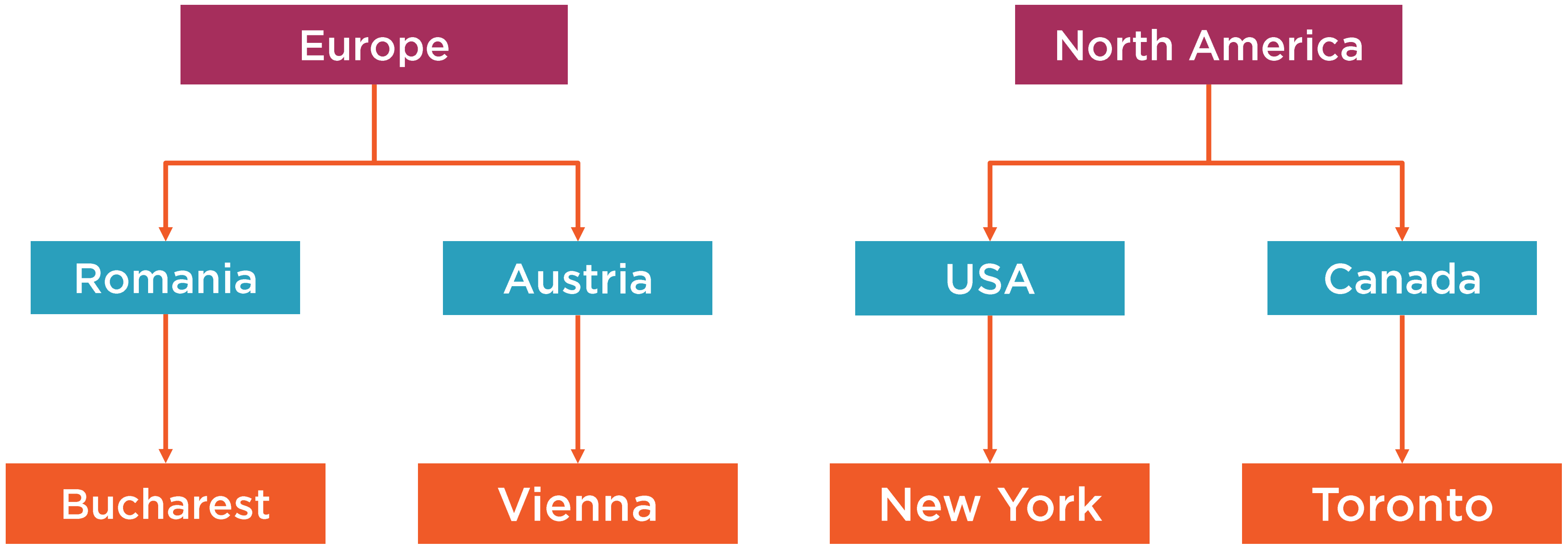

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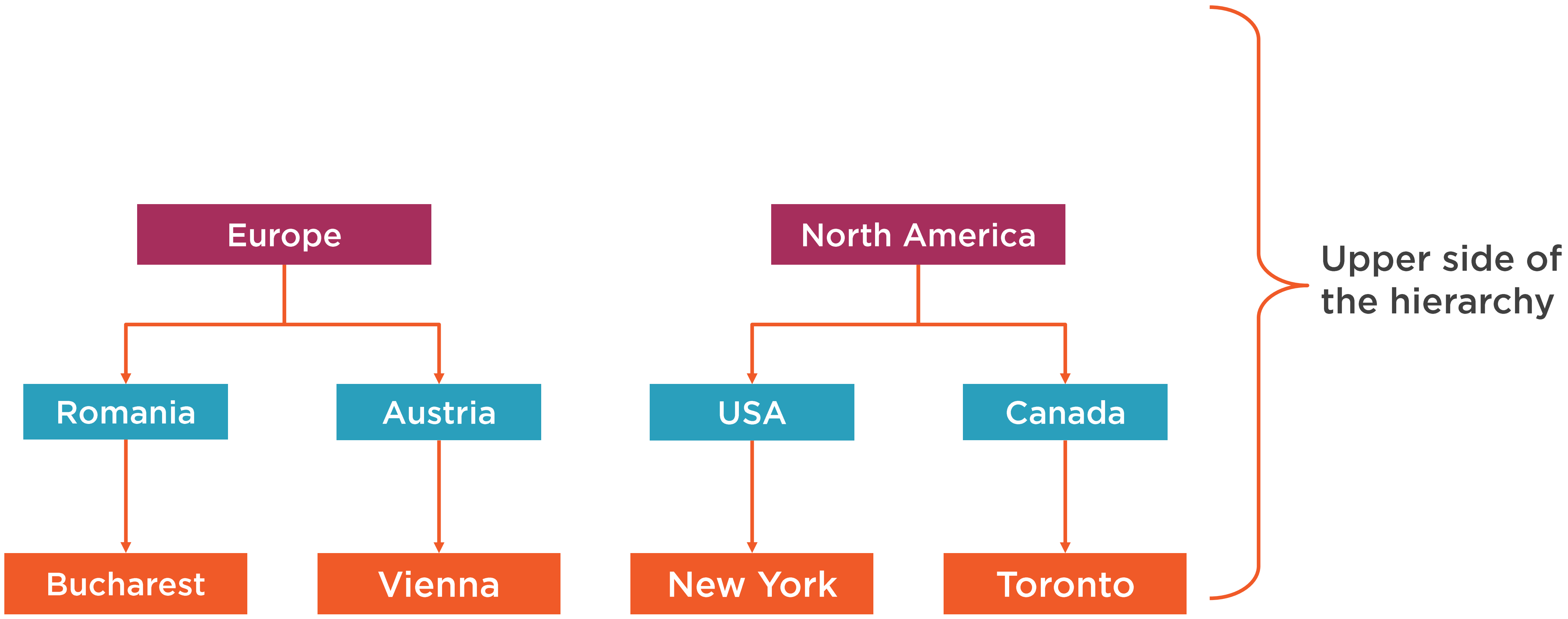

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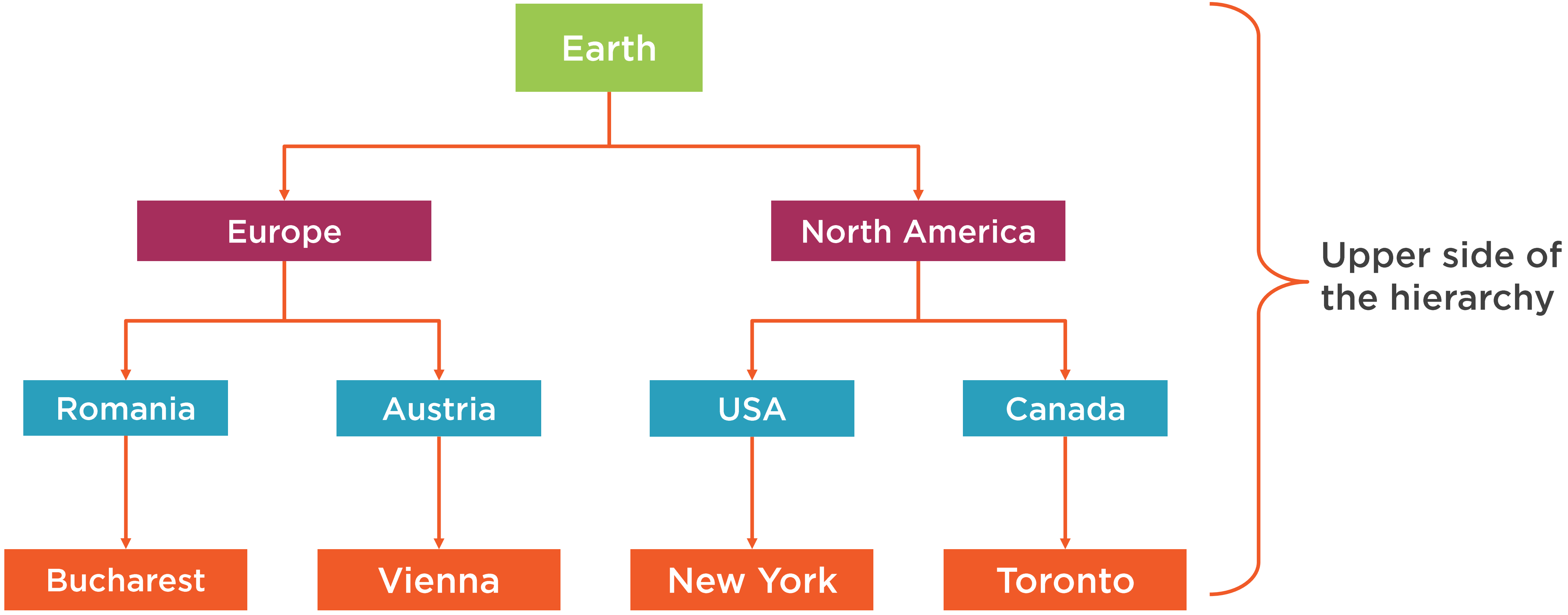

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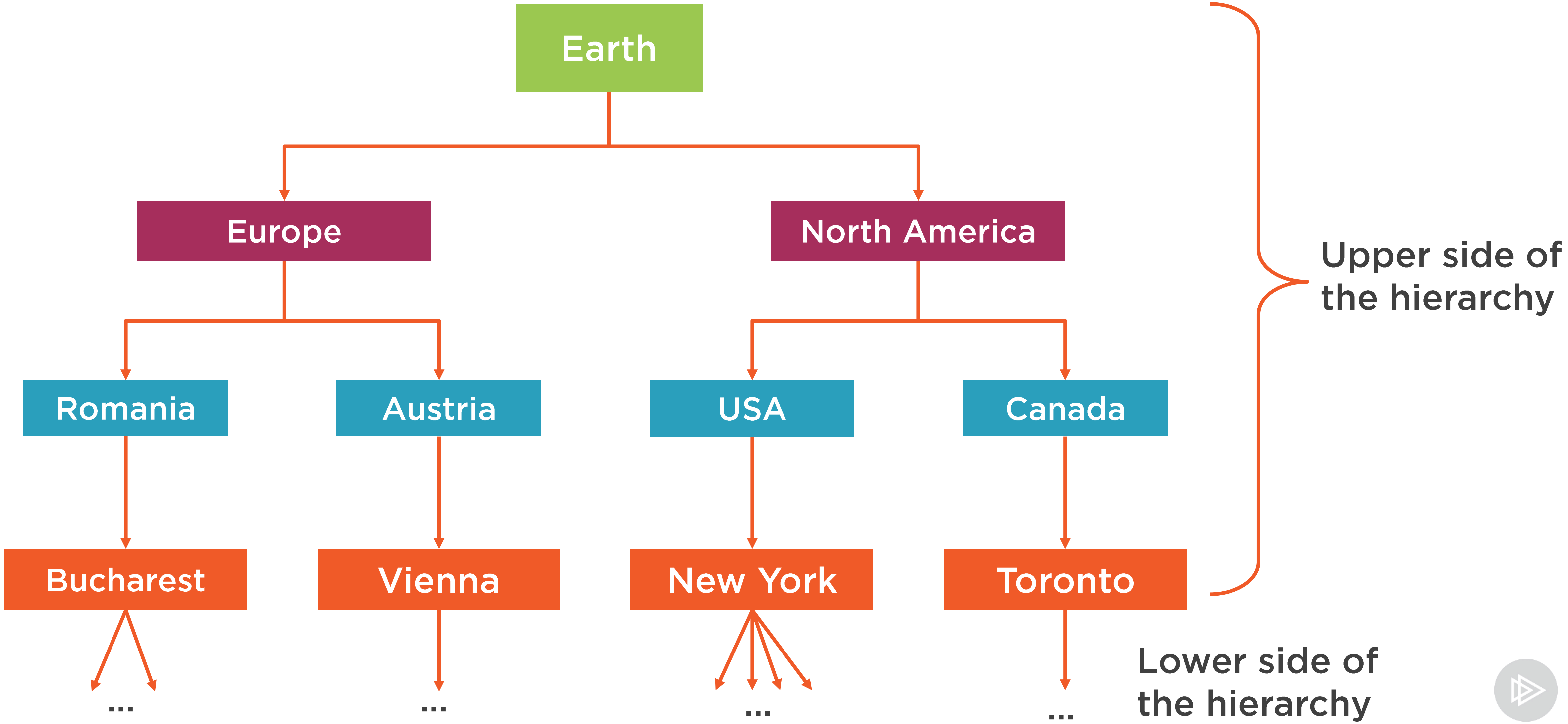
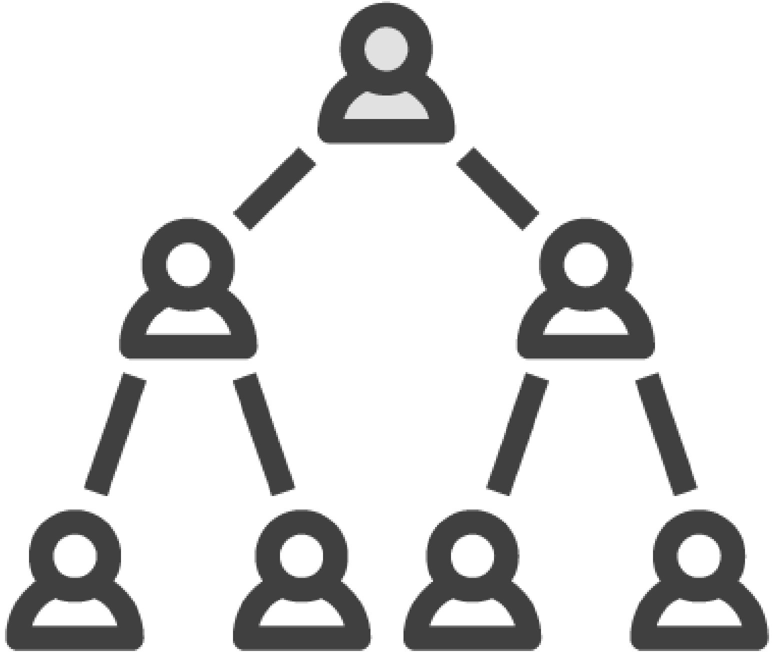


What Is a Hierarchy?



Data structure

- Attributes of a dimension are organized together
- Going down the hierarchy nodes -> more details
- Going up the hierarchy -> summarized data

Advantages of Using Hierarchies

Structure

- Important dimensions have plenty attributes
- Analyzing important data can become overwhelming
- Hierarchies provide order in the data

Multiple perspectives

Merchandise hierarchy

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Multiple perspectives

Merchandise hierarchy

- Department
  - Category
    - Subcategory
      - Product name

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Packaging hierarchy

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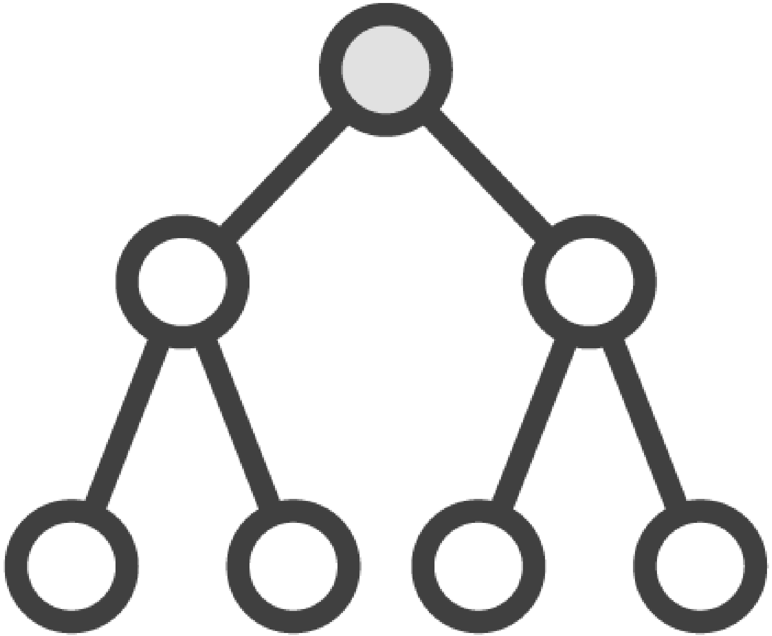
Packaging hierarchy

- Package type
  - Package size
    - Product name

Zoom in/zoom out

- Visualize summarized data and detailed data
- Go as deep as the business requires it

Types of Hierarchies



Fixed-depth (balanced)

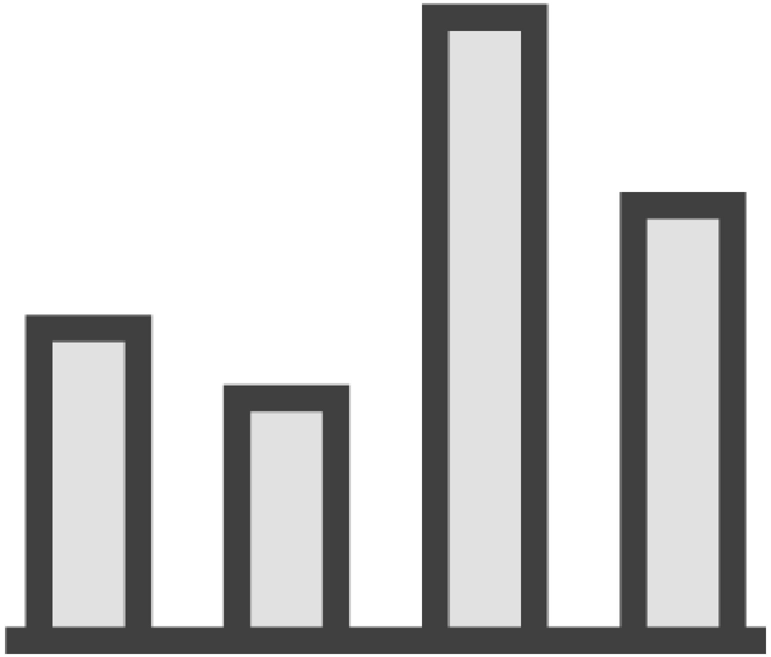
- Fixed number of levels
- Easy to create and work with

Variable-depth (unbalanced or ragged)

- Uneven number of levels
- Creating them is more complex task

Drilling Down a Hierarchy

Data Warehouse Analysis



Minimum requirements for doing data warehouse analysis

- One fact table
- One dimension table

Example: sales per product report

- Sales fact
- Product dimension

Example of Drilling Down

Sales fact
Store key
Date key
Product key
Employee key
Customer key
…
Transaction #
Unit price
Quantity
Amount

Example of Drilling Down

Sales fact
Store key
Date key
Product key
Employee key
Customer key
…
Transaction #
Unit price
Quantity
Amount

Product dimension
Product key
Product name
Department
Category
Subcategory
Package size
Package type
Description
Unit of measure
…

Example of Drilling Down

Sales fact
Store key
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Subcategory
Package size
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Description
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…

Merchandise hierarchy

- Department
  - Category
    - Subcategory
      - Product name

Example of Drilling Down

Sales

80.000

Department
Sales

Bakery	Sweets	Beverages
25.000	40.000	15.000

Example of Drilling Down

Department
Category
Sales

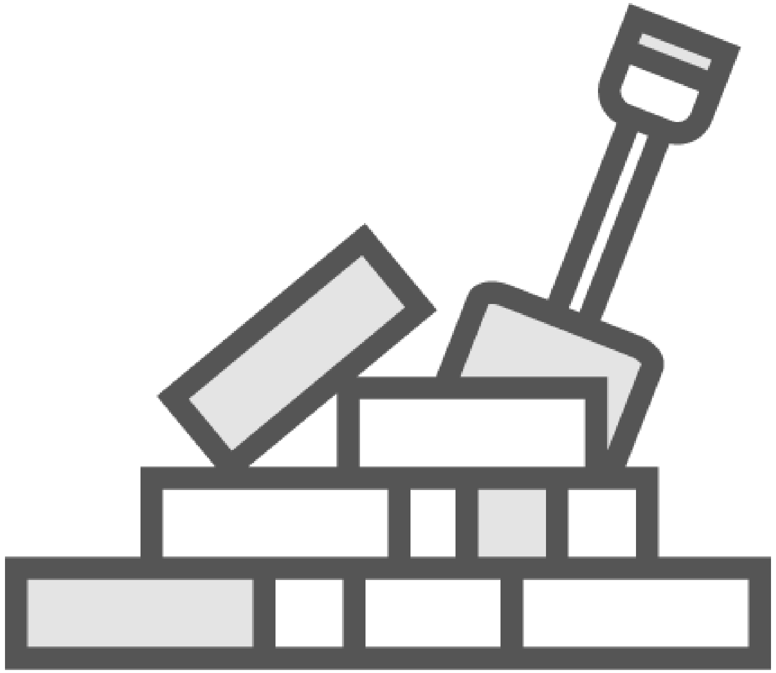
Bakery			Sweets			Beverages	
Bread	Pie	Croissant	Cookie	Cake	Candy	Juice	Tea
7.000	13.000	5.000	8.700	6.300	5.000	7.000	6.600

Example of Drilling Down

Department
Category
Subcategory
Sales

Bakery							
Bread			Pie			Croissant	
Baguette	Pita	Banana br.	Cream	Fruit	Custard	Sweet	Salty
2.000	3.000	2.000	2.500	2.200	8.300	3.000	2.000

Drilling Down - Summary



Drilling down

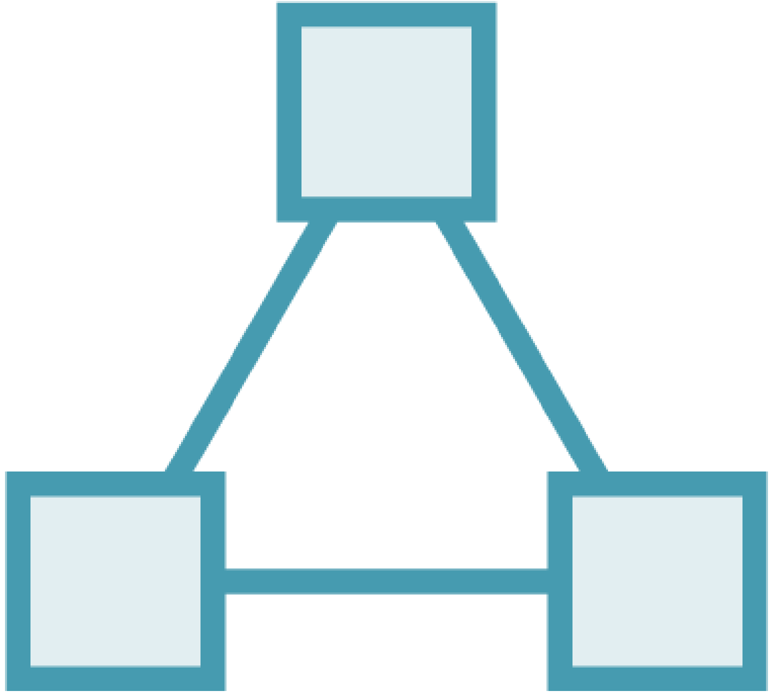
- Adding another member of the dimension to the report
- The member doesn't need to be part of a hierarchy

Drilling up/rolling up

- Taking out an attribute of a dimension from a report

Fixed-depth Positional Hierarchies

Fixed-depth Positional Hierarchies



The number of levels is known upfront

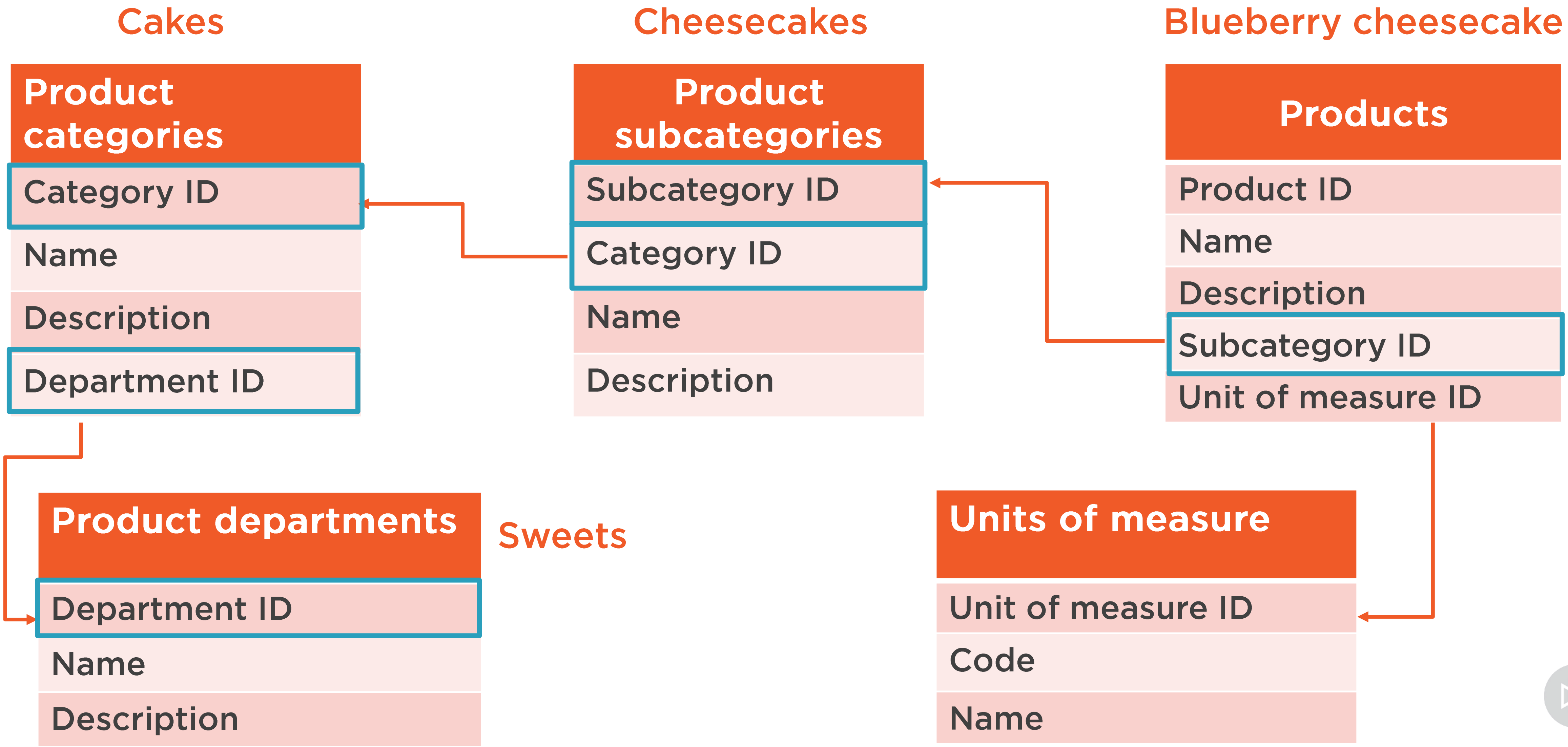
The levels are attributes in the dimension table

It is a series of many-to-one relationships

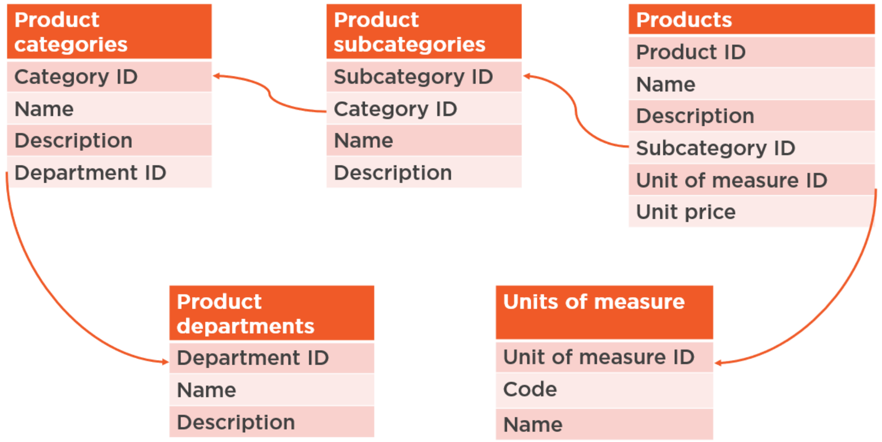
Advantages

- Easy to navigate
- Offers predictable results
- No impact on performance

Product Information from Different Tables



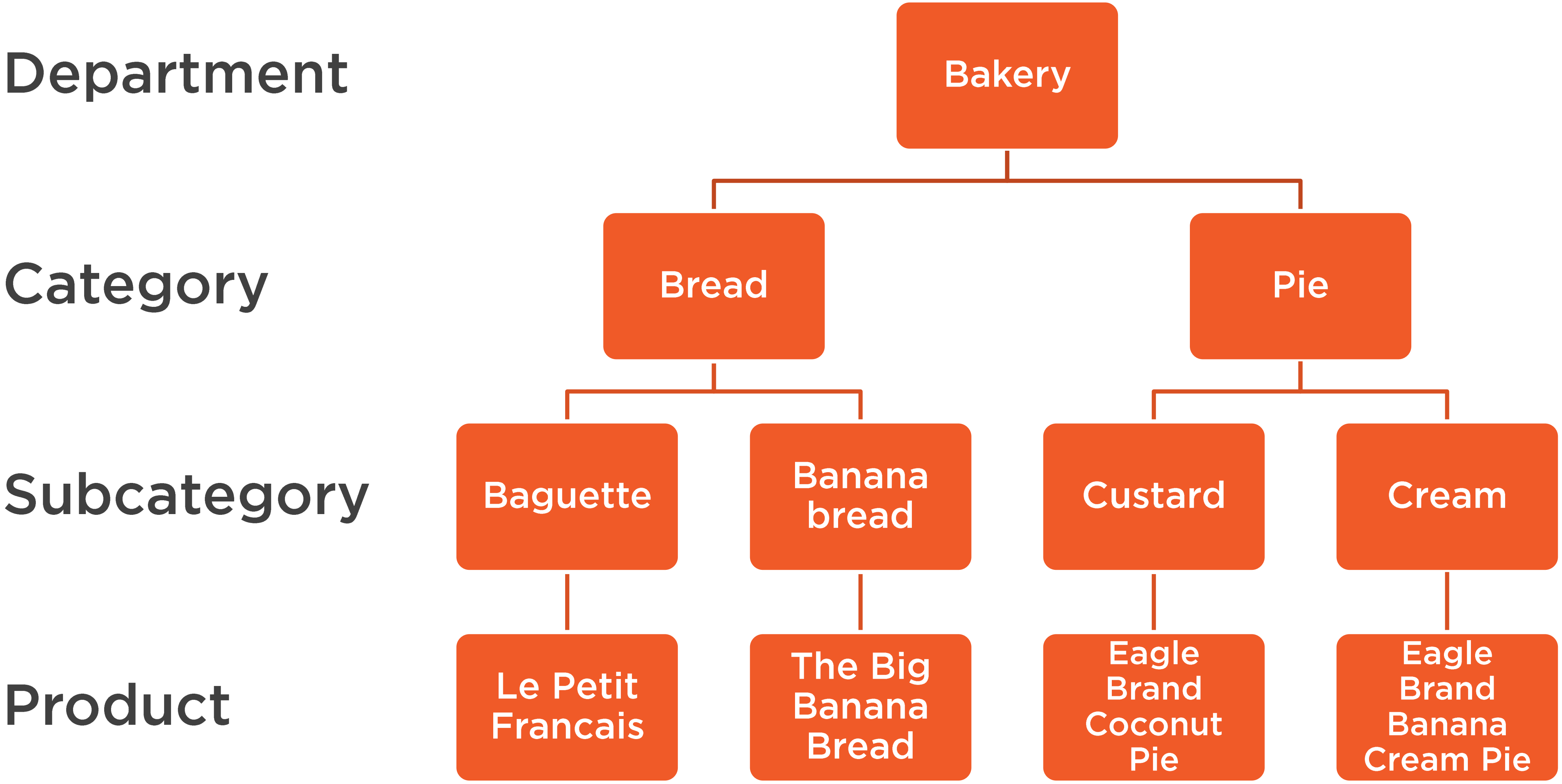
Product Information from the Data Warehouse



Keep in mind:

- Don't create many snowflake designs
- Most relationships should be from fact tables to the dimensions

Creating the Merchandise Hierarchy

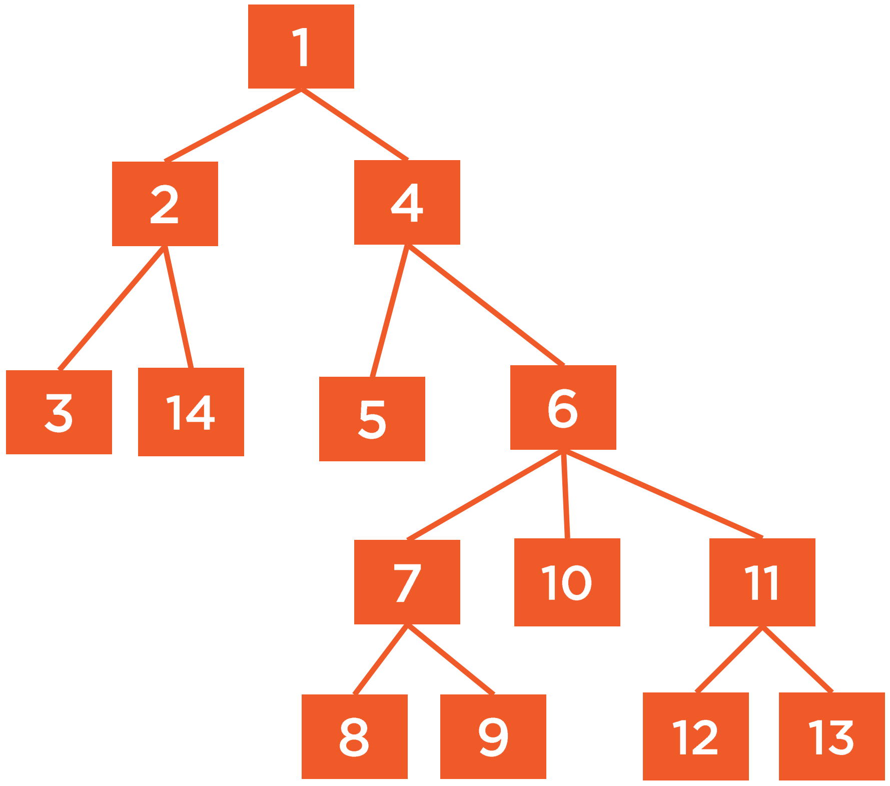


Demo

Creating a fixed-depth positional hierarchy

Variable-depth Positional Hierarchies

Characteristics of Variable-depth Hierarchies



The number of levels is not known at design time

- Example: an organizational chart

Are more complex structures (compared to the fixed-depth hierarchies)

Should be used with moderation

Classification of Variable-depth Hierarchies

Slightly ragged

Ragged, created with a hierarchy bridge

Ragged, created with pathstring attributes

Slightly Ragged Hierarchies

The number of levels is not known beforehand

The range in depth is small

Geographic hierarchies are slightly ragged

Example of a Slightly Ragged Hierarchy

Location hierarchy

- Country
  - Province (or state)
    - City
      - Neighborhood
        - Address

Examples of data with missing levels

Singapore (country and city)

Vatican (independent city-state)

Small cities, that don't have neighborhoods

Fitting Data into a Slightly Ragged Hierarchy

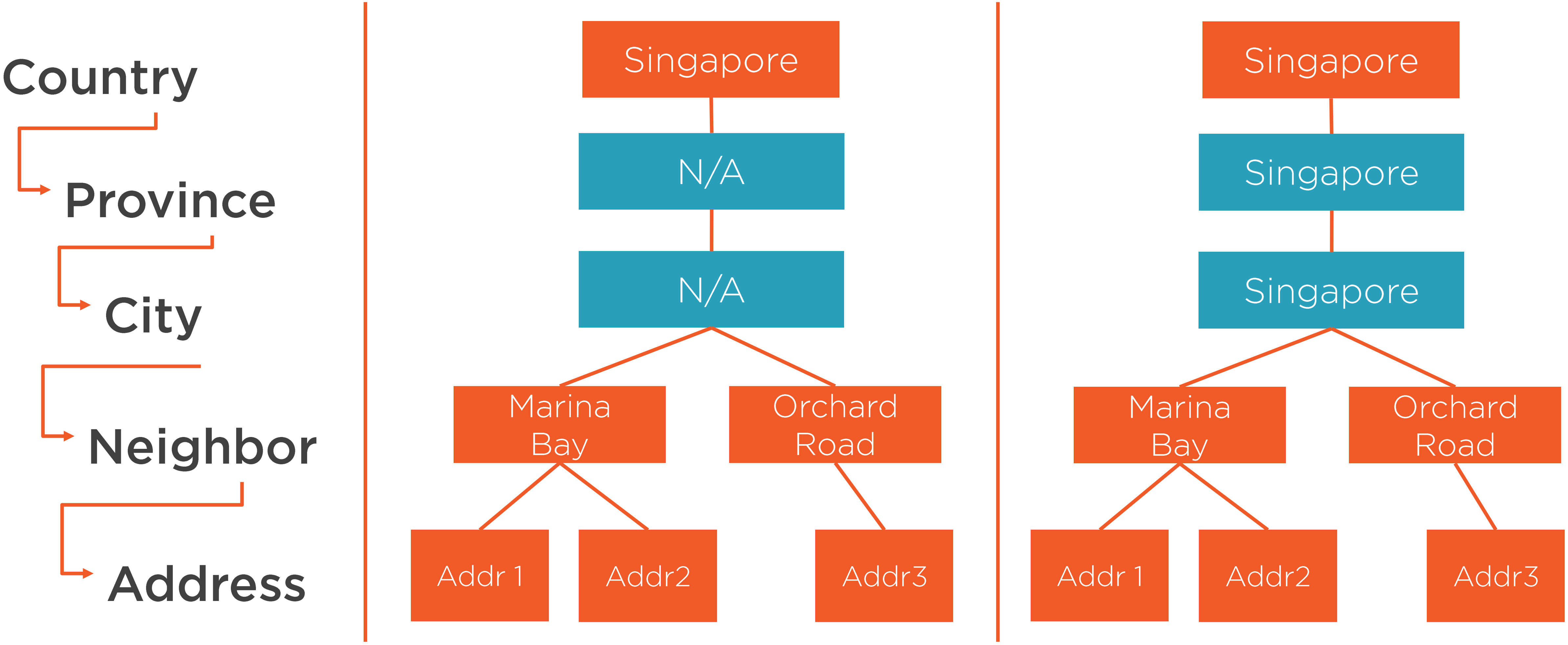
Step 1: Create all possible levels of the hierarchy

Step 2: Fill in the missing values per each level with:

- An expression, similar to “not applicable”
- The value of the next parent member

Step 3: Handle the ragged hierarchy as a fixed-depth one

Populating a Slightly Ragged Hierarchy



Demo

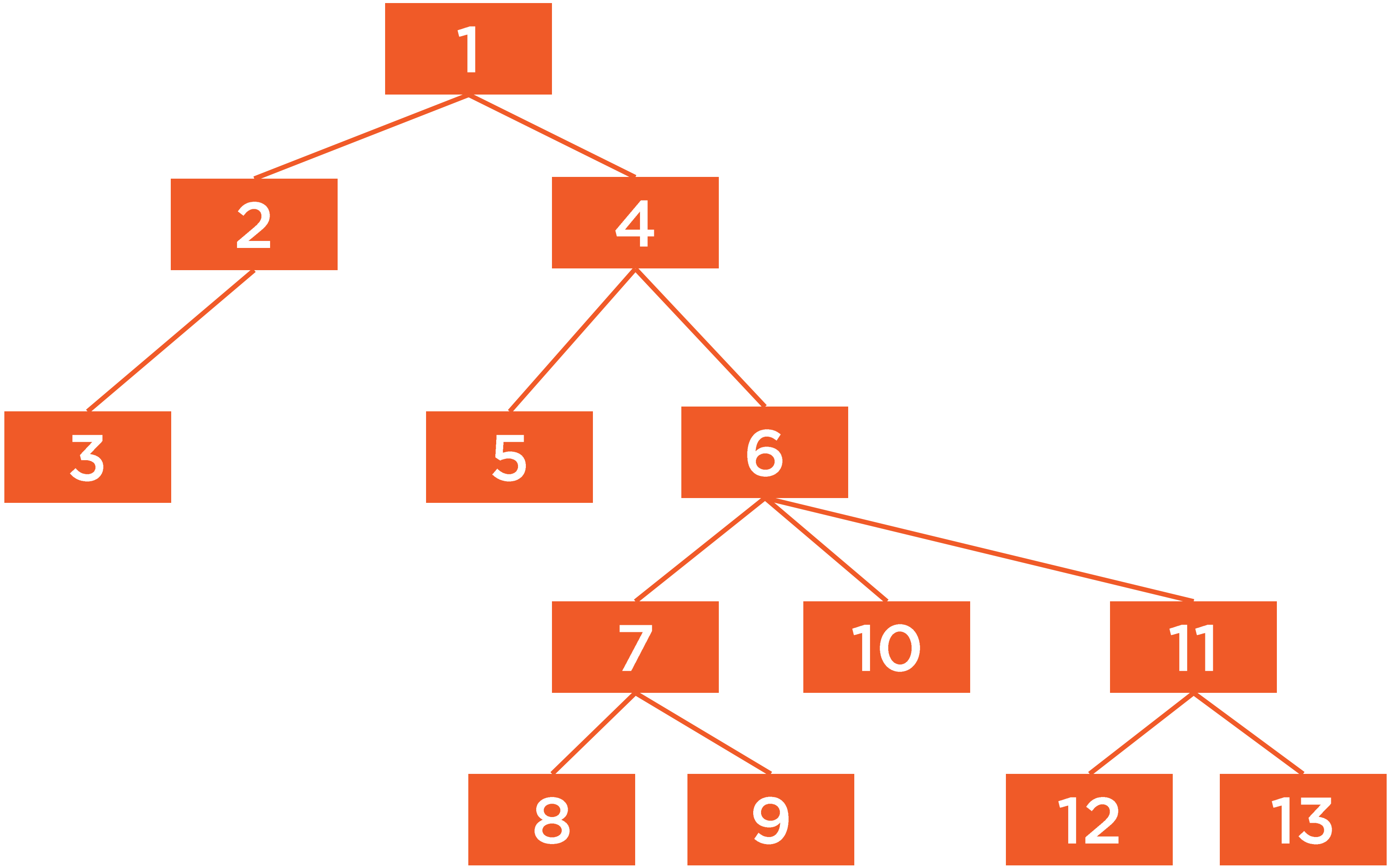
Creating and working with a slightly ragged hierarchy

- Based on the Location dimension

Ragged Hierarchies

Example of a Ragged Hierarchy

The organizational chart



Implementing a Ragged Hierarchy Using a Bridge

A row for each possible path in the hierarchy is stored in a table

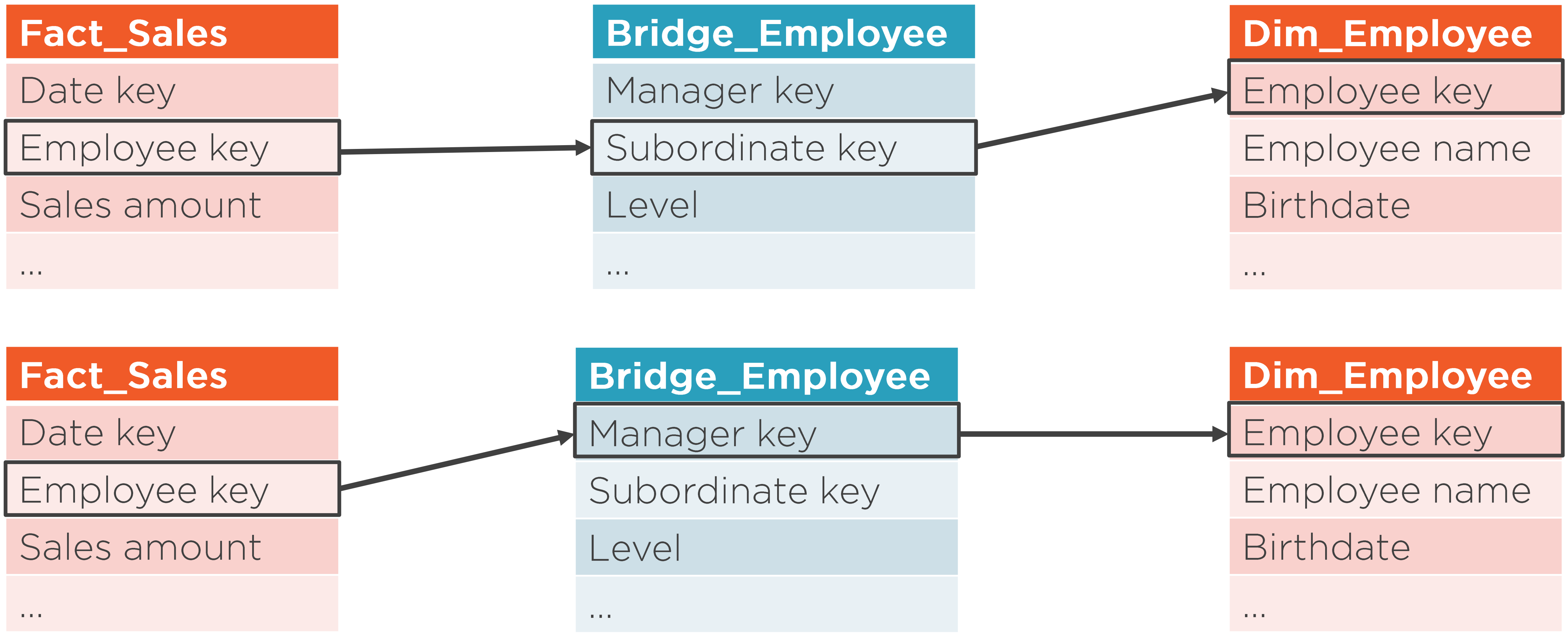
Columns in the bridge table

- ID of the parent
- ID of the child
- Number of levels between them
- Whether the node it a top node or bottom node
- Other information relevant for analysis

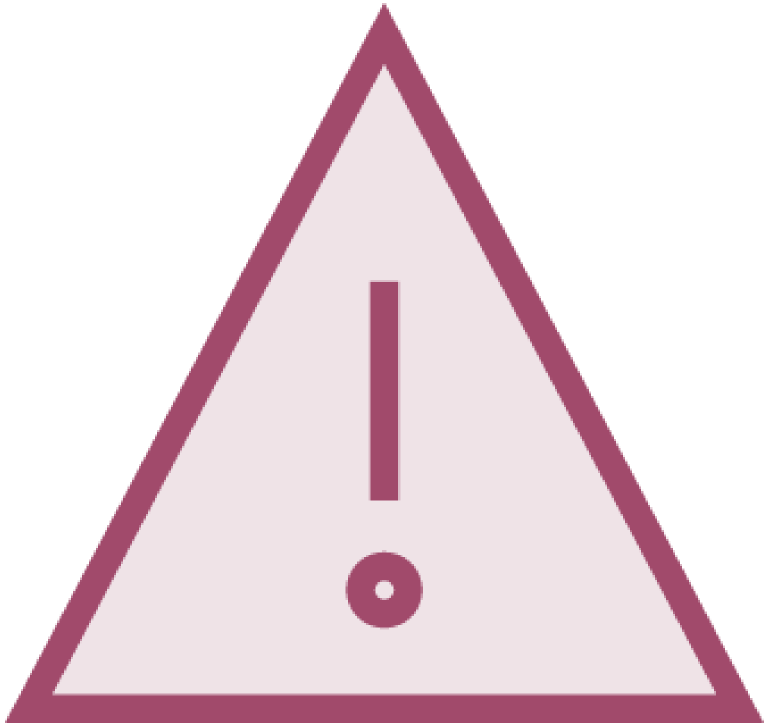
Example of a Hierarchy Bridge Table

Parent key	Child Key	Level	Top flag	Bottom flag
Julia	Julia	0	Y	N
Julia	Marc	1	N	N
Julia	Theodora	2	N	Y
Julia	Greg	2	N	Y
Marc	Marc	0	Y	N
Marc	Theodora	1	N	Y
Marc	Greg	1	N	Y
Theodora	Theodora	0	Y	Y
Greg	Greg	0	Y	Y

Linking the Fact and the Dimension Table



Limitations of the Hierarchy Bridge

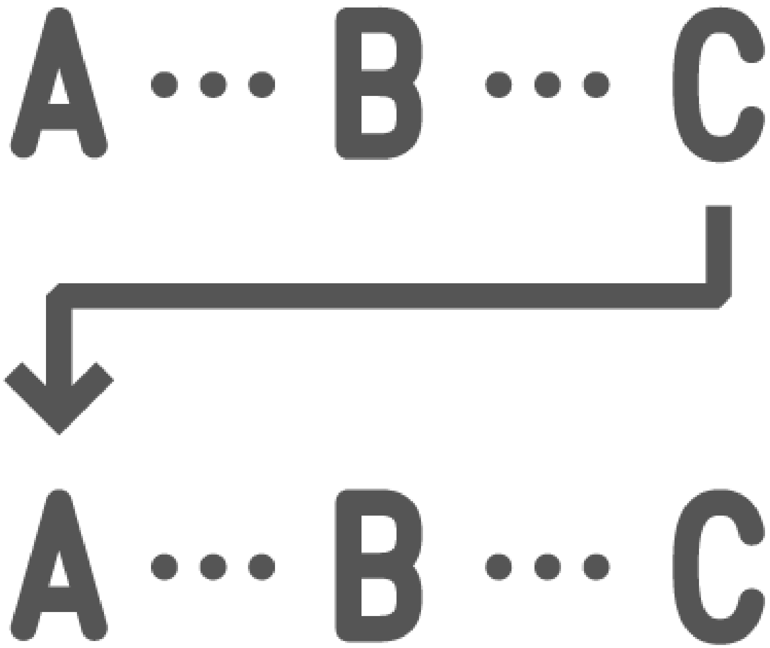


Can grow a lot in size

Performance impact

Difficult to work with

Ragged Hierarchies Created with Pathstring Attributes

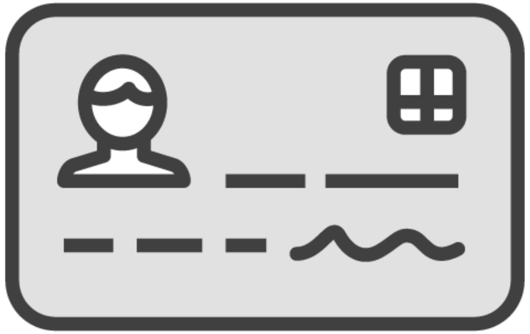


Alternative to the bridge table

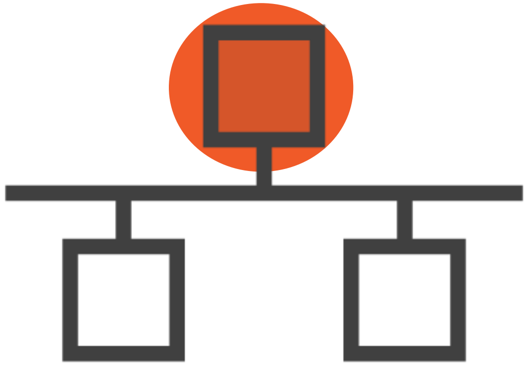
The pathstring attribute:

- A special attribute created in the dimension
- A string of characters
- Consists of all the parents of a member from the top of the hierarchy

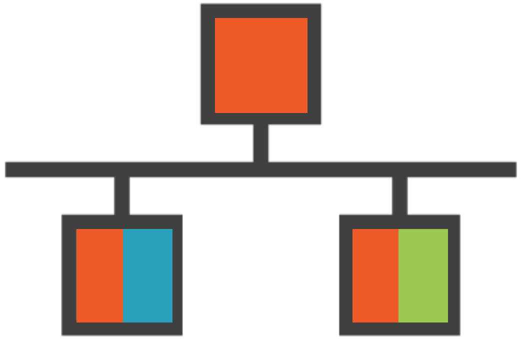
Creating a Hierarchy with Based on Pathstring Attribute



Each node is labeled with a unique value

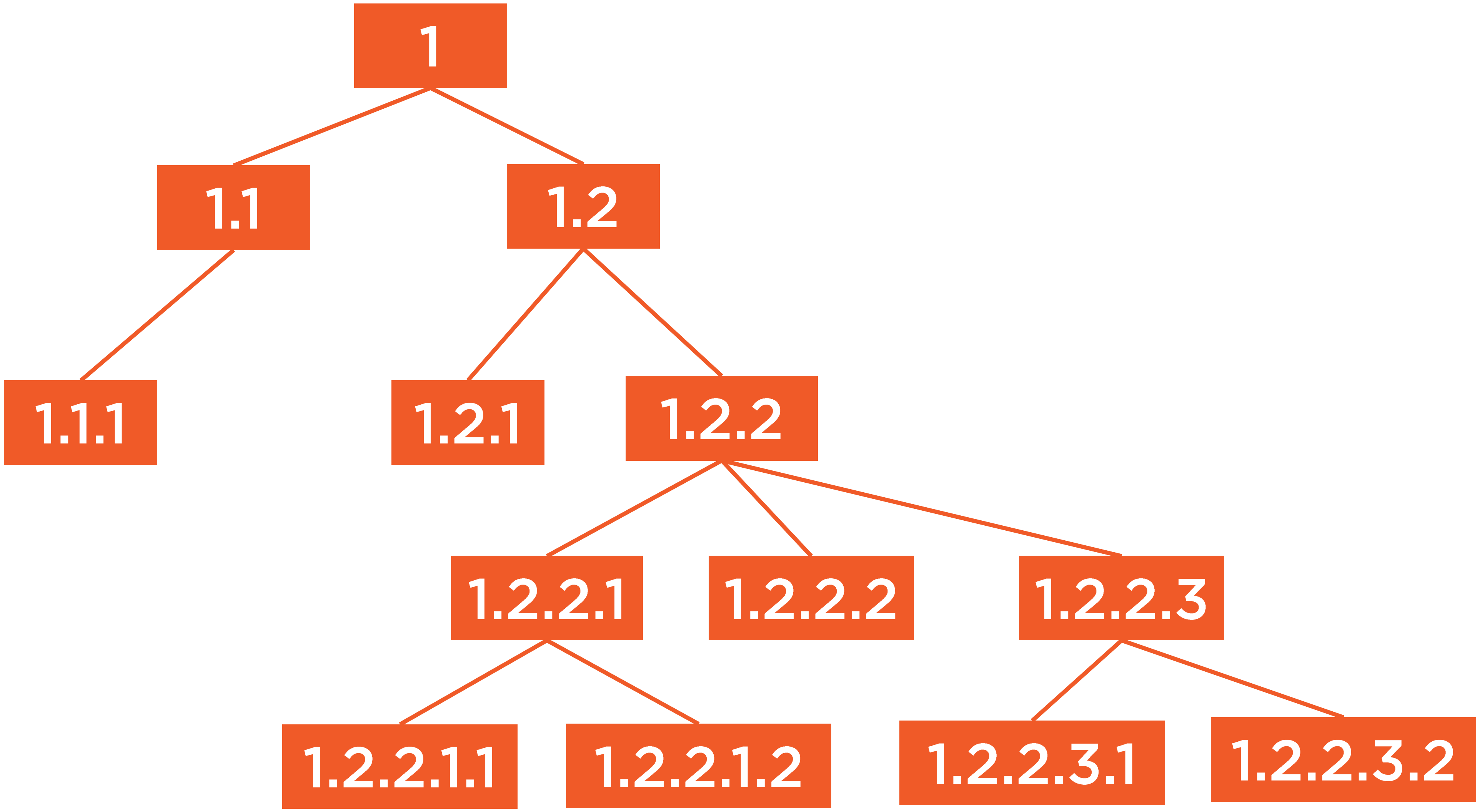


The pathstring of the root node is its unique label

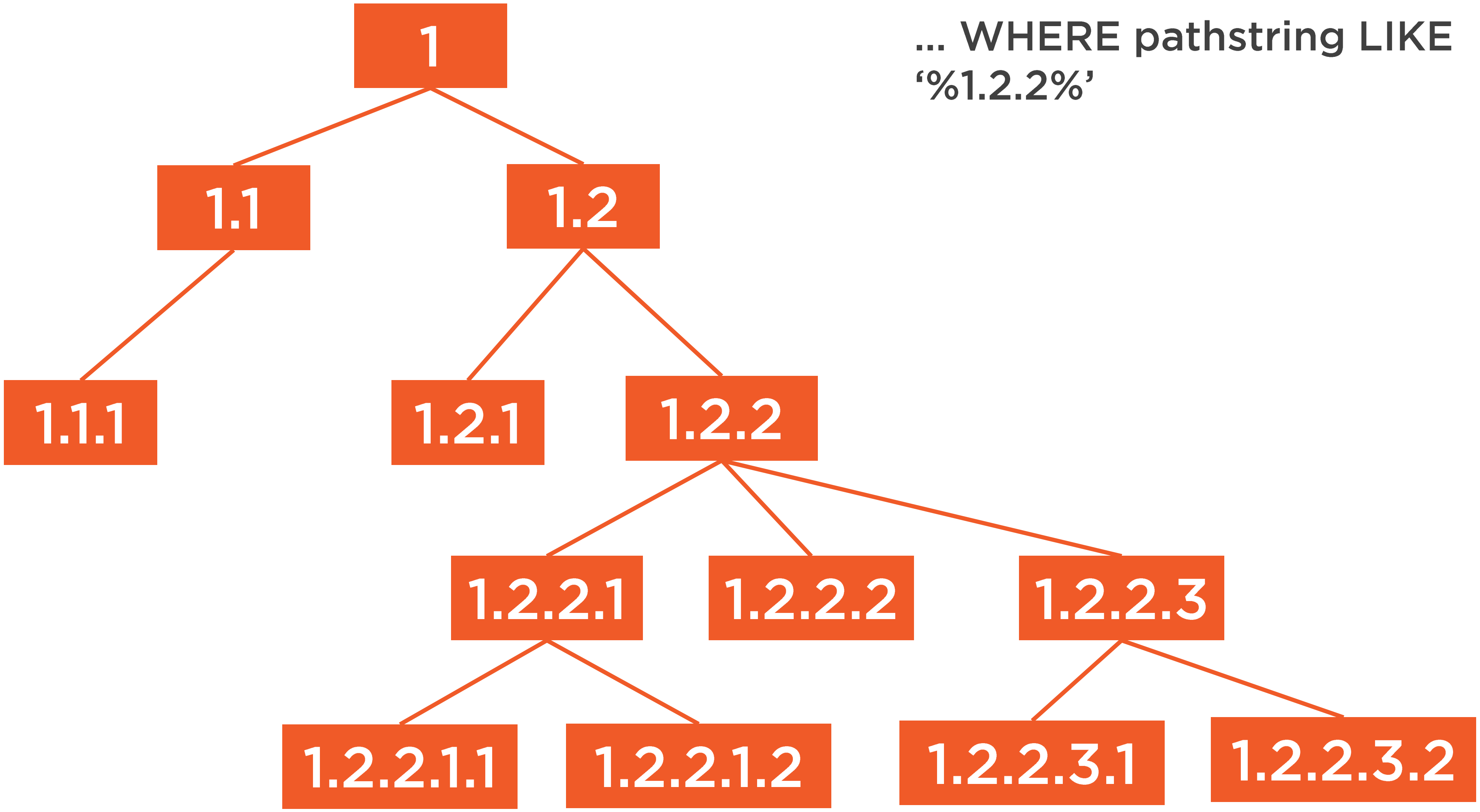


The pathstring on one level includes the pathstring of the parent

Hierarchy Based on Pathstring Attribute

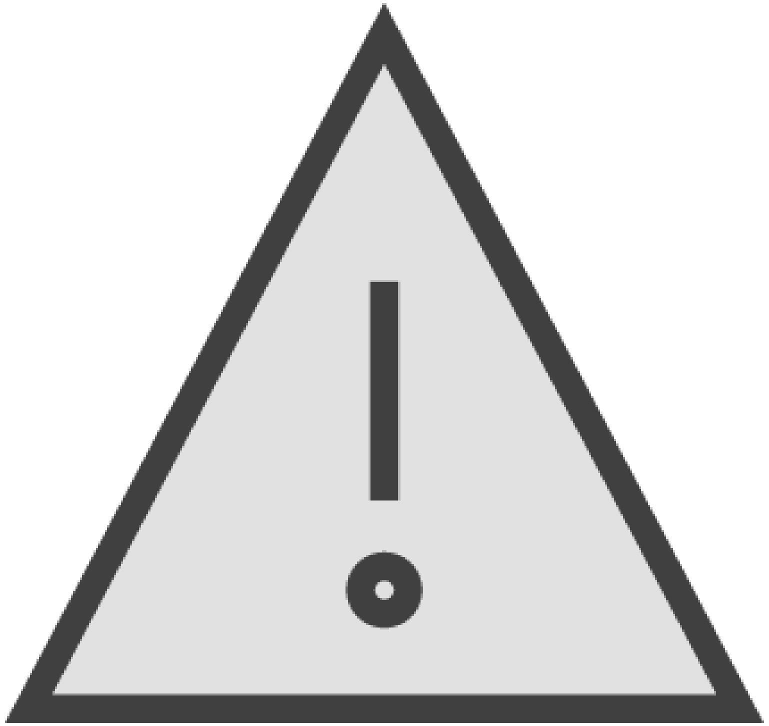


Hierarchy Based on Pathstring Attribute



… WHERE pathstring LIKE '%1.2.2%'

Limitations of the Pathstring Attribute



Vulnerable to structure changes

- If a member is moved within the organization (or added or deleted)
- Entire hierarchy must be relabeled

Complicated to use by business users

- Accessing the database directly
- Using the ‘LIKE’ operator in SQL queries

Summary

There is no “best solution” to this problem

A good enough solution is generated by having a clear understanding of

- The data available
- The business requirements

Summary

Hierarchy definition

- Data structures with multiple levels
- Levels are formed with attributes of a dimension

Advantages of hierarchies

- Structure the data
- Multiple perspectives of the same data
- Easily visualize summarized or detailed data

Types of hierarchies

- Fixed-depth
- Variable-depth
    - Slightly ragged
    - Ragged

Creating and Working with Hierarchies

Ana Voicu

@ana_voicu

Overview

In short, a hierarchy is:

- A data structure
- Created with attributes from a dimension
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Topics elaborated in this chapter:

- What is a hierarchy?
- Why is it useful?
- What does drilling-down mean?
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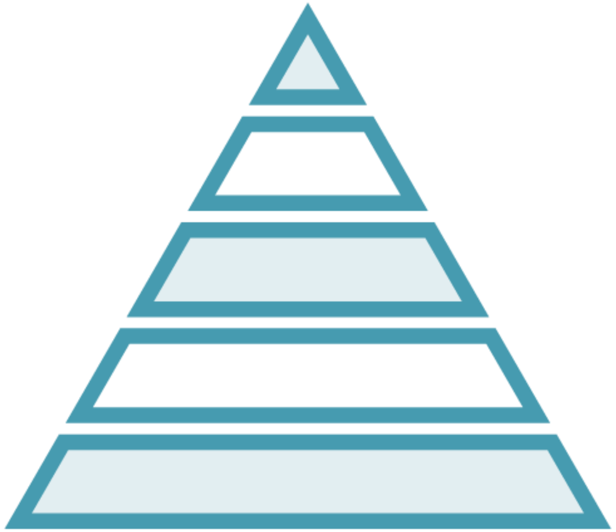

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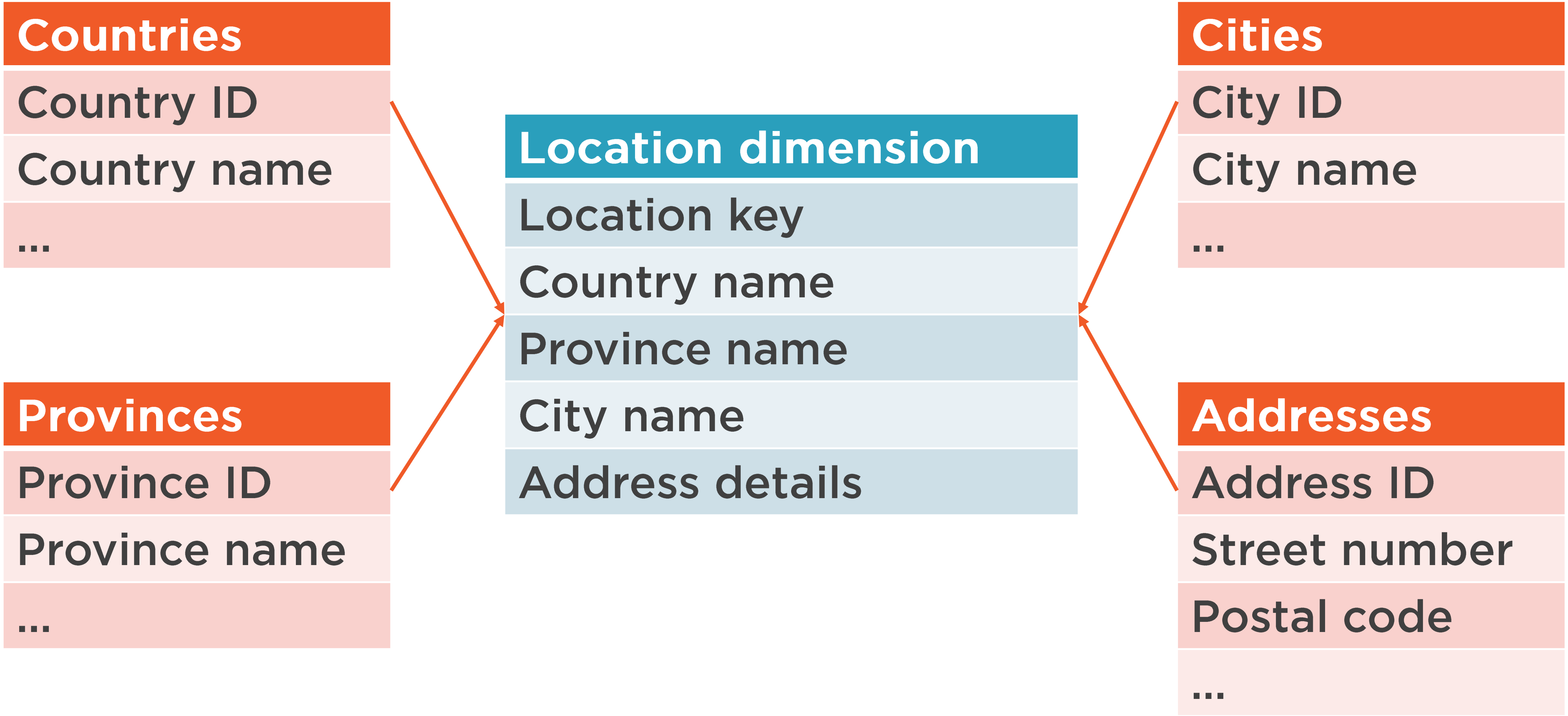


A Hierarchy in the Location Dimension

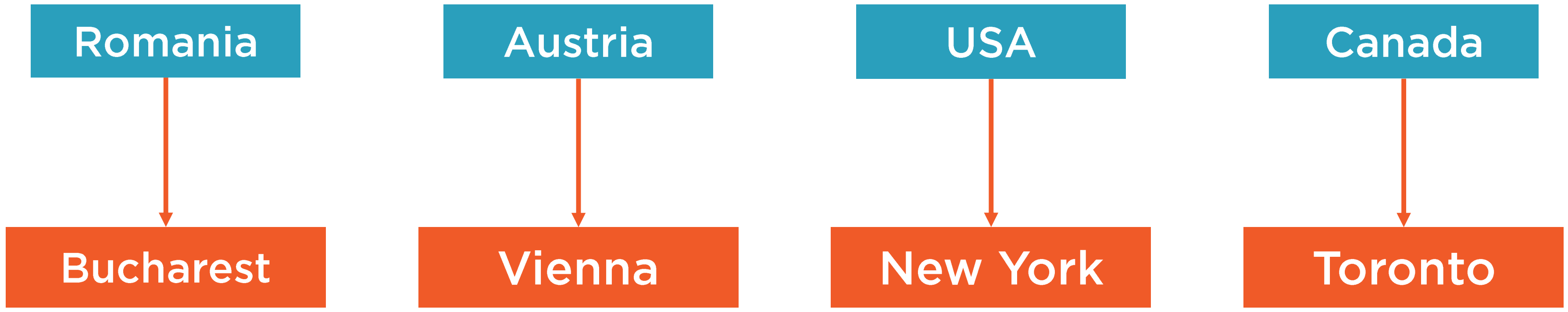
Bucharest

Vienna

New York

Toronto

A Hierarchy in the Location Dimension



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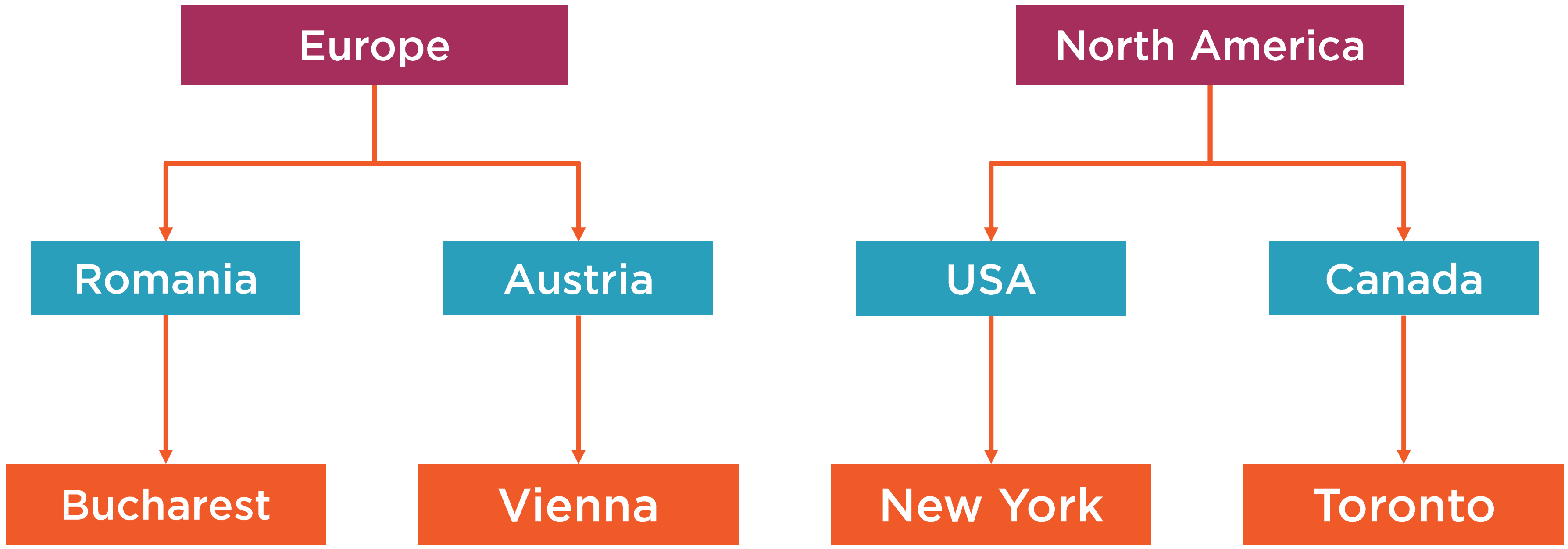

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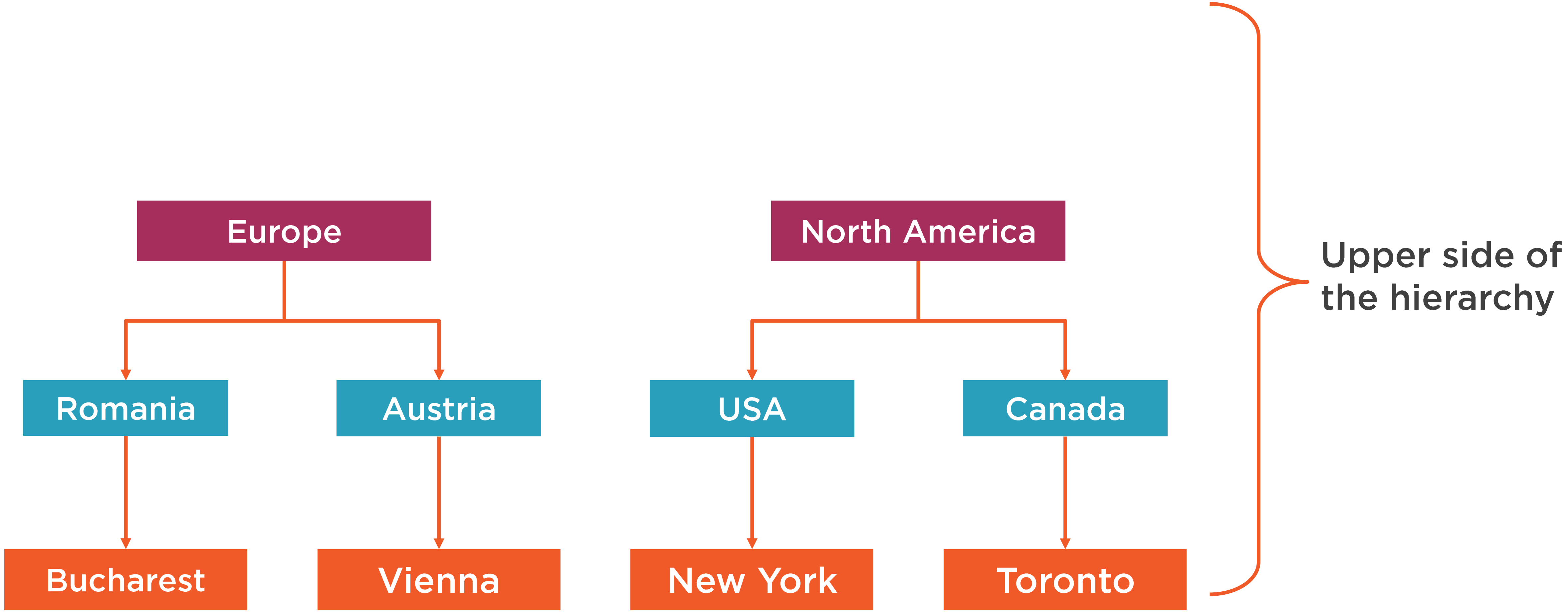

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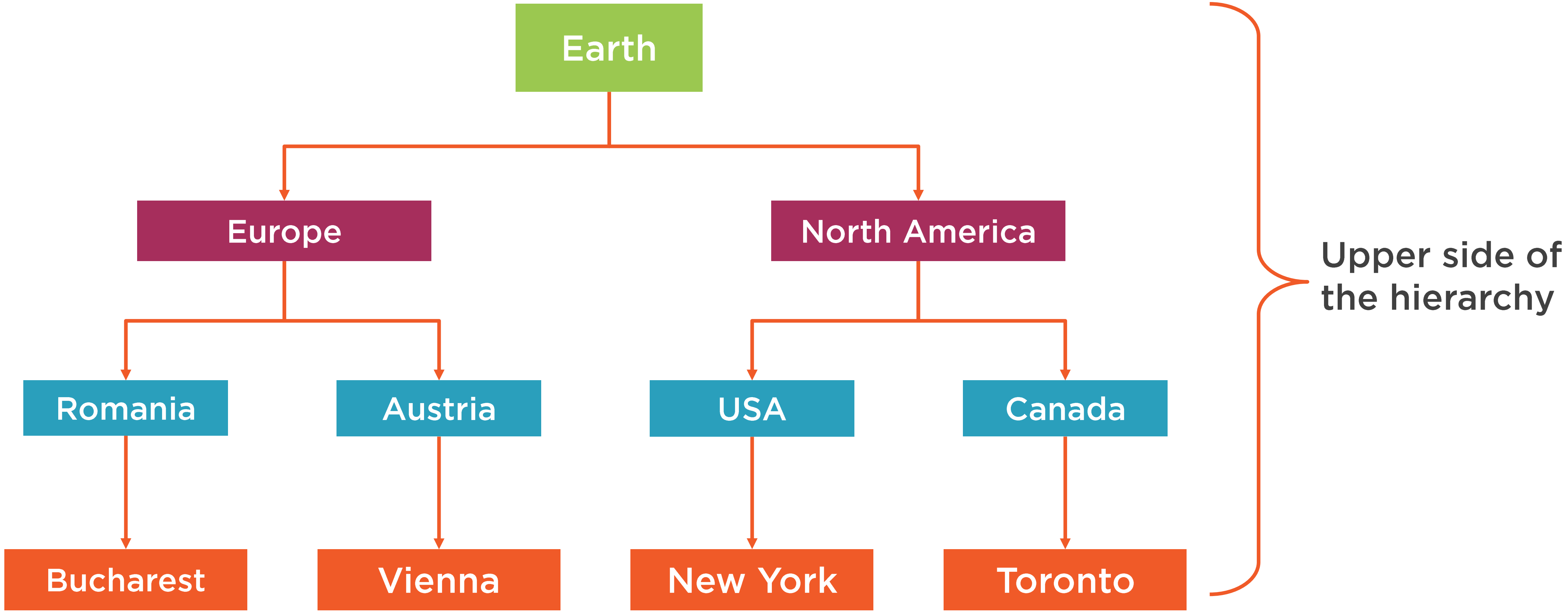

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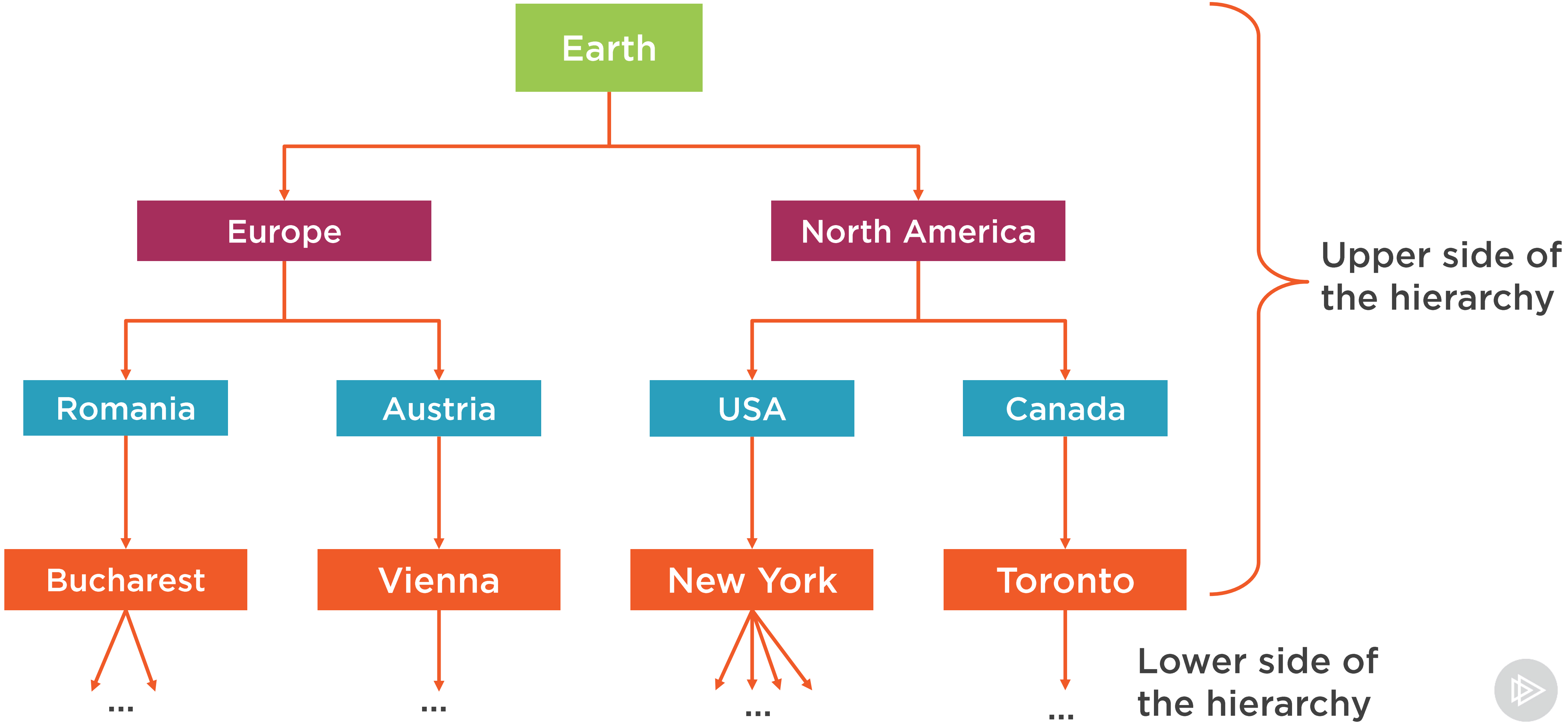

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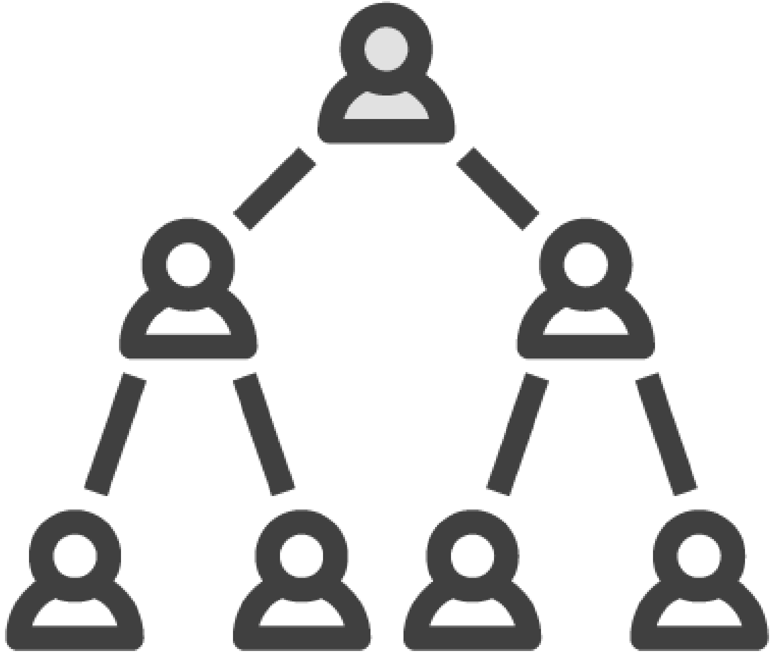

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Merchandise hierarchy

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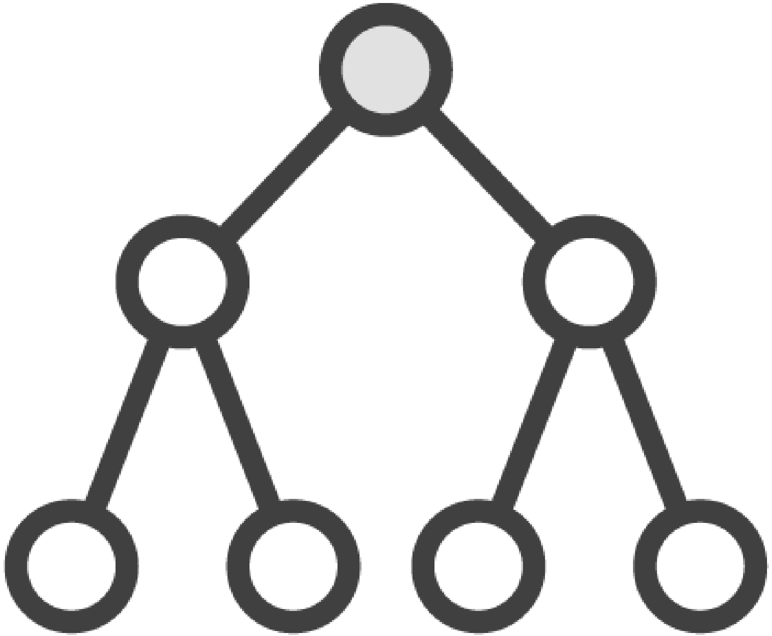

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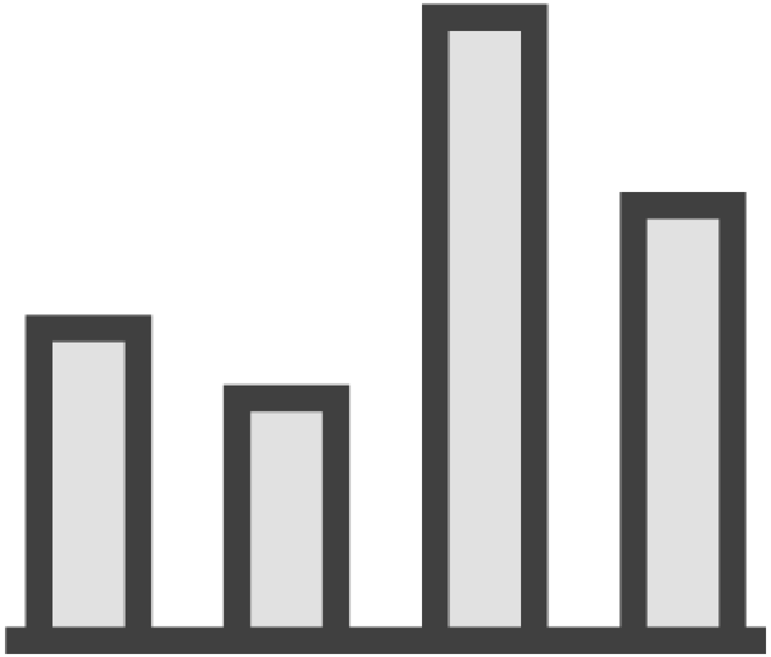
Drilling Down a Hierarchy

Data Warehouse Analysis



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Unit of measure
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Merchandise hierarchy

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        - Subcategory
            - Product name

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Sales

80.000

Department Sales

Bakery	Sweets	Beverages
25.000	40.000	15.000

Example of Drilling Down

Department

Category

Sales

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Department
Category
Subcategory
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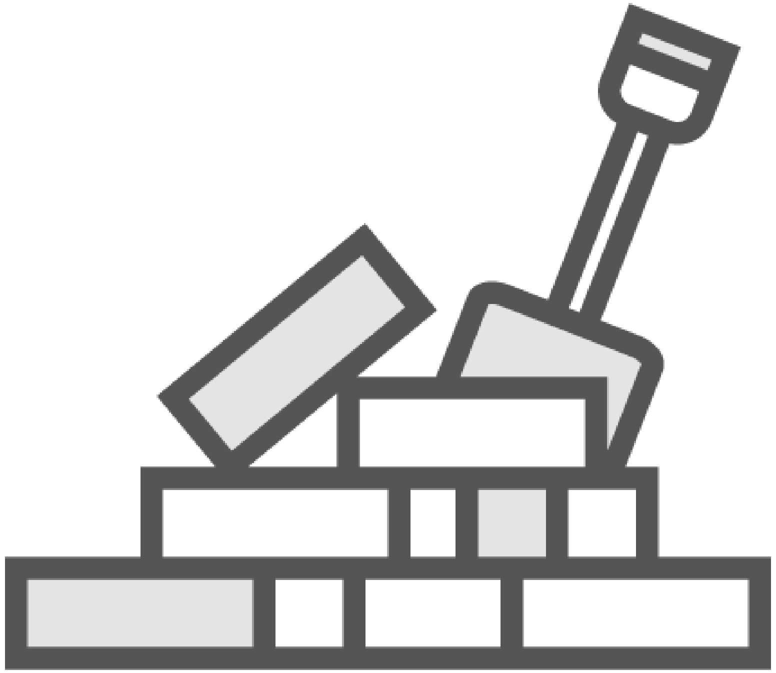
2.000	3.000	2.000	2.500	2.200	8.300	3.000	2.000

Drilling Down - Summary



Drilling down

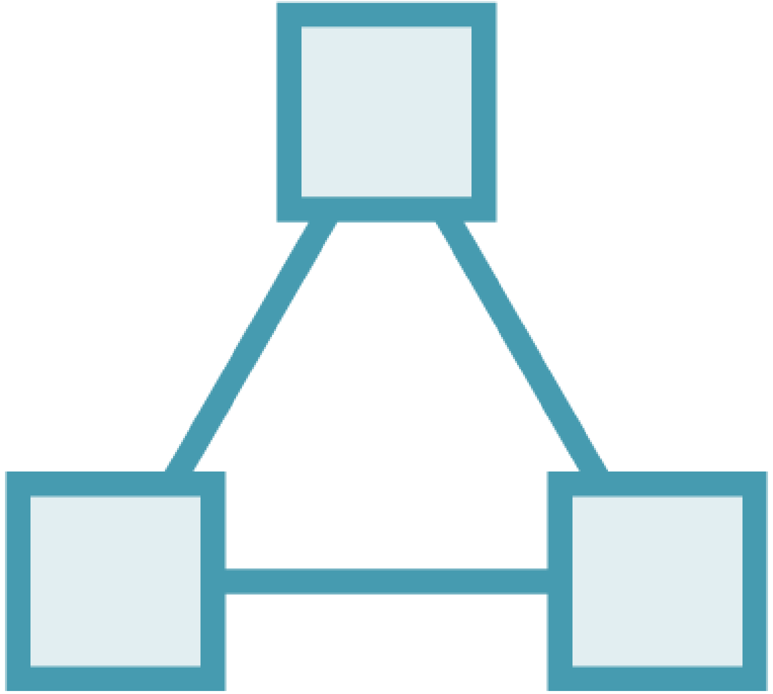
- Adding another member of the dimension to the report
- The member doesn't need to be part of a hierarchy

Drilling up/rolling up

- Taking out an attribute of a dimension from a report

Fixed-depth Positional Hierarchies

Fixed-depth Positional Hierarchies



The number of levels is known upfront

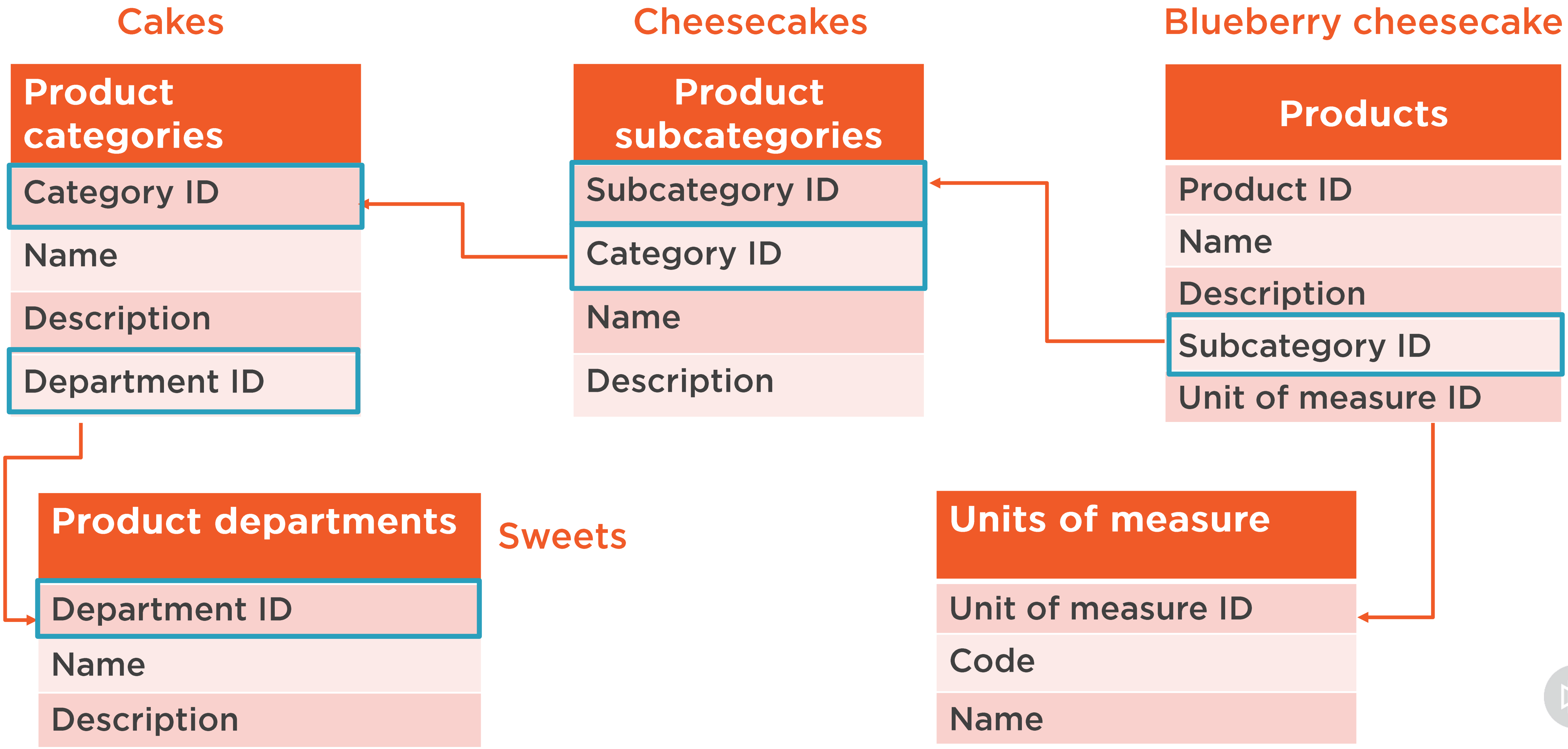
The levels are attributes in the dimension table

It is a series of many-to-one relationships

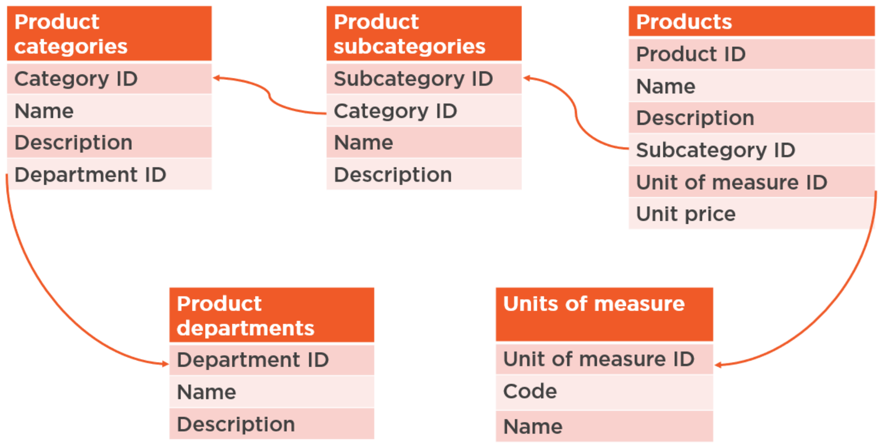
Advantages

- Easy to navigate
- Offers predictable results
- No impact on performance

Product Information from Different Tables



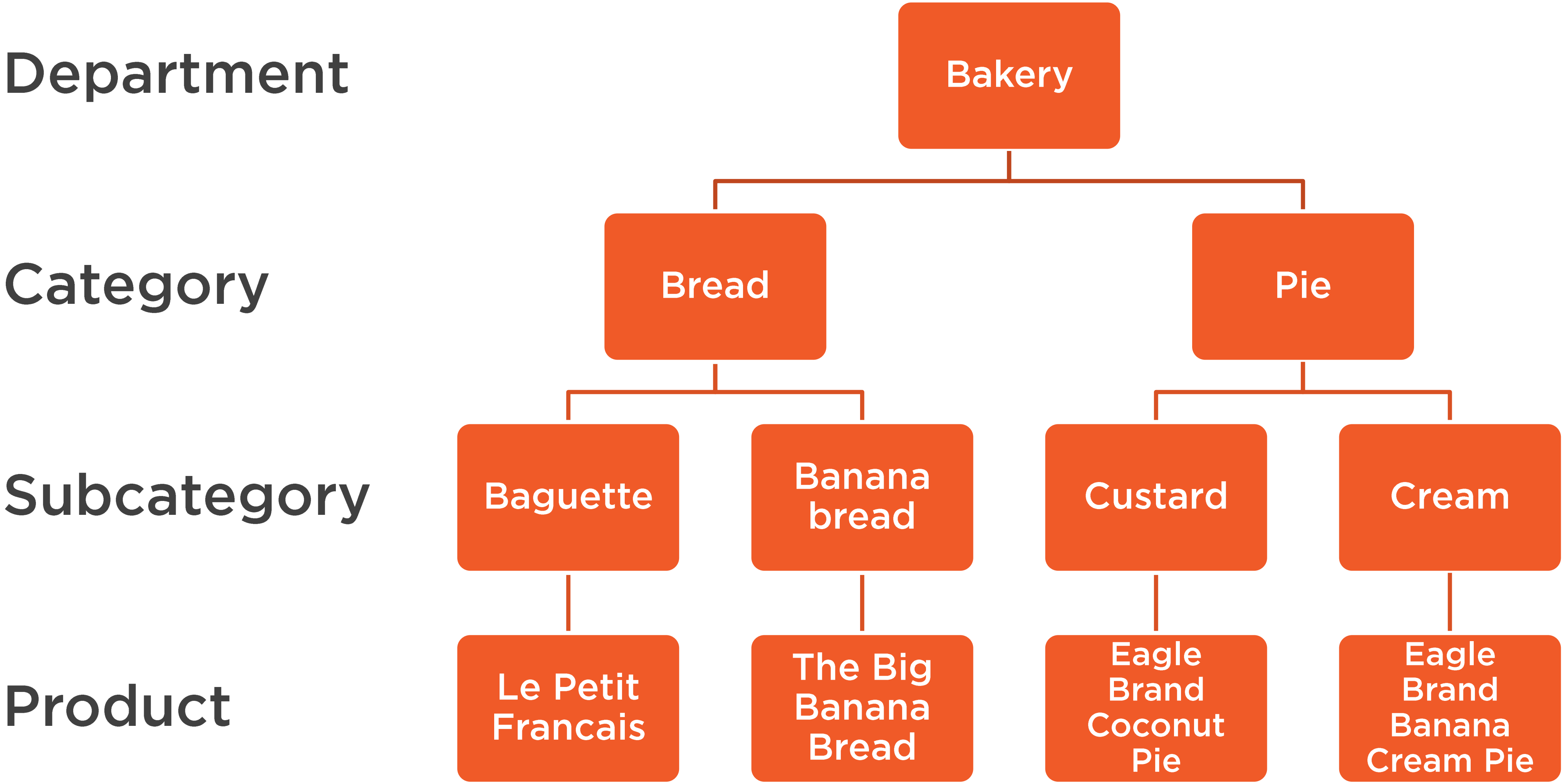
Product Information from the Data Warehouse



Keep in mind:

- Don't create many snowflake designs
- Most relationships should be from fact tables to the dimensions

Creating the Merchandise Hierarchy

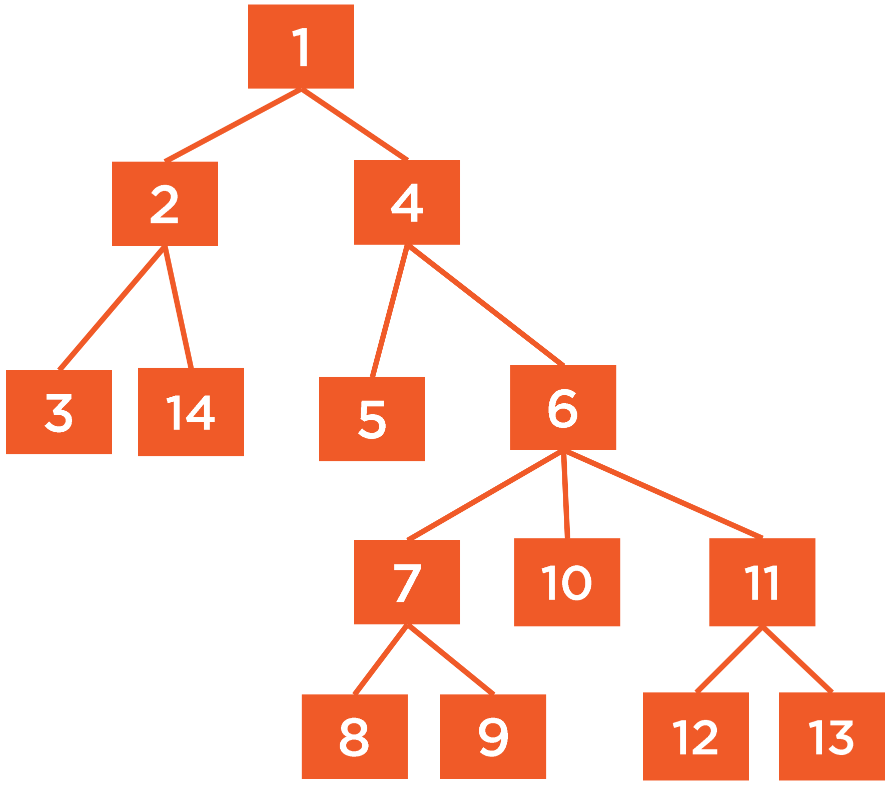


Demo

Creating a fixed-depth positional hierarchy

Variable-depth Positional Hierarchies

Characteristics of Variable-depth Hierarchies



The number of levels is not known at design time

- Example: an organizational chart

Are more complex structures (compared to the fixed-depth hierarchies)

Should be used with moderation

Classification of Variable-depth Hierarchies

Slightly ragged

Ragged, created with a hierarchy bridge

Ragged, created with pathstring attributes

Slightly Ragged Hierarchies

The number of levels is not known beforehand

The range in depth is small

Geographic hierarchies are slightly ragged

Example of a Slightly Ragged Hierarchy

Location hierarchy

- Country
  - Province (or state)
    - City
      - Neighborhood
        - Address

Examples of data with missing levels

Singapore (country and city)

Vatican (independent city-state)

Small cities, that don’t have neighborhoods

Fitting Data into a Slightly Ragged Hierarchy

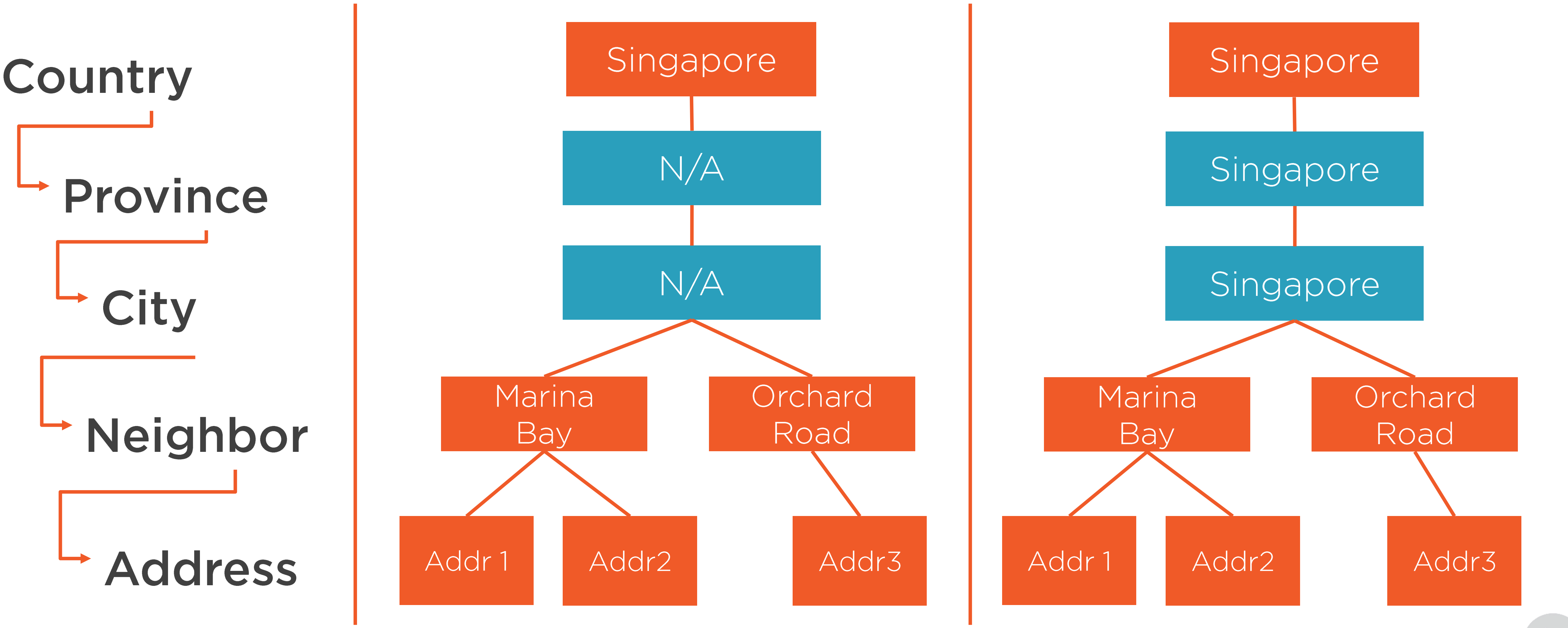
Step 1: Create all possible levels of the hierarchy

Step 2: Fill in the missing values per each level with:

- An expression, similar to "not applicable"
- The value of the next parent member

Step 3: Handle the ragged hierarchy as a fixed-depth one

Populating a Slightly Ragged Hierarchy



Demo

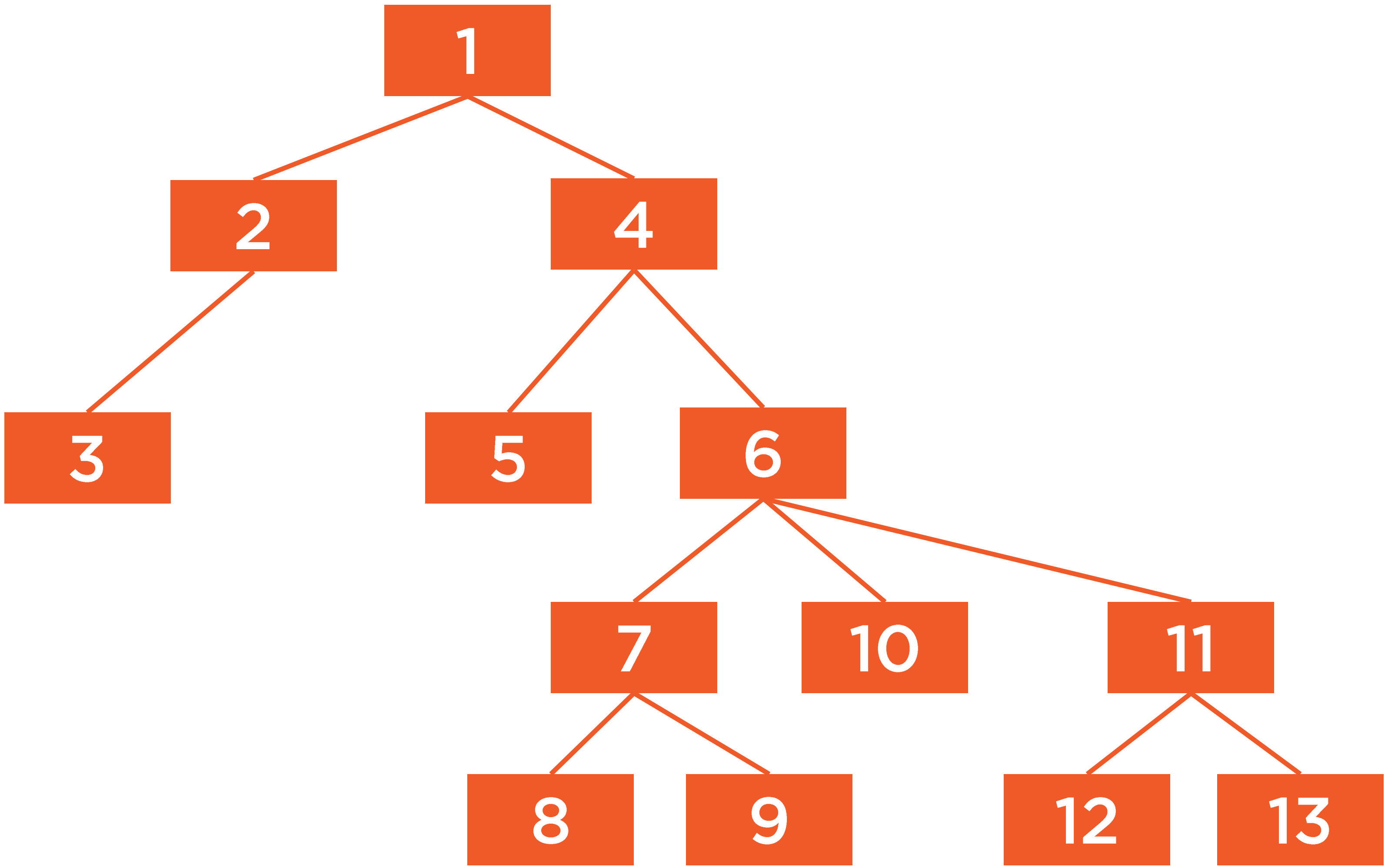
Creating and working with a slightly ragged hierarchy

- Based on the Location dimension

Ragged Hierarchies

Example of a Ragged Hierarchy

The organizational chart



Implementing a Ragged Hierarchy Using a Bridge

A row for each possible path in the hierarchy is stored in a table

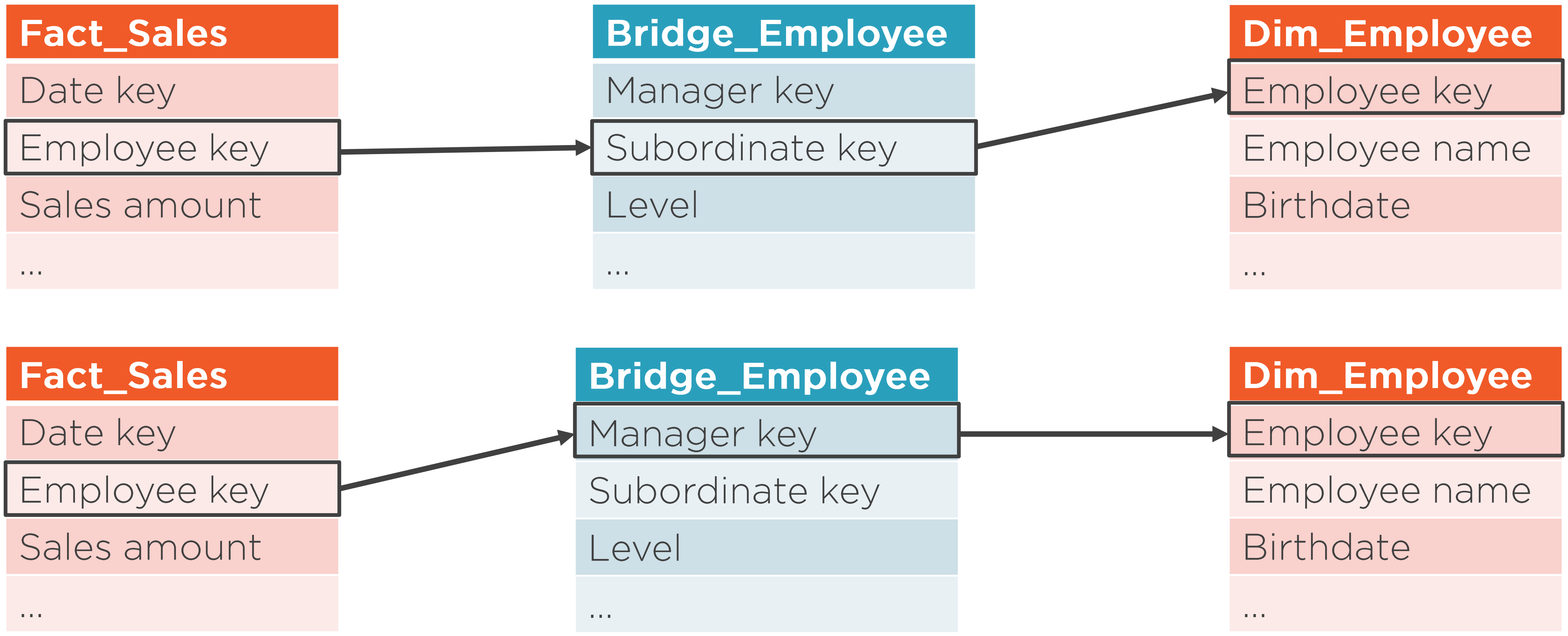
Columns in the bridge table

- ID of the parent
- ID of the child
- Number of levels between them
- Whether the node it a top node or bottom node
- Other information relevant for analysis

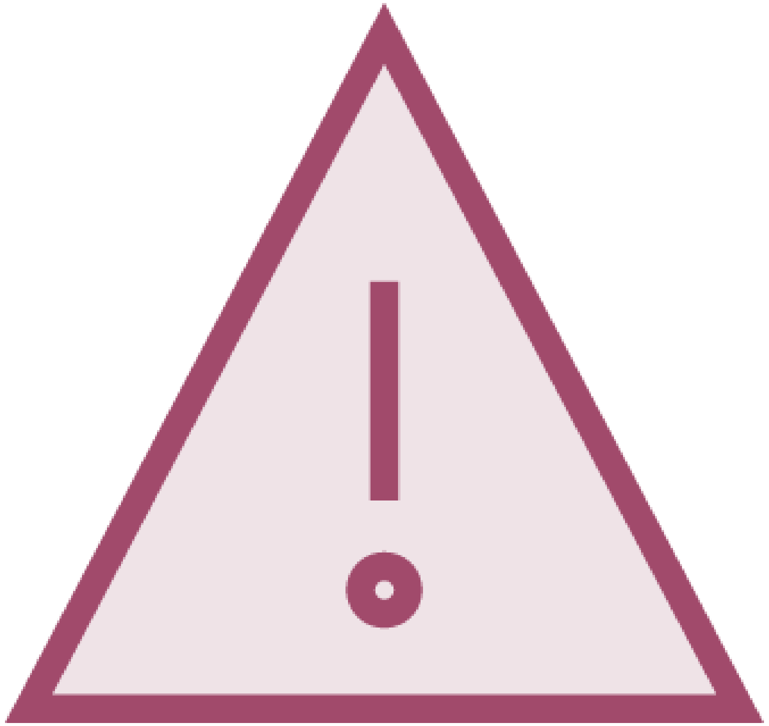
Example of a Hierarchy Bridge Table

Parent key	Child Key	Level	Top flag	Bottom flag
Julia	Julia	0	Y	N
Julia	Marc	1	N	N
Julia	Theodora	2	N	Y
Julia	Greg	2	N	Y
Marc	Marc	0	Y	N
Marc	Theodora	1	N	Y
Marc	Greg	1	N	Y
Theodora	Theodora	0	Y	Y
Greg	Greg	0	Y	Y

Linking the Fact and the Dimension Table



Limitations of the Hierarchy Bridge

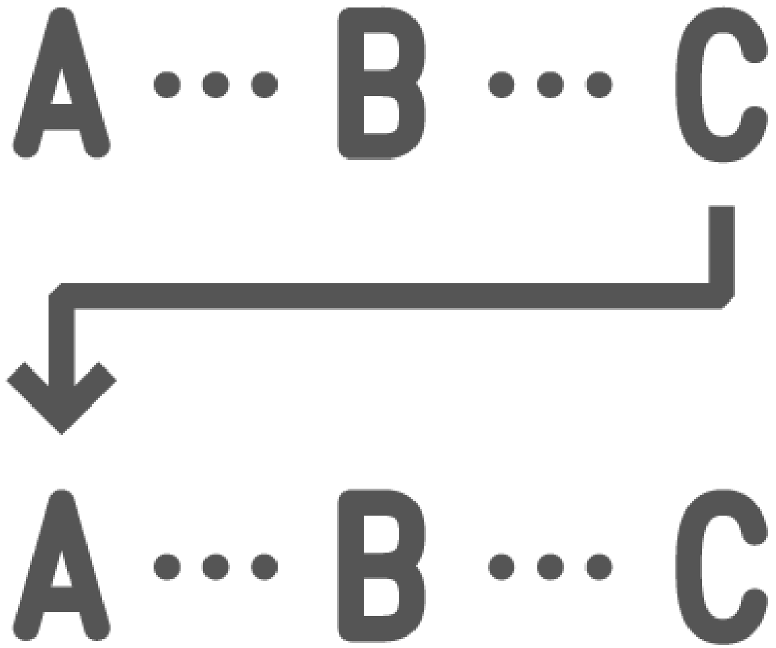


Can grow a lot in size

Performance impact

Difficult to work with

Ragged Hierarchies Created with Pathstring Attributes

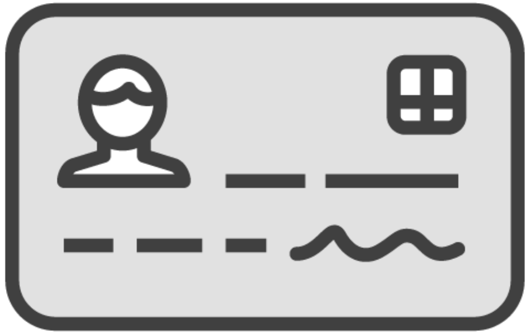


Alternative to the bridge table

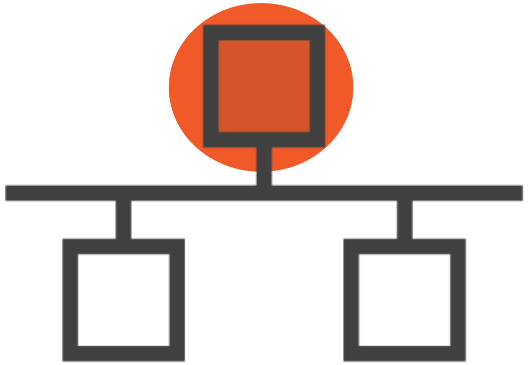
The pathstring attribute:

- A special attribute created in the dimension
- A string of characters
- Consists of all the parents of a member from the top of the hierarchy

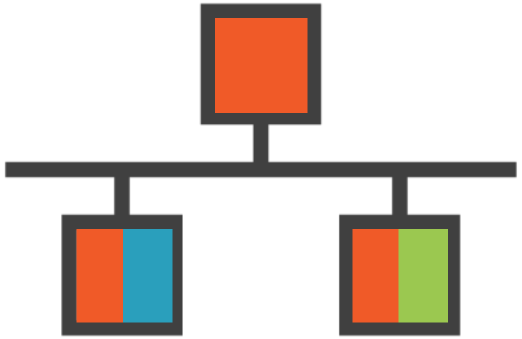
Creating a Hierarchy with Based on Pathstring Attribute



Each node is labeled with a unique value

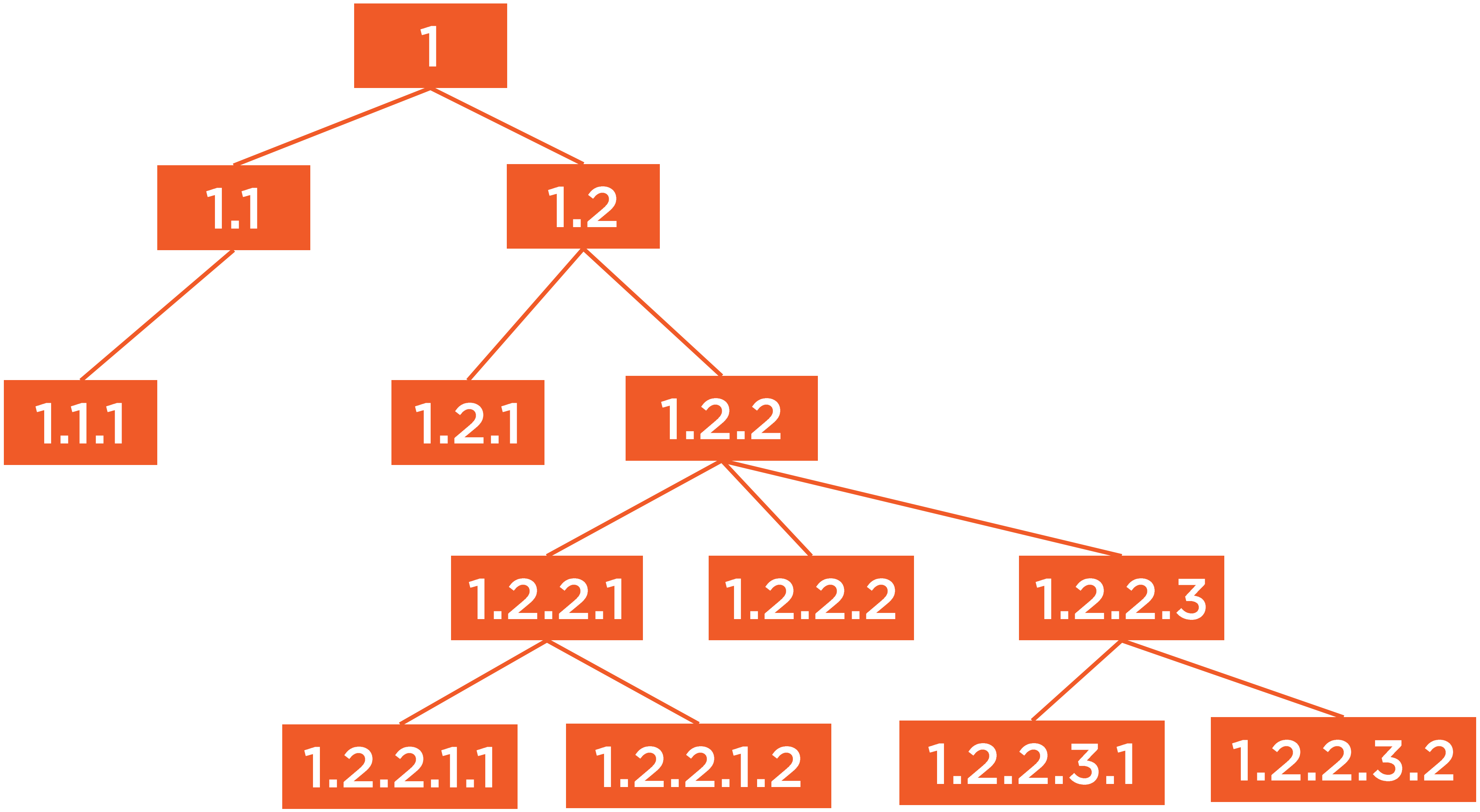


The pathstring of the root node is its unique label

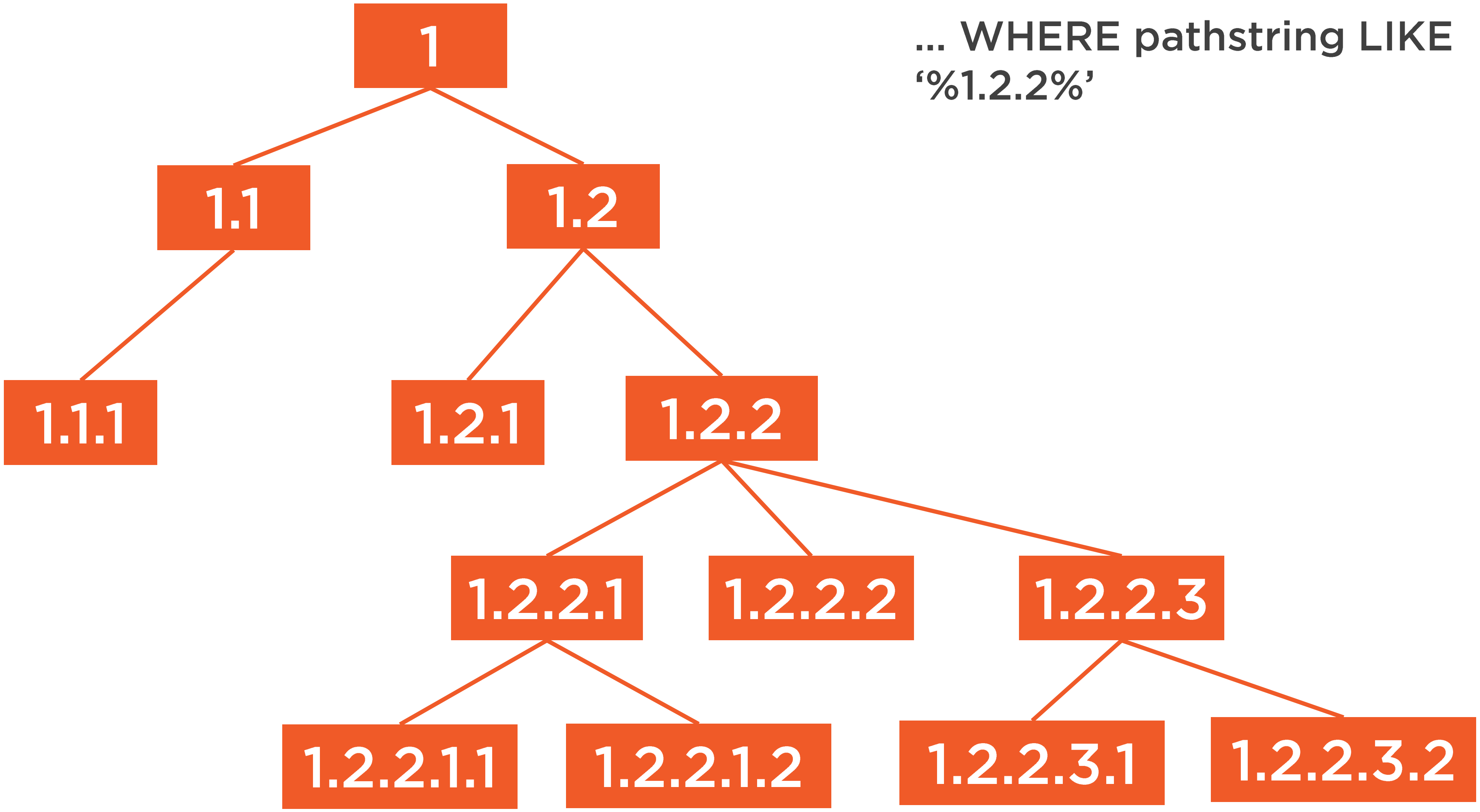


The pathstring on one level includes the pathstring of the parent

Hierarchy Based on Pathstring Attribute



Hierarchy Based on Pathstring Attribute



… WHERE pathstring LIKE '%1.2.2%'

Limitations of the Pathstring Attribute

Vulnerable to structure changes

- If a member is moved within the organization (or added or deleted)
- Entire hierarchy must be relabeled

Complicated to use by business users

- Accessing the database directly
- Using the ‘LIKE’ operator in SQL queries

Summary

There is no "best solution" to this problem

A good enough solution is generated by having a clear understanding of

- The data available
- The business requirements

Summary

Hierarchy definition

- Data structures with multiple levels
- Levels are formed with attributes of a dimension

Advantages of hierarchies

- Structure the data
- Multiple perspectives of the same data
- Easily visualize summarized or detailed data

Types of hierarchies

- Fixed-depth
- Variable-depth
  - Slightly ragged
  - Ragged

Implementing Fact Tables

Ana Voicu

@ana_voicu

Overview

Structure of a fact table

The most common types of fact tables

- Transaction
- Periodic snapshot
- Accumulating snapshot

Handling nulls in fact tables

Demo: Creating and working with fact tables

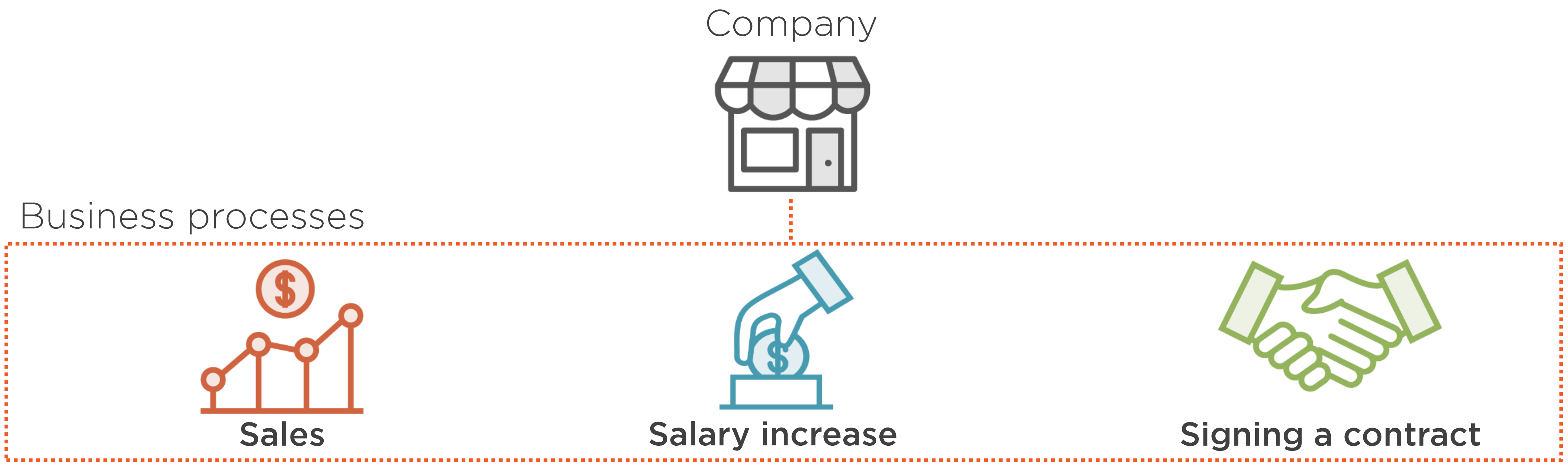
Structure of a Fact Table

Examining a Fact Table's Purpose

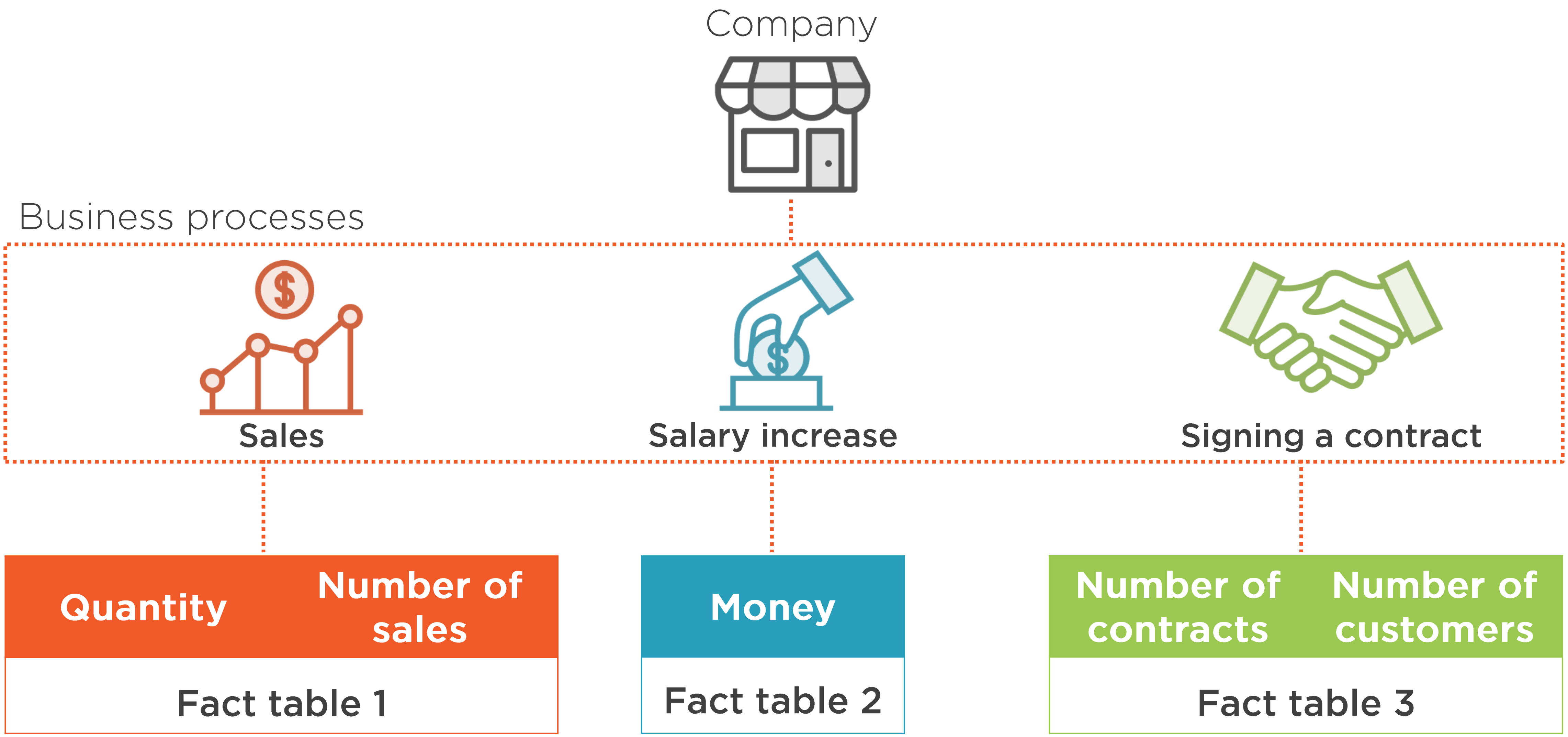
Examining a Fact Table's Purpose

Company

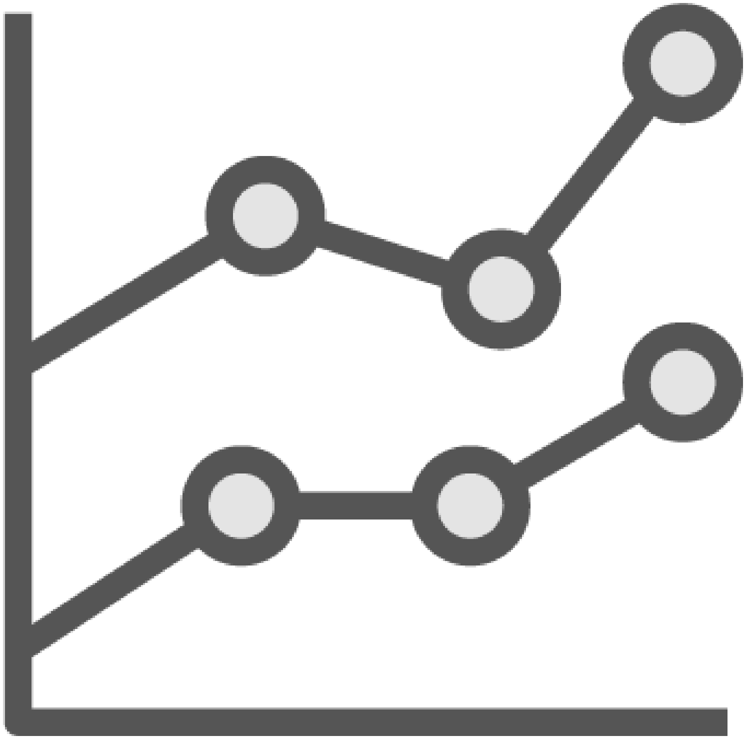
Examining a Fact Table's Purpose



Examining a Fact Table's Purpose



Fact Table Characteristics



Used with dimensions for:

- Reporting purposes
- Measuring performance
- Analyzing trends in time

Contain a lot of measurements

They tend to grow very fast

Performance is an important design factor

Walmart Case Study

As of April 2019

Number of stores	11.300
Annual revenue in previous fiscal year	514 billion dollars
Days in a year	365
Avg. revenue per day	1.4 billion dollars
Avg. revenue per day per store	124.000 dollars
Avg. price of a banana	19 cents

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Avg. revenue per day per store	124.000 dollars
Avg. price of a banana	19 cents

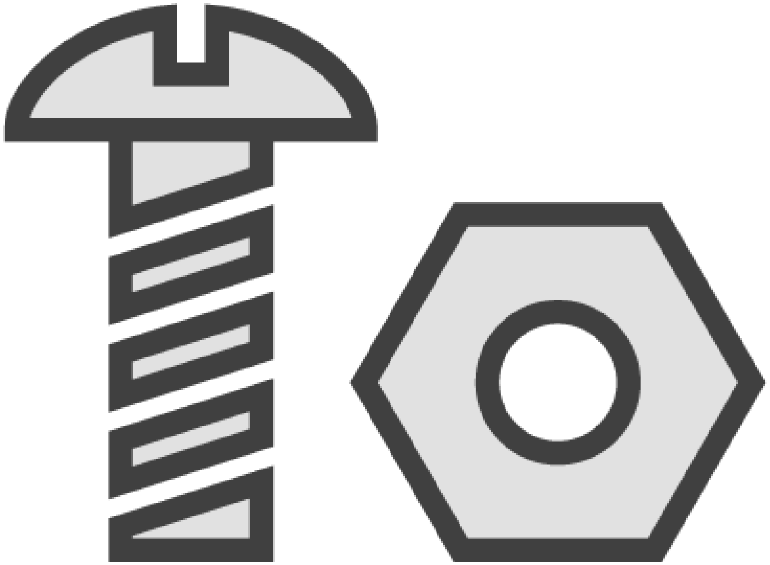
How many transactions are recorded per day?

What are the best sold products from each store?

Data warehouse fact tables

- Sales fact table
- Profit and loss
- Periodic revenue per period

Main Elements of a Fact Table



Facts

- Columns storing the measurements of the process

Primary key

- Uniquely identifies rows

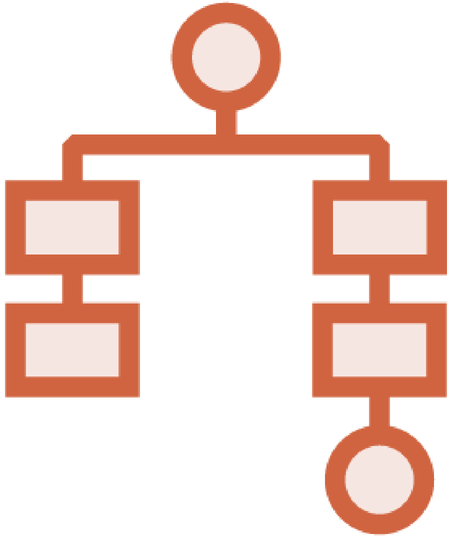
Foreign keys

- Linking the fact and the dimension tables

Steps for Identifying Facts

Analyze what is important in a business process

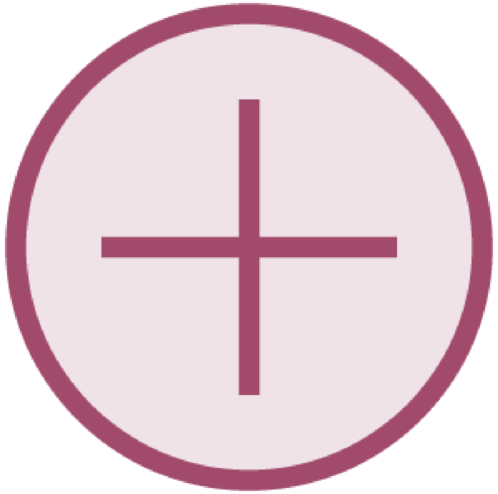
Identify multiple facts



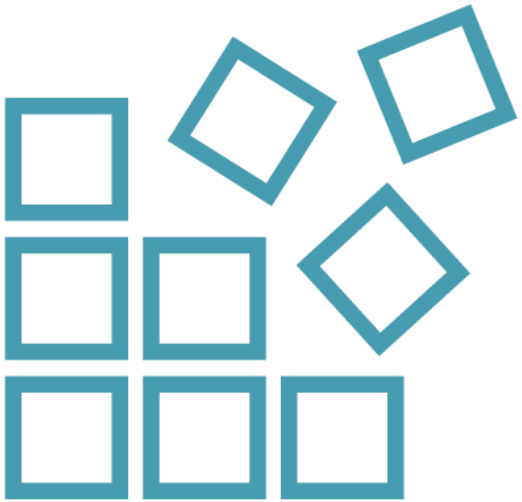
Group facts by granularity

Double-check the facts

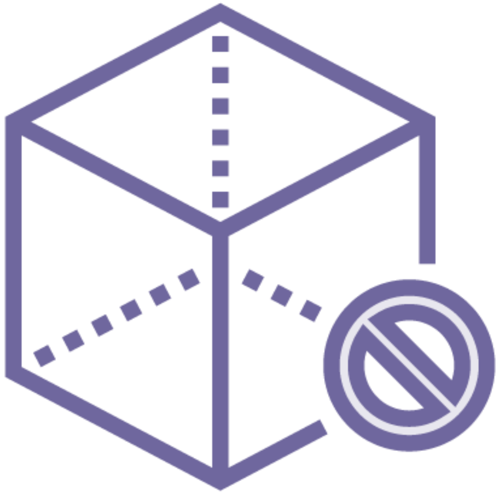
Types of Facts



Additive



Semi-additive



Non-additive

Additive Facts

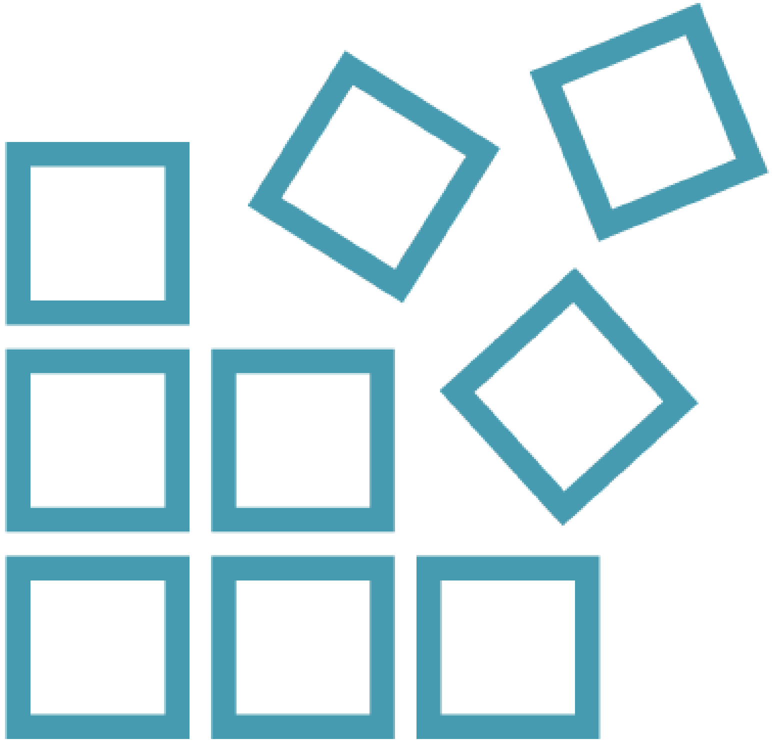
Can be summarized across all dimensions from a fact

The most common type of fact

Examples:

- Sales amount
- Sales quantity
- Purchase amount
- Number of transactions

Semi-additive Measures



Can be summarized across *some* dimensions

Cannot be summarized across time

Example of Semi-additive Measures

Example of Semi-additive Measures

Date key	Product key	Store key	Quantity	Inventory value at price ($)
04-03-2019	777	1	200	400
04-04-2019	777	1	100	200

Example of Semi-additive Measures

Date key	Product key	Store key	Quantity	Inventory value at price ($)
04-03-2019	777	1	200	400
04-04-2019	777	1	100	200
04-03-2019	80	1	50	50
04-04-2019	80	1	25	25

Example of Semi-additive Measures

Date key	Product key	Store key	Quantity	Inventory value at price ($)
04-03-2019	777	1	200	400
04-04-2019	777	1	100	200
04-03-2019	80	1	50	50
04-04-2019	80	1	25	25

How many units were in the store on the 3rd of April?

What was their value?

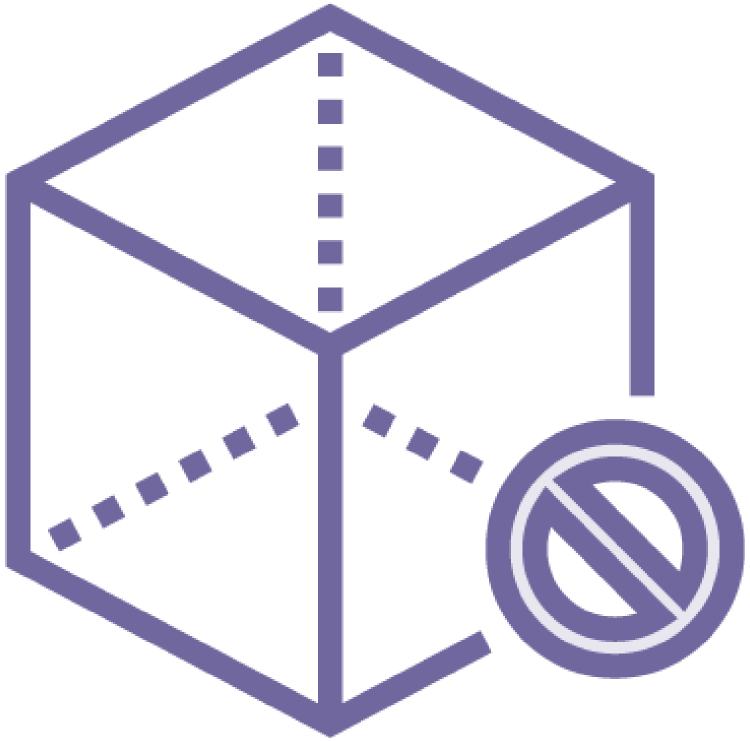
Example of Semi-additive Measures

Date key	Product key	Store key	Quantity	Inventory value at price ($)
04-03-2019	777	1	200	400
04-04-2019	777	1	100	200
04-03-2019	80	1	50	50
04-04-2019	80	1	25	25

Examples of semi-additive measures:

- Inventory information
- Financial account balances
- Water levels on rivers
- Temperature

Non-additive Measures



Ratios or percentages

Cannot be summarized across any dimension

Example of Non-additive Measures

Example of Non-additive Measures

Date key	Product key	Store key	Initial quantity	Removed quantity
04-03-2019	777	1	200	100
04-04-2019	777	1	100	40
04-03-2019	80	1	50	25
04-04-2019	80	1	25	9

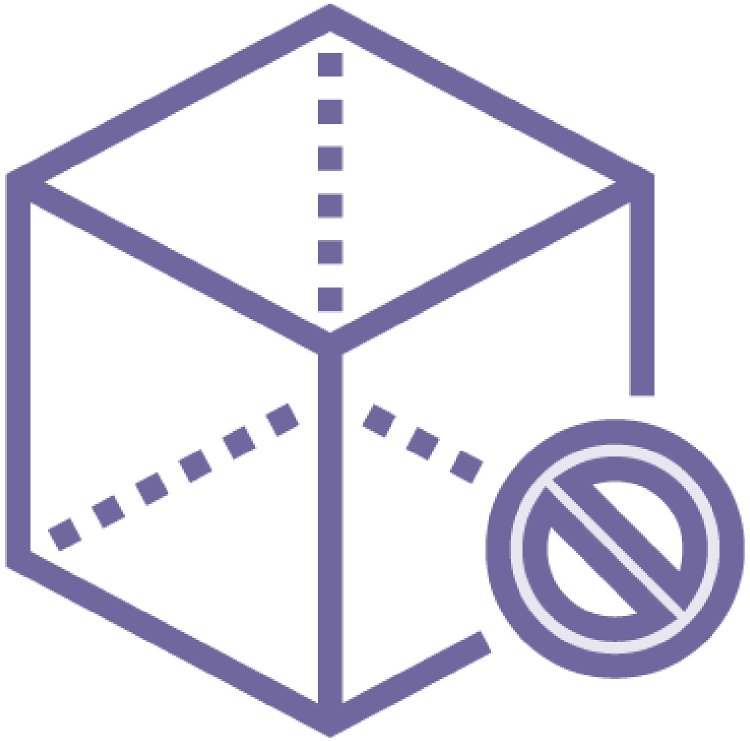
Example of Non-additive Measures

Date key	Product key	Store key	Initial quantity	Removed quantity	Removed quantity (%)
04-03-2019	777	1	200	100	50
04-04-2019	777	1	100	40	40
04-03-2019	80	1	50	25	50
04-04-2019	80	1	25	9	36

Example of Non-additive Measures

Date key	Product key	Store key	Initial quantity	Removed quantity	Removed quantity (%)	Unit price
04-03-2019	777	1	200	100	50	2
04-04-2019	777	1	100	40	40	2
04-03-2019	80	1	50	25	50	1
04-04-2019	80	1	25	9	36	1

Non-additive Measures



Ratios or percentages

Cannot be summarized across any dimension

Why are non-additive measures considered facts?

- Design preferences
  - Storing them in fact tables vs. in dimension tables, as attributes
- They are calculated based on columns from the fact table

They should be used with care by users

Keys in a Fact Table

Identifying the Keys

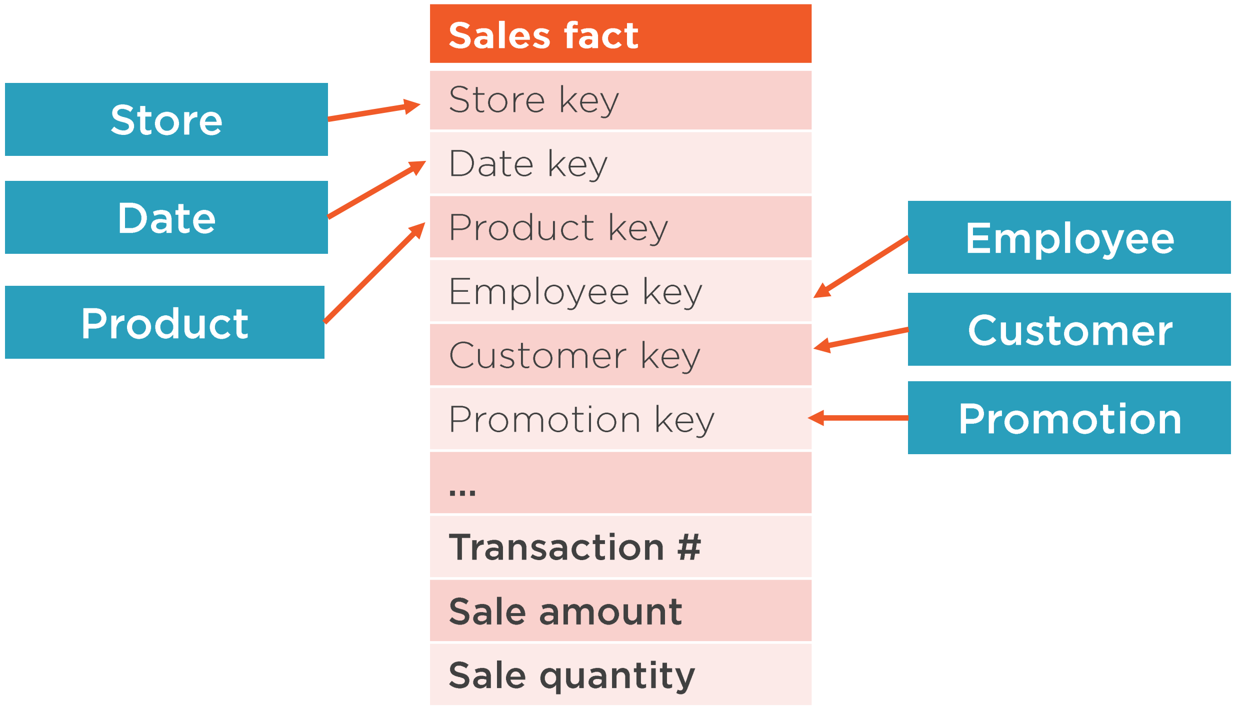
Primary key

- Composite key
- Surrogate key

Foreign keys for dimensions

Identifying the Primary Key

Identifying the Primary Key



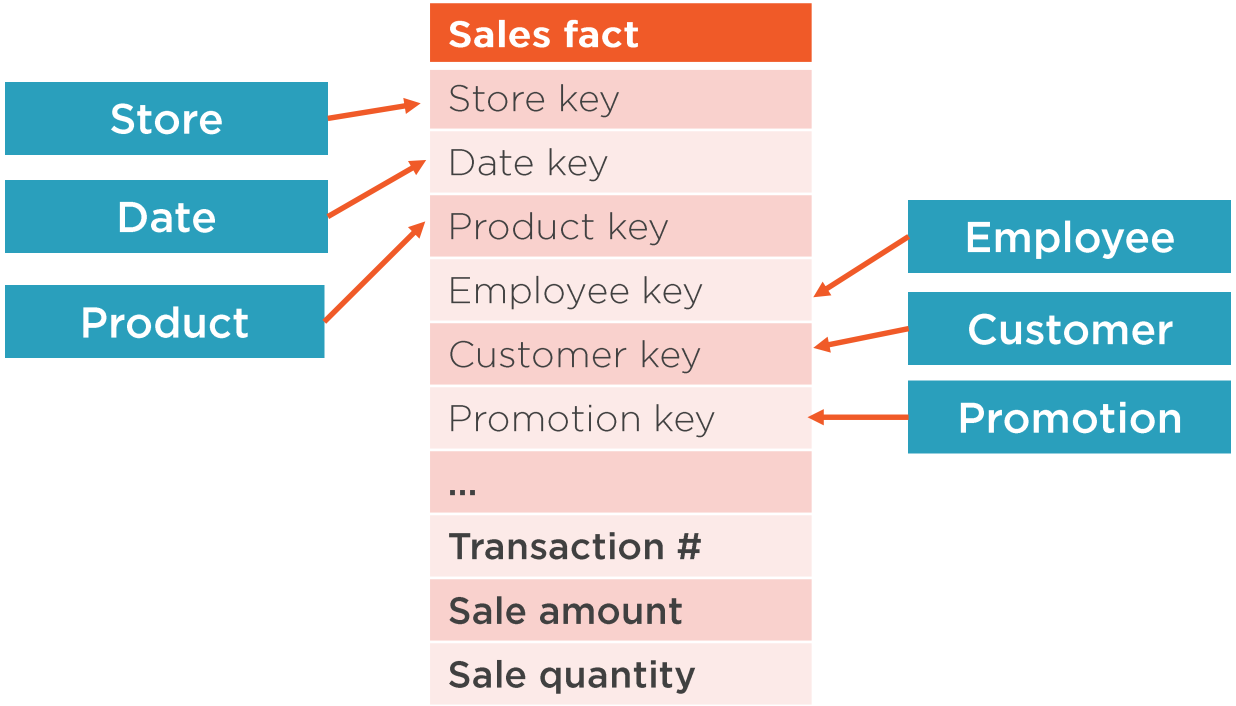
Relationships between fact and dimension are many-to-many

Examples

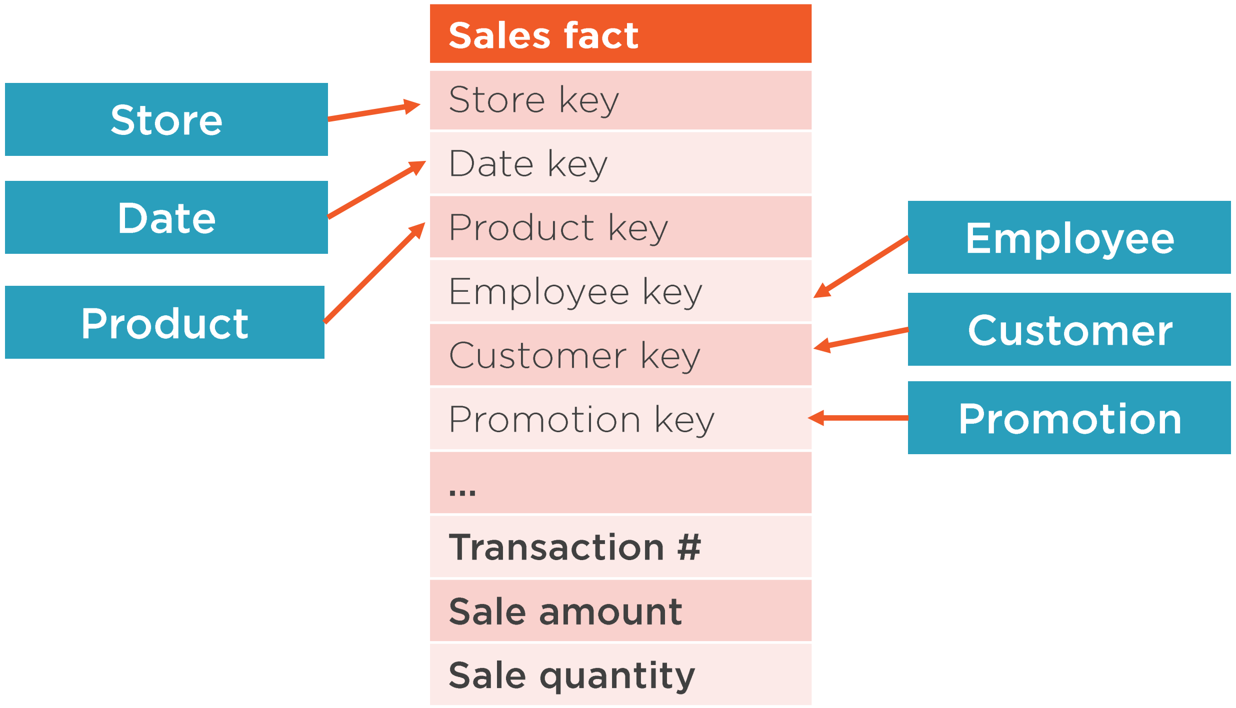
1.a. One sale can have multiple products
1.b. One product can be part of multiple sales

2.a. One sale can have multiple promotions applied
2.b. One promotion can be applied to many sales

Identifying the Primary Key



Identifying the Primary Key



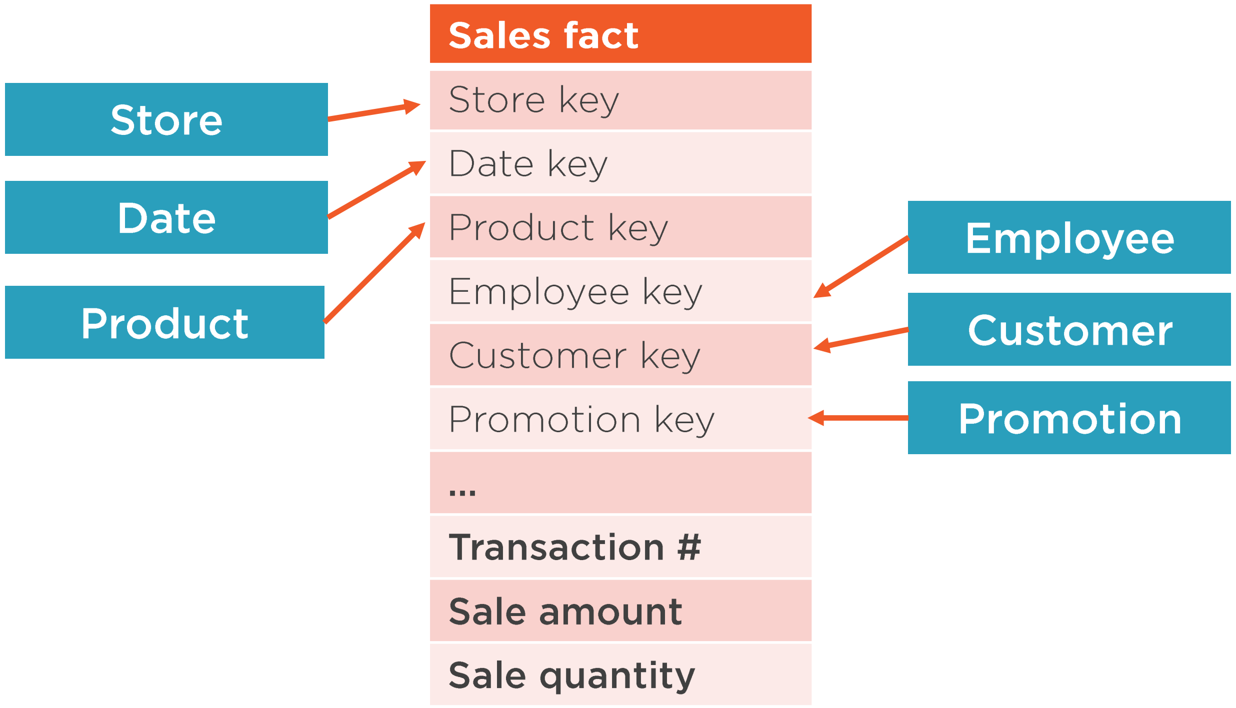
1. Combine a subset of the foreign keys

Also called

- Composite key
- Compound key
- Concatenated key

The combination must ensure row uniqueness

Identifying the Primary Key



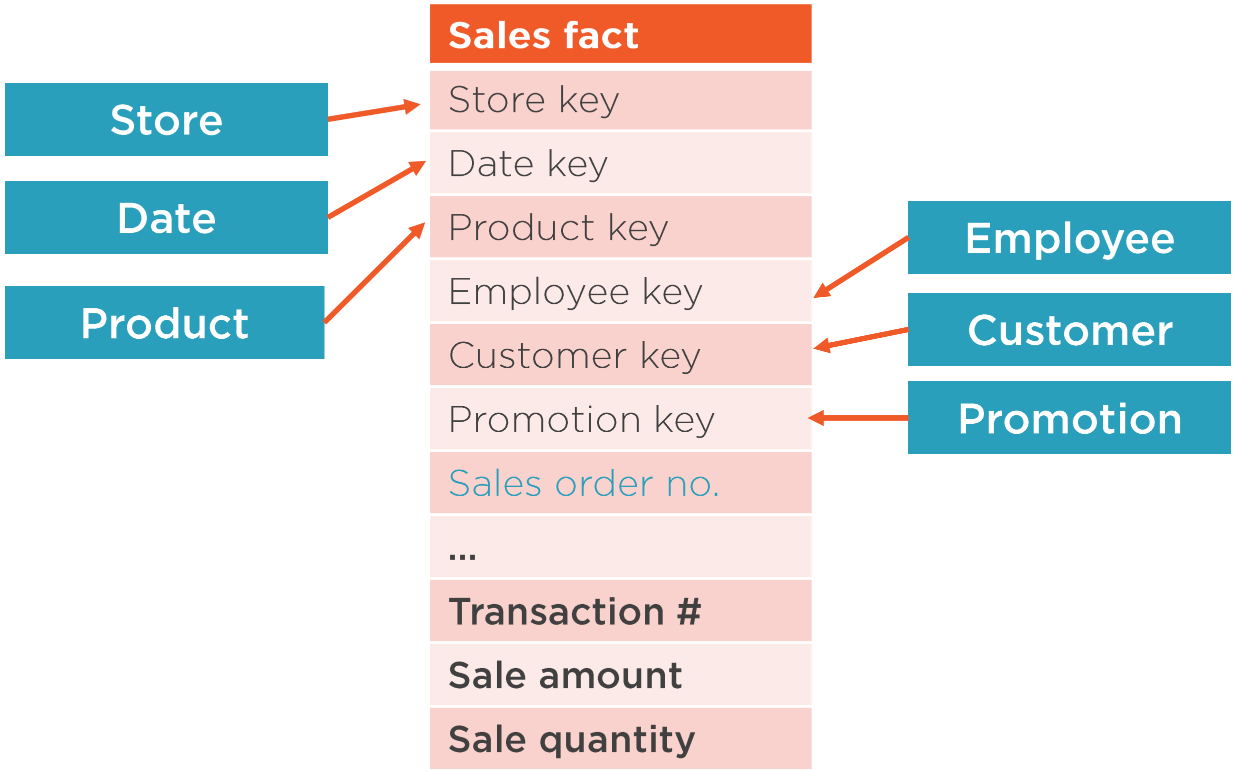
1. Combine a subset of the foreign keys
Also called

- Composite key
- Compound key
- Concatenated key

The combination must ensure row uniqueness

2. Use another column from the source system: the primary key for the transactions
Merge the new column to the subset of FKs

Identifying the Primary Key



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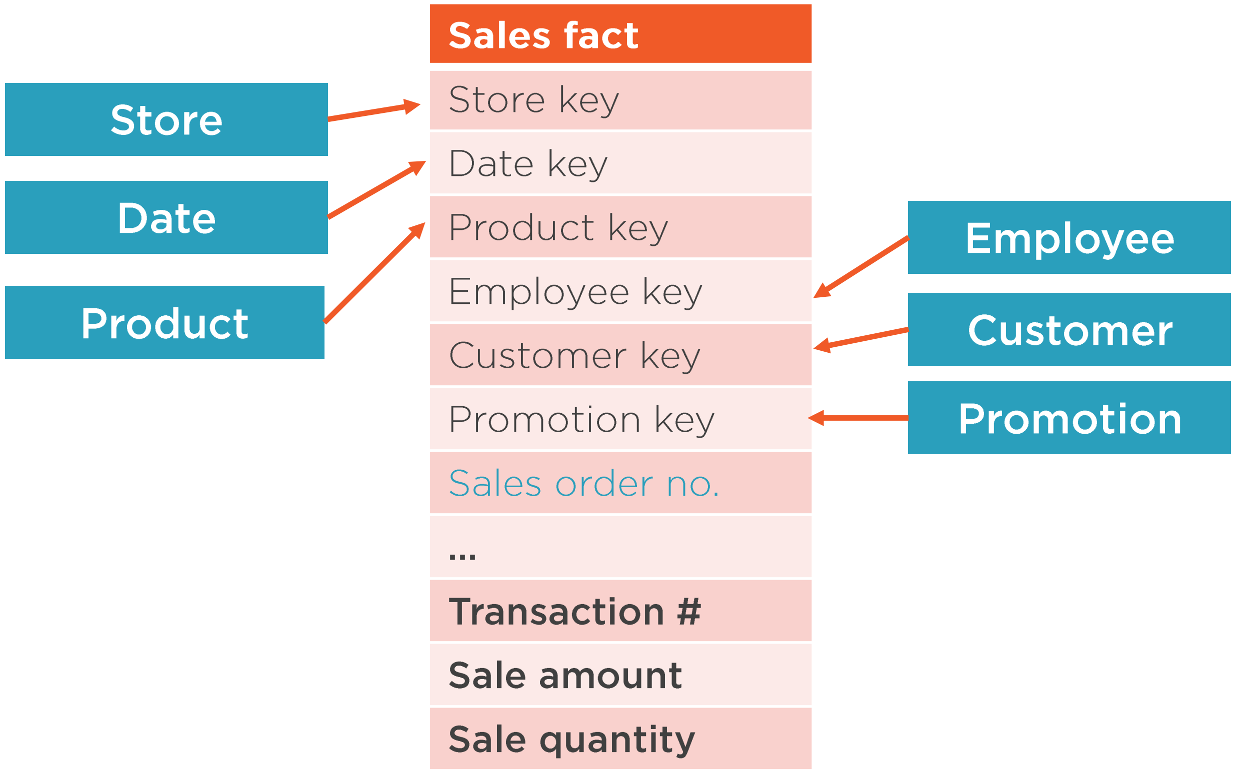

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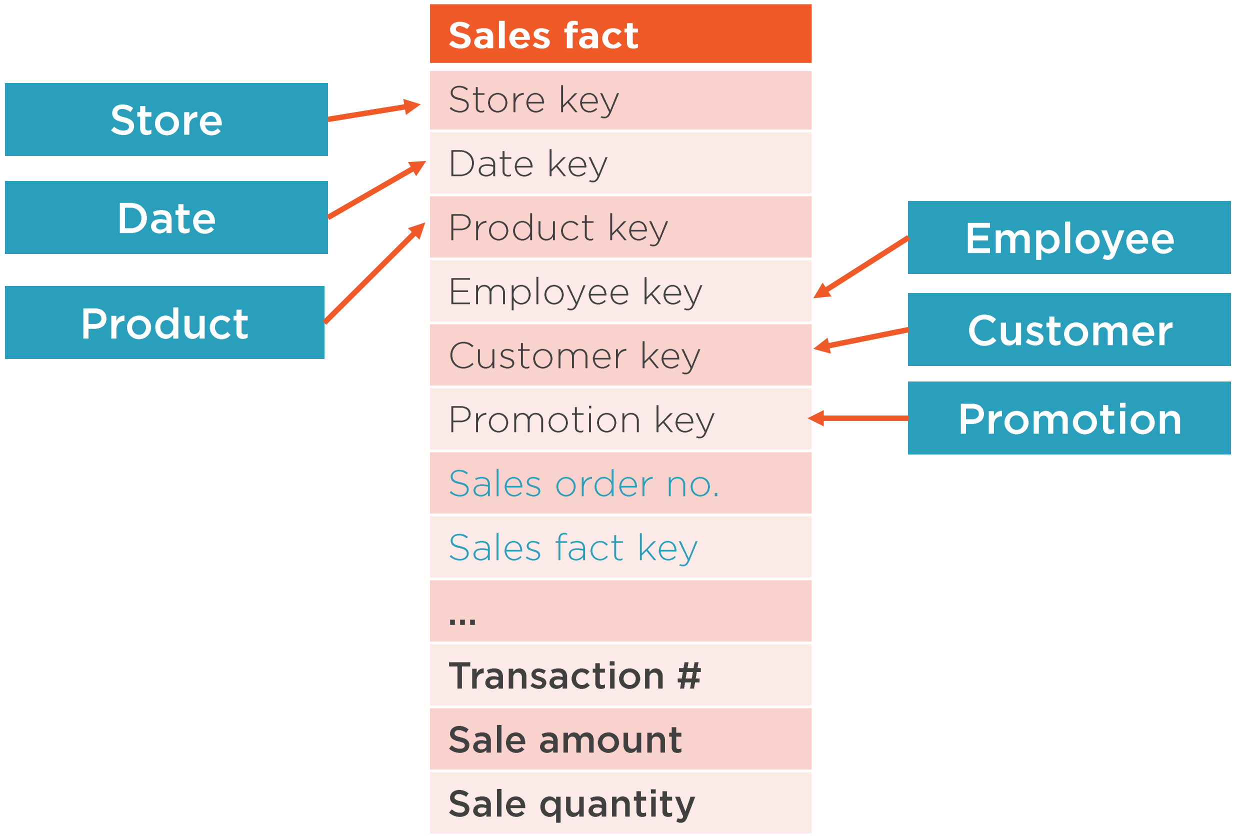
2. Use another column from the source system: the primary key for the transactions
Merge the new column to the subset of FKs

3. Create a surrogate key
- Small integer
- Auto-incremented
- No business value

The FKs don't play a special role anymore

Identifying the Primary Key



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Merge the new column to the subset of FKs

3. Create a surrogate key
- Small integer
- Auto-incremented
- No business value

The FKs don't play a special role anymore

Advantages of Using a Surrogate Key

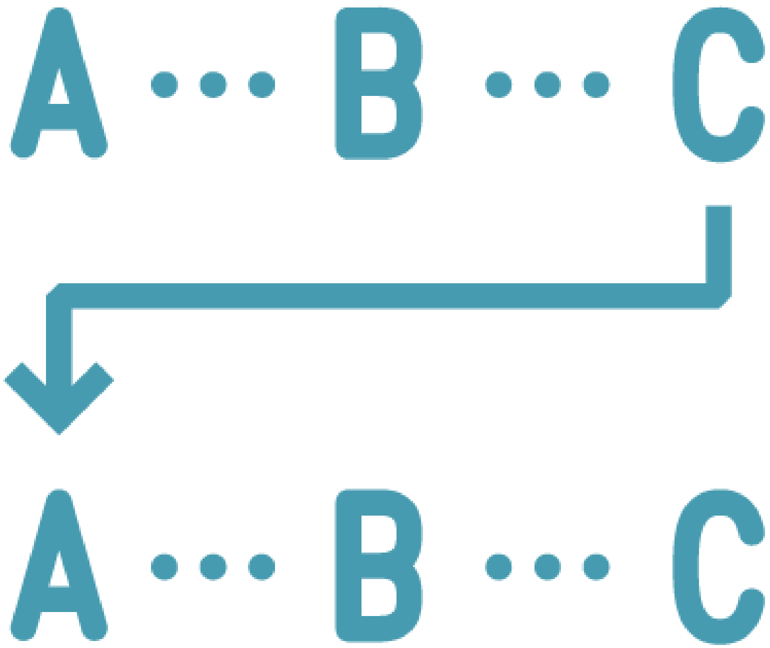
Easier to identify a row in the fact table

Debugging a load that stopped midway

Transforming an update into a combination of

- Inserts
- Deletes

Creating the Foreign Keys



Each dimension has

- A surrogate key (PK)
- A business key (PK of the source system)

A fact table has

- A primary key
- Foreign keys to its dimensions, linked to the dimensions' surrogate key

Relationship between the fact and the dimension

- The business key from the dimension
- An intermediary (staging) fact table
  - Fact table data is joined with dimension table data on the real join conditions
  - Staging table stores the PKs from the source tables for dimensions

Creating the Foreign Keys

Sources of data

Products
- **Product source key**
- Name
- …

Sales orders
- **Sales order no.**
- Sales order date
- …

Sales order lines
- **Line no.**
- Sales order no.
- …

Staging area

Staging sales fact
- Sales order no.
- Sales line no.
- Sales order date
- Product source key
- …
- Sale amount

DW dimensions

Product dimension
- **Product key**
- Source key
- Name
- Description
- Category
- …

DW facts

Sales fact

Creating the Foreign Keys

Sources of data

Products
- **Product source key**
- Name
- ...

Sales orders
- **Sales order no.**
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DW dimensions

Product dimension
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DW facts

Sales fact
- ...
- Sale amount

Creating the Foreign Keys

Sources of data

Products
Product source key
Name
...

Sales orders
Sales order no.
Sales order date
...

Sales order lines
Line no.
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Staging area

Staging sales fact
Sales order no.
Sales line no.
Sales order date
Product source key
...
Sale amount

DW dimensions

Product dimension
Product key
Source key
Name
Description
Category
...

DW facts

Sales fact
Product key
...
Sale amount

Creating the Foreign Keys

Sources of data

Products
Product source key
Name
...

Sales orders
Sales order no.
Sales order date
...

Sales order lines
Line no.
Sales order no.
...

Staging area

Staging sales fact
Sales order no.
Sales line no.
Sales order date
Product source key
...
Sale amount

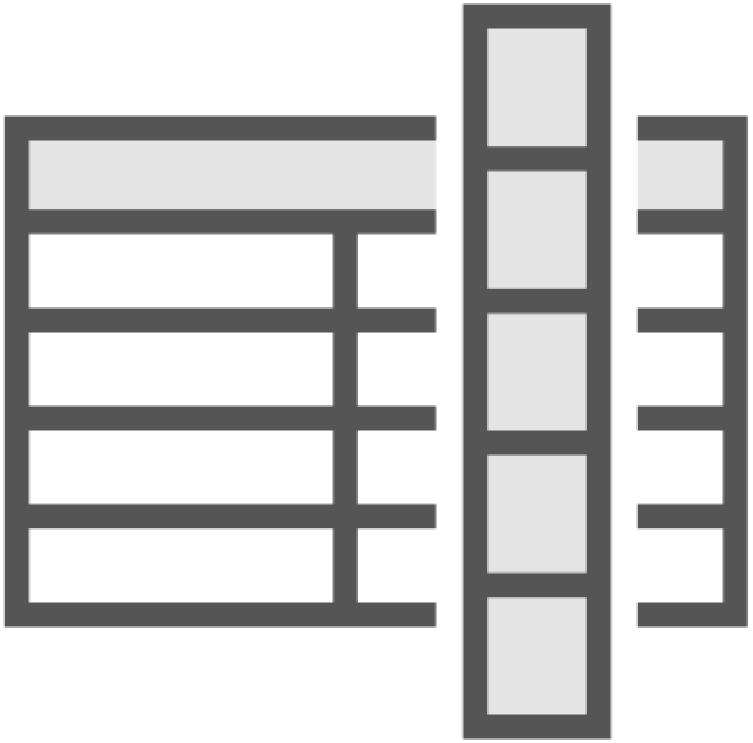
DW dimensions

Product dimension
Product key
Source key
Name
Description
Category
...

DW facts

Sales fact
Product key
Date key
Employee key
Customer key
...
Sale amount

Degenerate Dimensions



Columns added to fact tables

- Different than facts
- Different than keys

Similar to foreign keys, but don’t point to any dimension

Examples:

- Sales order number
- Invoice number
- Other transaction numbers

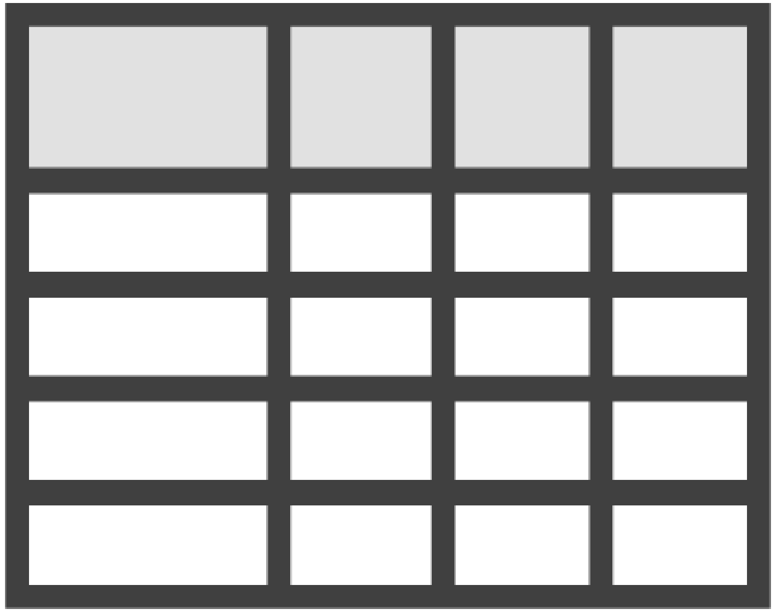
Advantages of degenerate dimensions

- Usually part of the fact’s PK
- Group all rows that were part of the same transaction
- Track data back to the operational system

Storing too many may impact the performance of the fact table

Types of Fact Tables

Most Common Types of Fact Tables



Transaction fact tables

Periodic snapshot

Accumulating snapshot

Transaction Fact Tables

The most common type of fact table in a data warehouse

Data inside it represents a process that happened at a certain point in time

A row exists for a dimension member only if the member was involved in a transaction

Properties of Transaction Fact Tables

The granularity is the transaction or transaction line

Tendency to become very large

Relationships with many dimensions

Sparsely populated

The facts are additive

Periodic Snapshot Fact Tables

Show information as it was at the end of a time interval

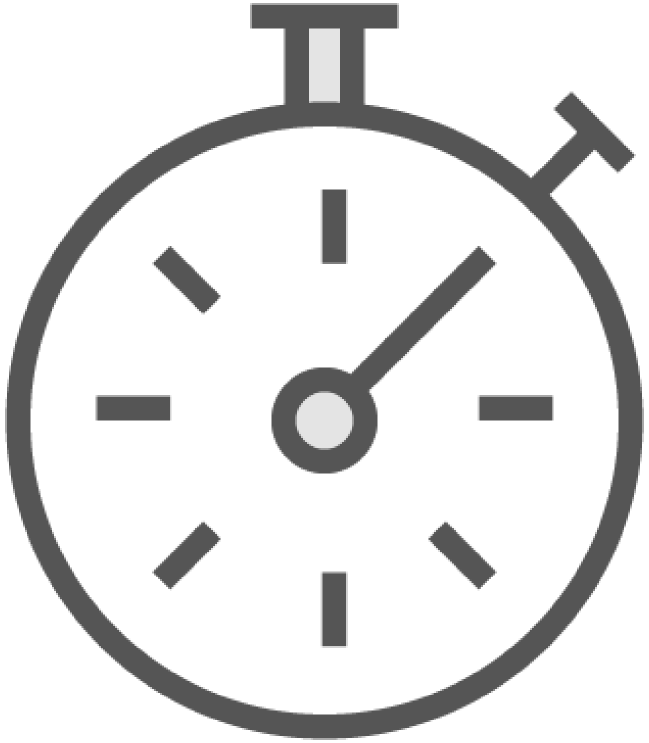
- End of each day
- End of each month, etc.

Are not periodically refreshed

- The new snapshots are added on top of the existing ones
- Are useful for analyzing trends in time

Transactional fact tables can be a starting point for the periodic snapshots

Accumulating Snapshot Fact Tables



Store information about a process that has

- A clear beginning
- A clear end
- A number of intermediary steps

Example: pipeline or workflow processes

- Fulfilling an order
- Progress of a mortgage application
- Status of a support ticket

Accumulating Snapshot Fact Tables

Handling support calls

Accumulating Snapshot Fact Tables

Handling support calls

Accumulating Snapshot Fact Tables

Handling support calls

Created date key	Assigned date key	In progress date key	In testing date key	Done date key
20190404	20190405	20190406	20190412	20190419

Accumulating Snapshot Fact Tables

Handling support calls

Created date key	Assigned date key	In progress date key	In testing date key	Done date key
20190404	20190405	20190406	20190412	20190419
20190407	17530101	17530101	17530101	17530101

Accumulating Snapshot Fact Tables

Handling support calls

Created date key	Assigned date key	In progress date key	In testing date key	Done date key
20190404	20190405	20190406	20190412	20190419
20190407	20190407	17530101	17530101	17530101

Accumulating Snapshot Fact Tables

Handling support calls

Created date key	Assigned date key	In progress date key	In testing date key	Done date key
20190404	20190405	20190406	20190412	20190419
20190407	20190407	20190407	17530101	17530101

Accumulating Snapshot Fact Tables

Handling support calls

Created date key	Assigned date key	In progress date key	In testing date key	Done date key	Duration development	Duration testing
20190404	20190405	20190406	20190412	20190419	6	3
20190407	20190407	20190407	17530101	17530101	NULL	NULL

Accumulating Snapshot Fact Tables

Handling support calls

Created date key	Assigned date key	In progress date key	In testing date key	Done date key	Duration development	Duration testing	Is done
20190404	20190405	20190406	20190412	20190419	6	3	1
20190407	20190407	20190407	17530101	17530101	NULL	NULL	0

Accumulating Snapshot Fact Tables

Handling support calls

Created date key	Assigned date key	In progress date key	In testing date key	Done date key	Duration development	Duration testing	Is done	Current status key
20190404	20190405	20190406	20190412	20190419	6	3	1	6
20190407	20190407	20190407	17530101	17530101	NULL	NULL	0	4

Handling Null Values in Fact Tables

Nulls in the facts

It is alright to have nulls in the facts

The aggregate functions can handle null values

Replacing null with zeros would influence the calculations performed

Value
2
2
null

Average: 2

Value
2
2
0

Average: 1

Nulls in the foreign keys

Will produce a referential integrity violation error

This situation must be avoided

Use the "empty row" technique:

- Every dimension should have an empty row, with its own primary key
- When there is no link between fact and dimension, the foreign key column will store the PK of the empty row

Demo

Creating and working with a transaction fact table

- Populate staging table with source data
- Populate fact table with data from staging
- Use the fact table in reports

Summary

Components of a fact table:

- Facts (or numeric measurements)
  - Additive
  - Semi-additive
  - Non-additive
- The primary key
  - Surrogate key
  - Composite key
- Foreign keys for dimensions
- Degenerate dimensions

The most common types of fact tables:

- Transaction fact table
- Periodic snapshot
- Accumulating snapshot

Be aware of the null values in fact tables

- Measures can have null values
- Foreign key columns must not have nulls

Loading Data in a Data Warehouse

Ana Voicu

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Review of the Previous Steps

Discuss with the business people

- Processes
- Analysis needs

Investigate data sources

Implement the dimensional model

- End result will be the physical design
- Fact and dimension tables are defined

Populate the data warehouse tables with source data

- Also called “loading” the data warehouse
- Implement the ETL system

The ETL system

Similar to a "black box" for the data warehouse users

Data is:

- Integrated from multiple sources
- Transformed into meaningful reports
- Helping people make decisions

The ETL should be properly designed and implemented

Overview

What does ETL mean?

- Extraction
- Transformation
- Load

Types of loads

- Full (initial) load
- Incremental load

Data lineage

- What is data lineage?
- Why is it important?
- How can you implement it?

Demos

Perform the needed steps to load a dimension table

Create and work with the auxiliary objects involved in a load

- Staging tables
- Lineage table
- Incremental loads table

Overview of an ETL System

What Is ETL?

A system that incorporates all operations performed on data

- Since it's selected from data sources
- Until it reaches the presentation area

Consists of three phases

- Extraction (E)
- Transformation (T)
- Loading (L)

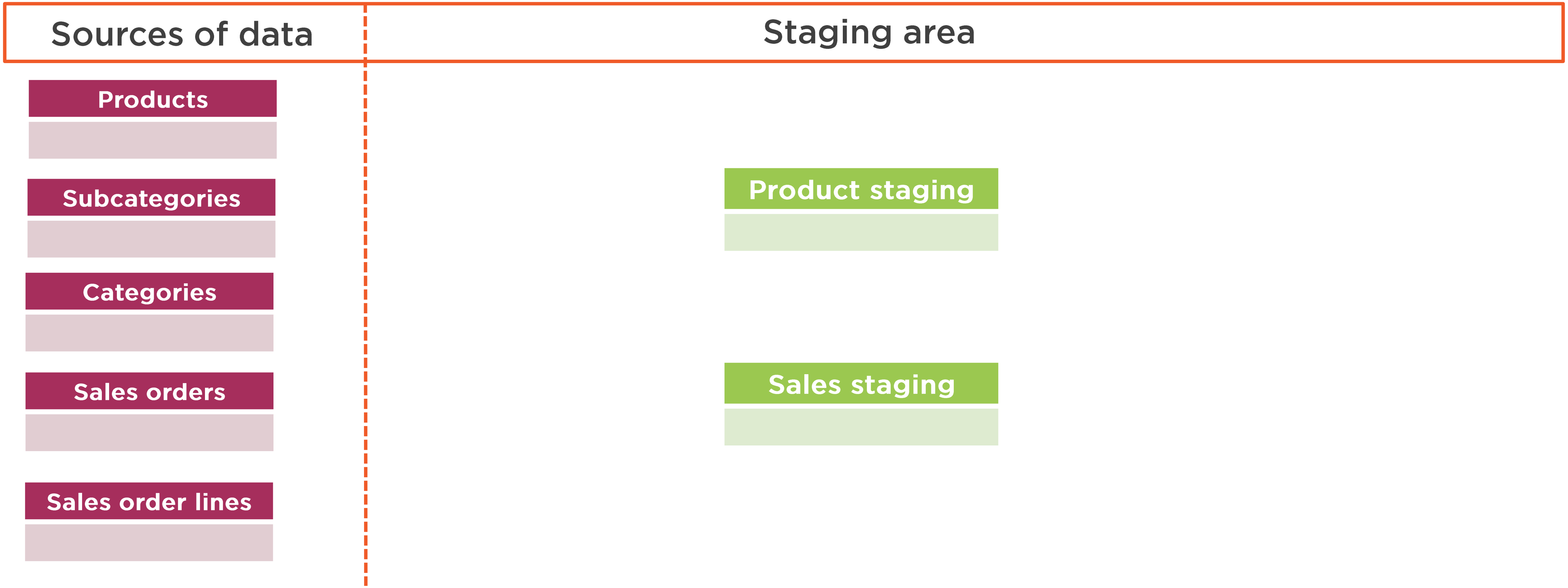
Overview of an ETL System

Overview of an ETL System

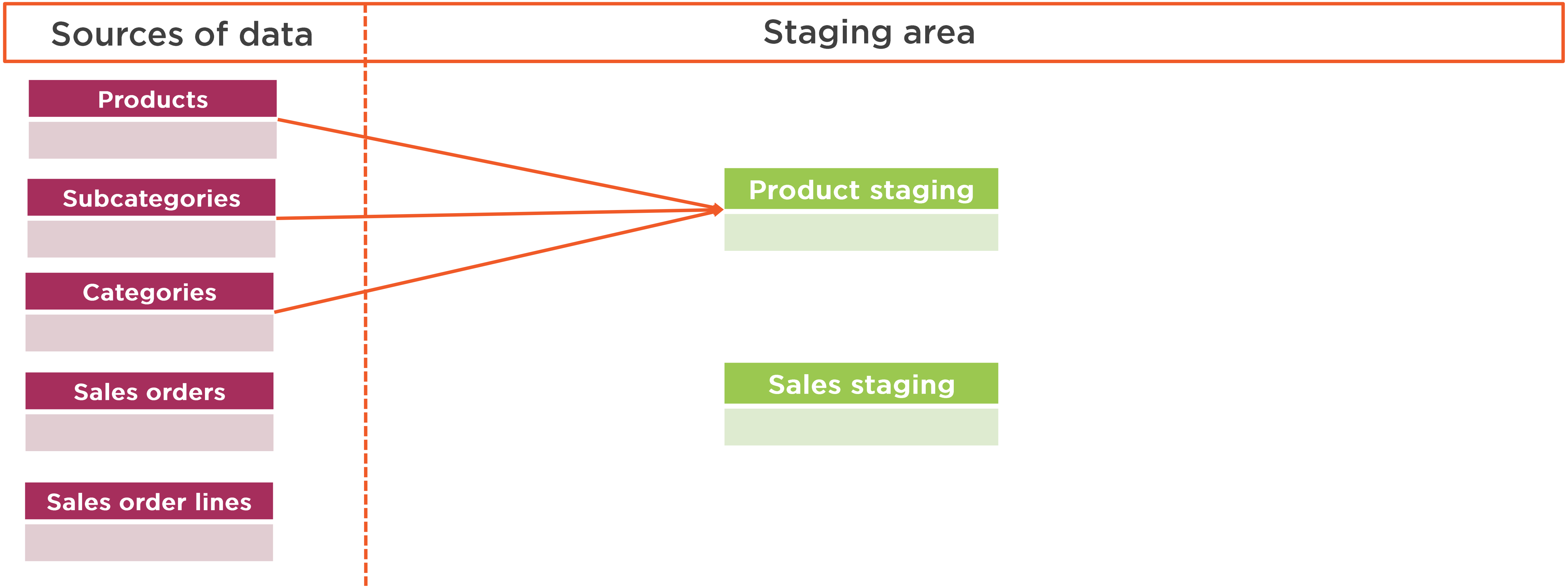
Sources of data

- Products
- Subcategories
- Categories
- Sales orders
- Sales order lines

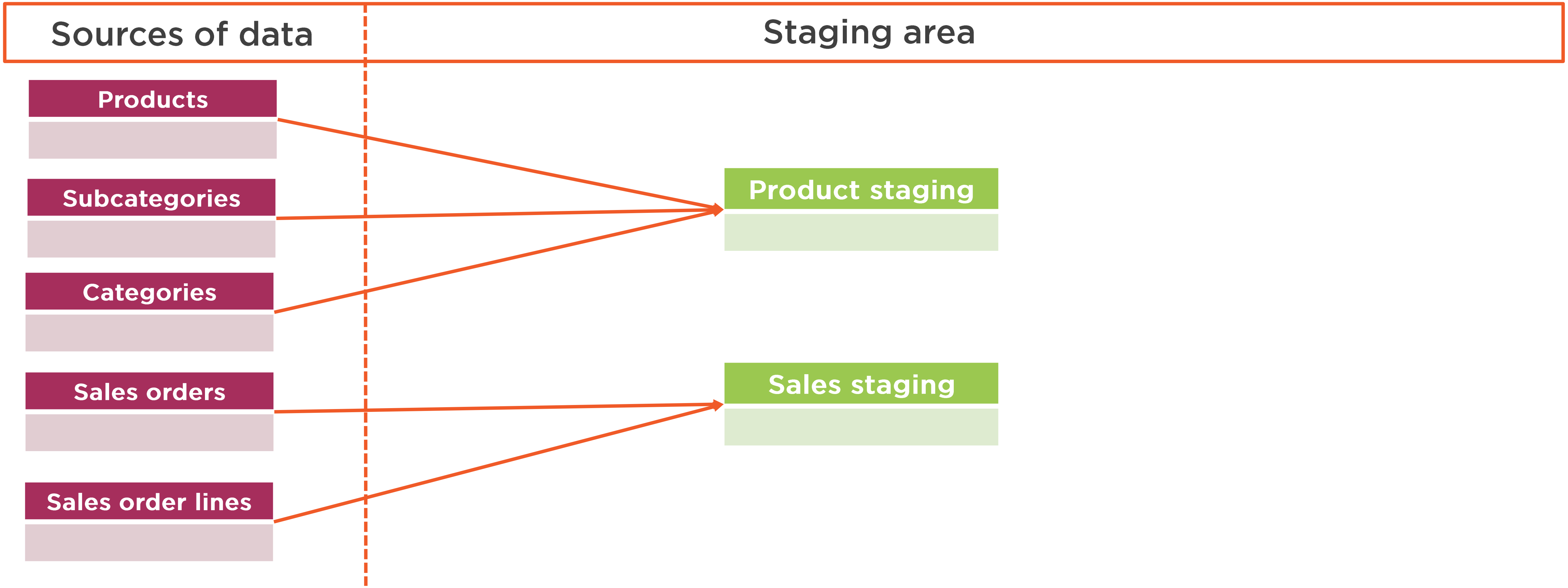
Overview of an ETL System



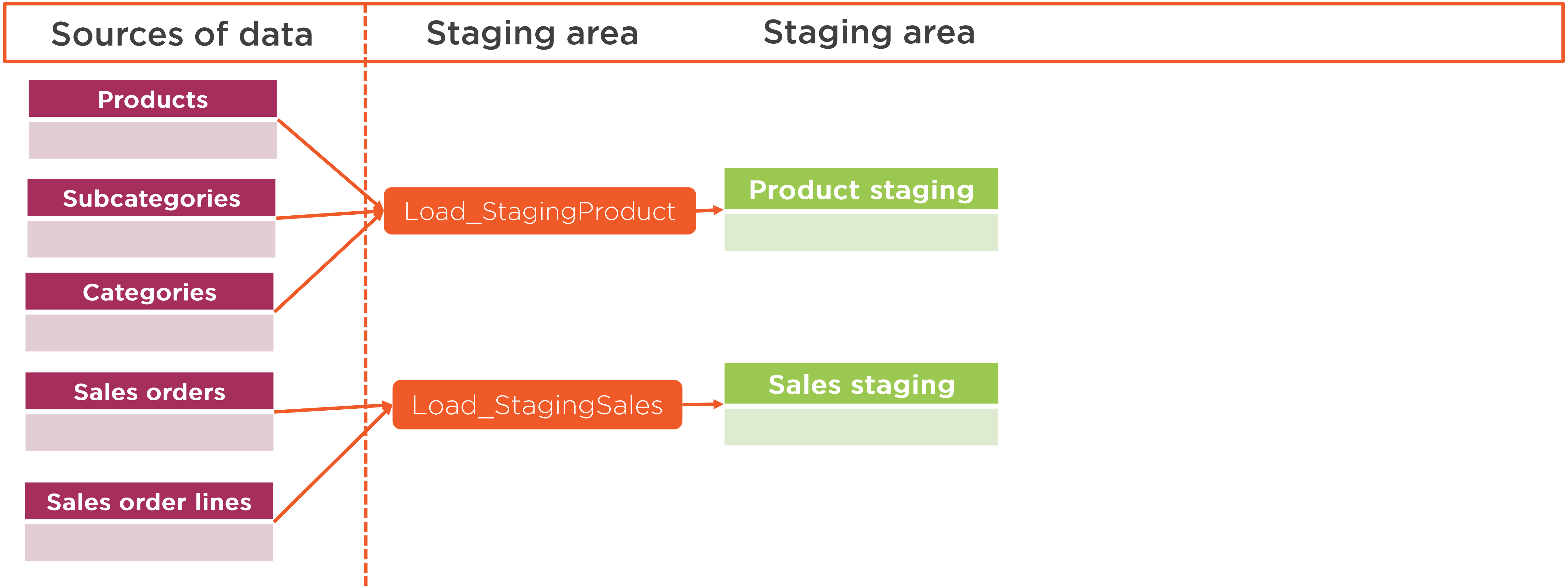
Overview of an ETL System



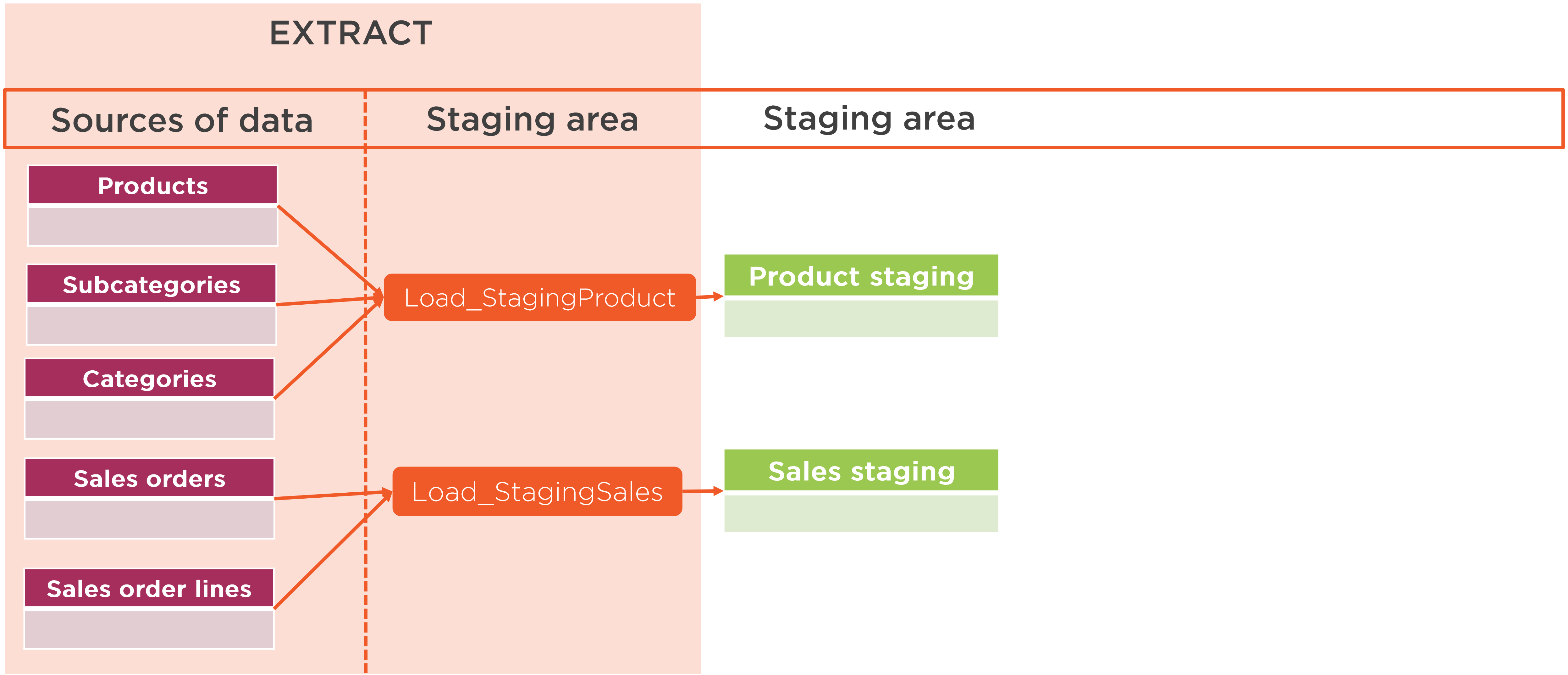
Overview of an ETL System



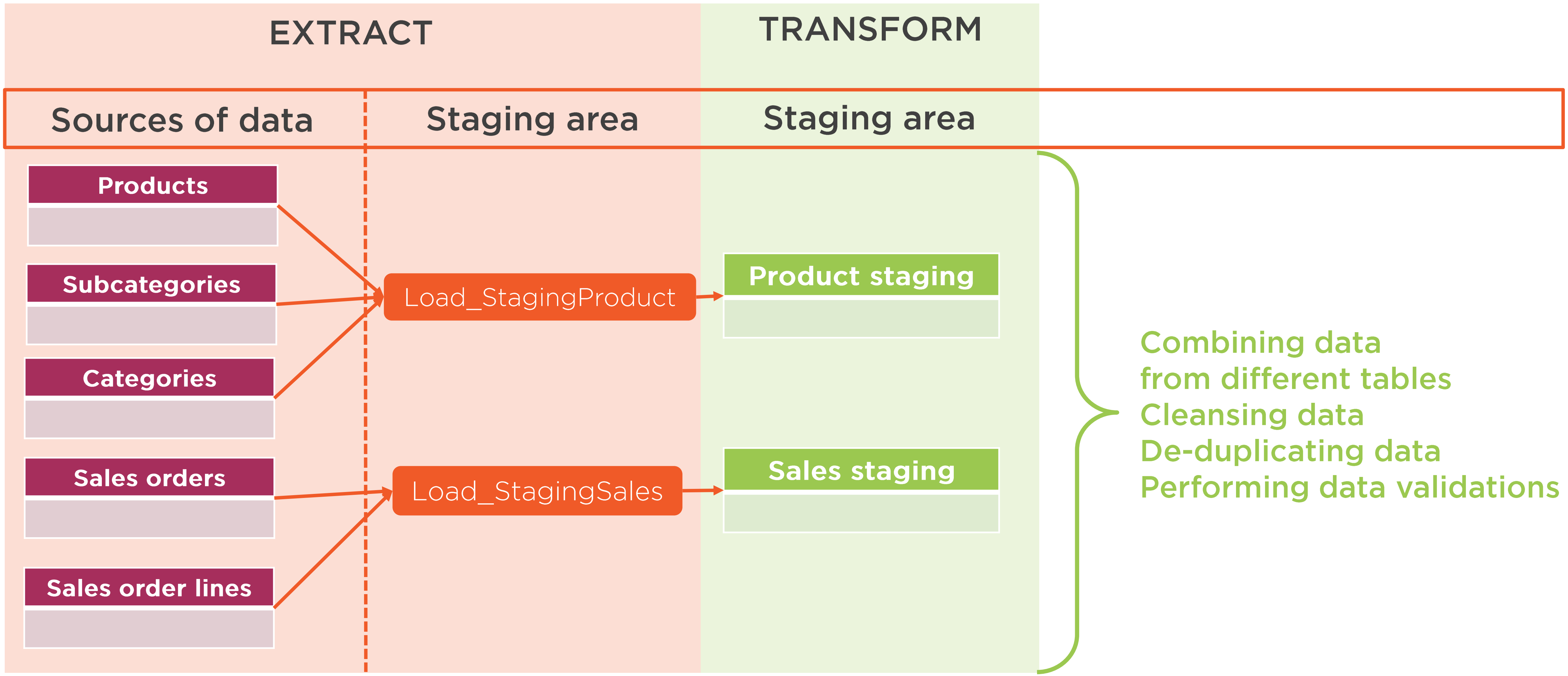
Overview of an ETL System



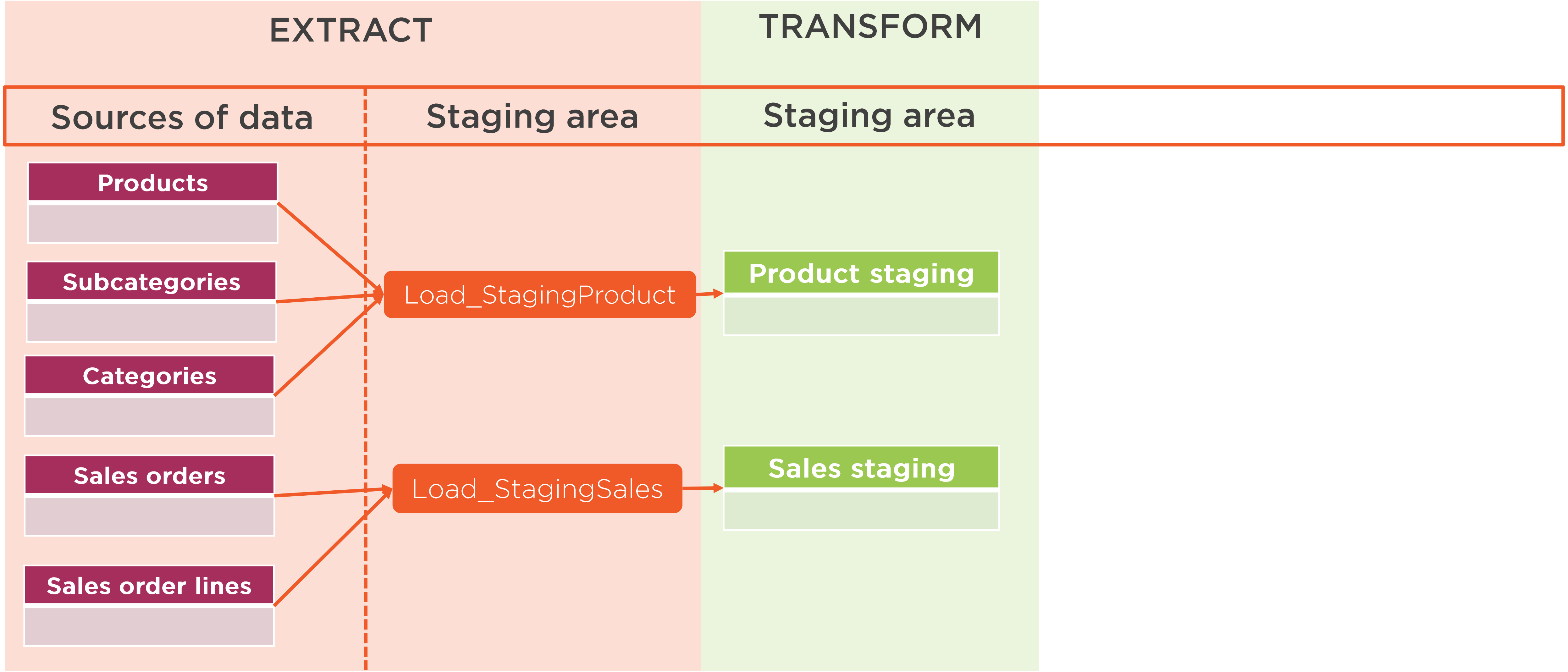
Overview of an ETL System



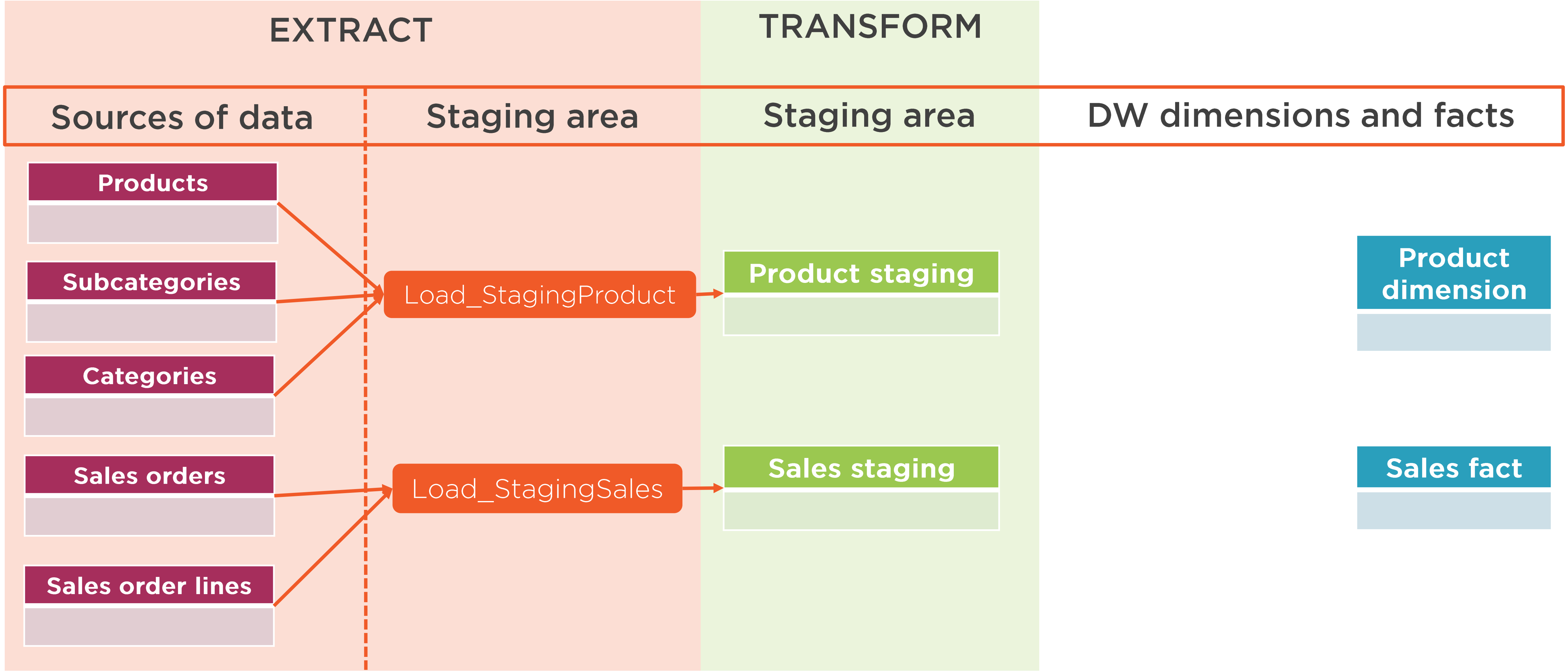
Overview of an ETL System



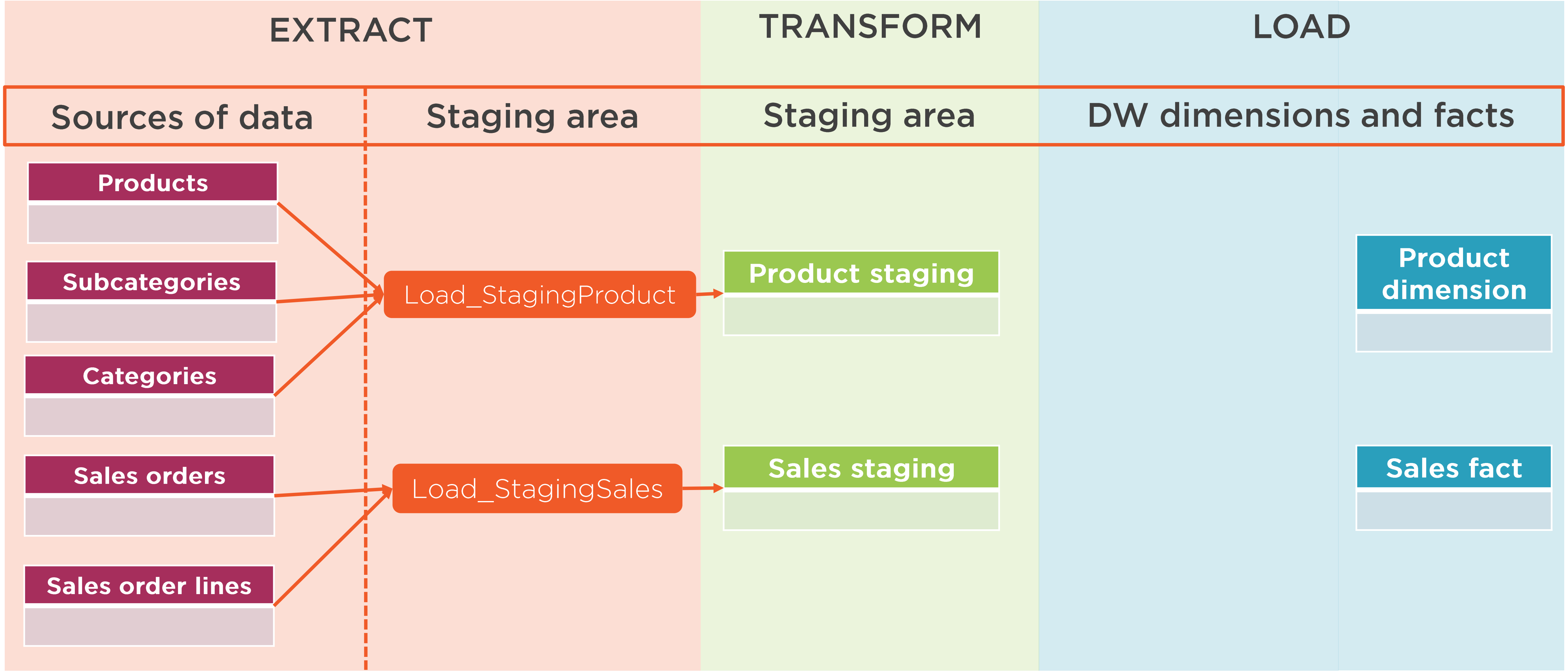
Overview of an ETL System



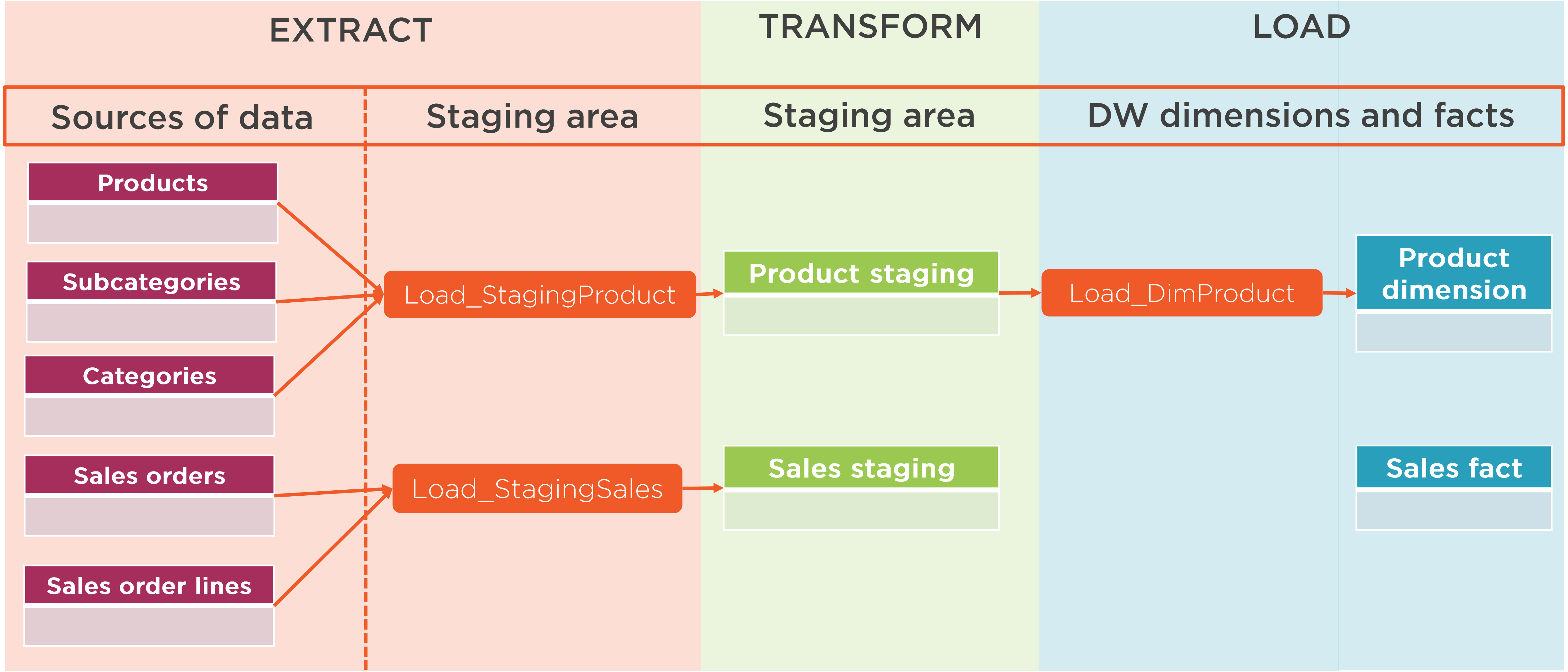
Overview of an ETL System



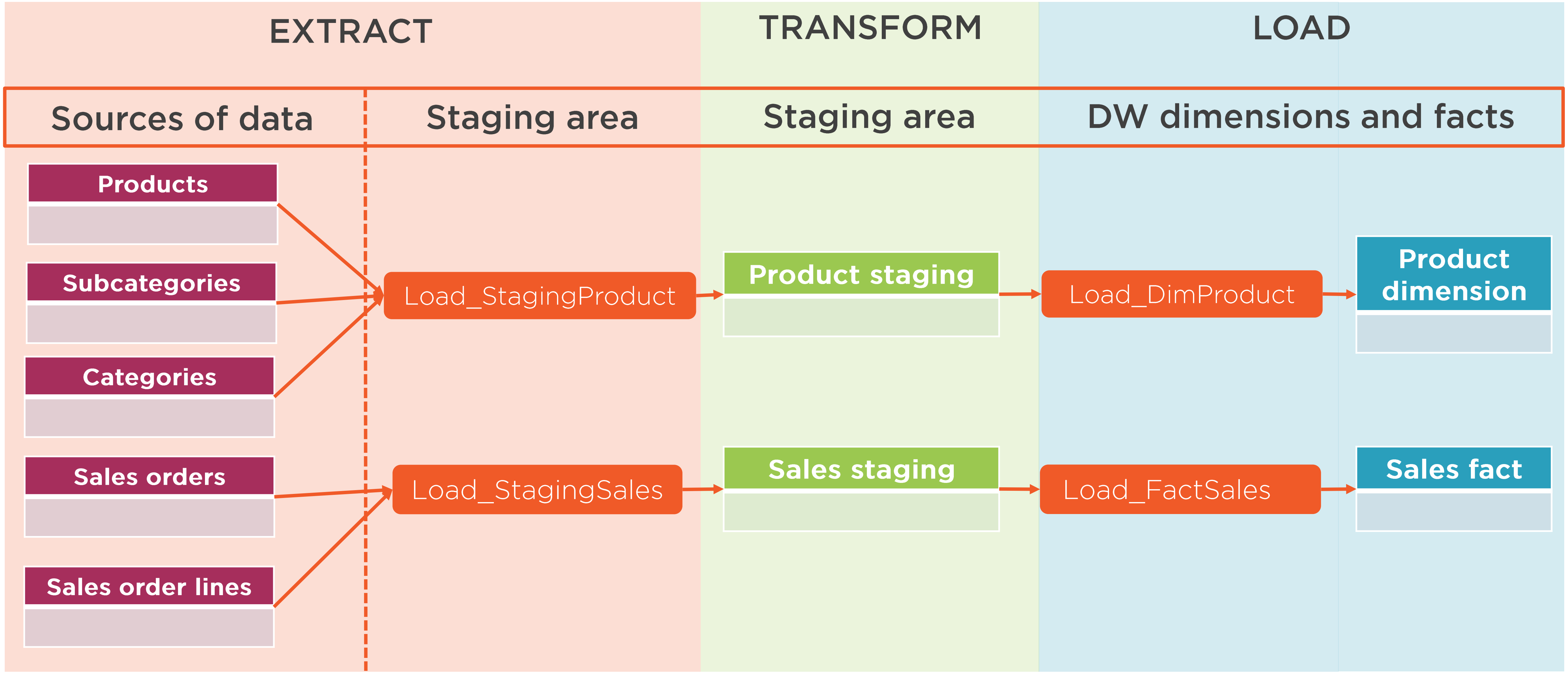
Overview of an ETL System



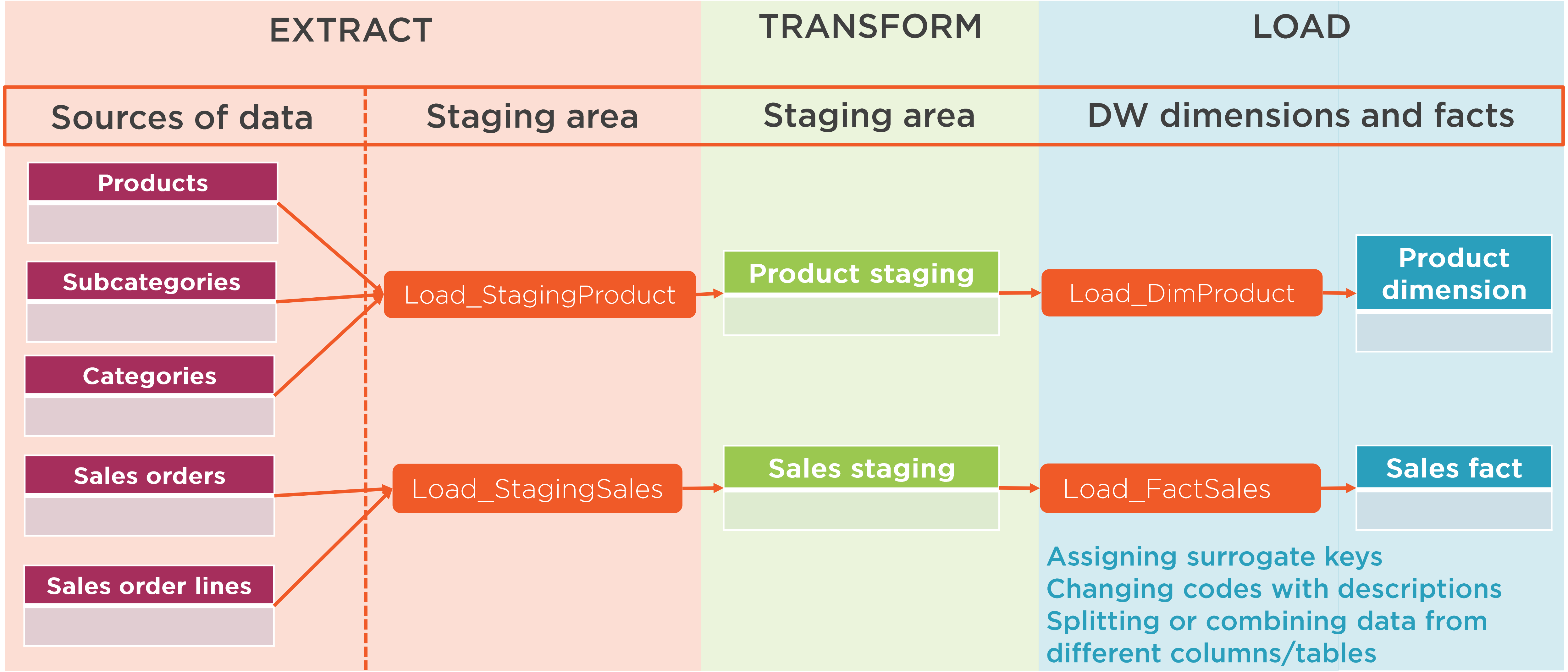
Overview of an ETL System



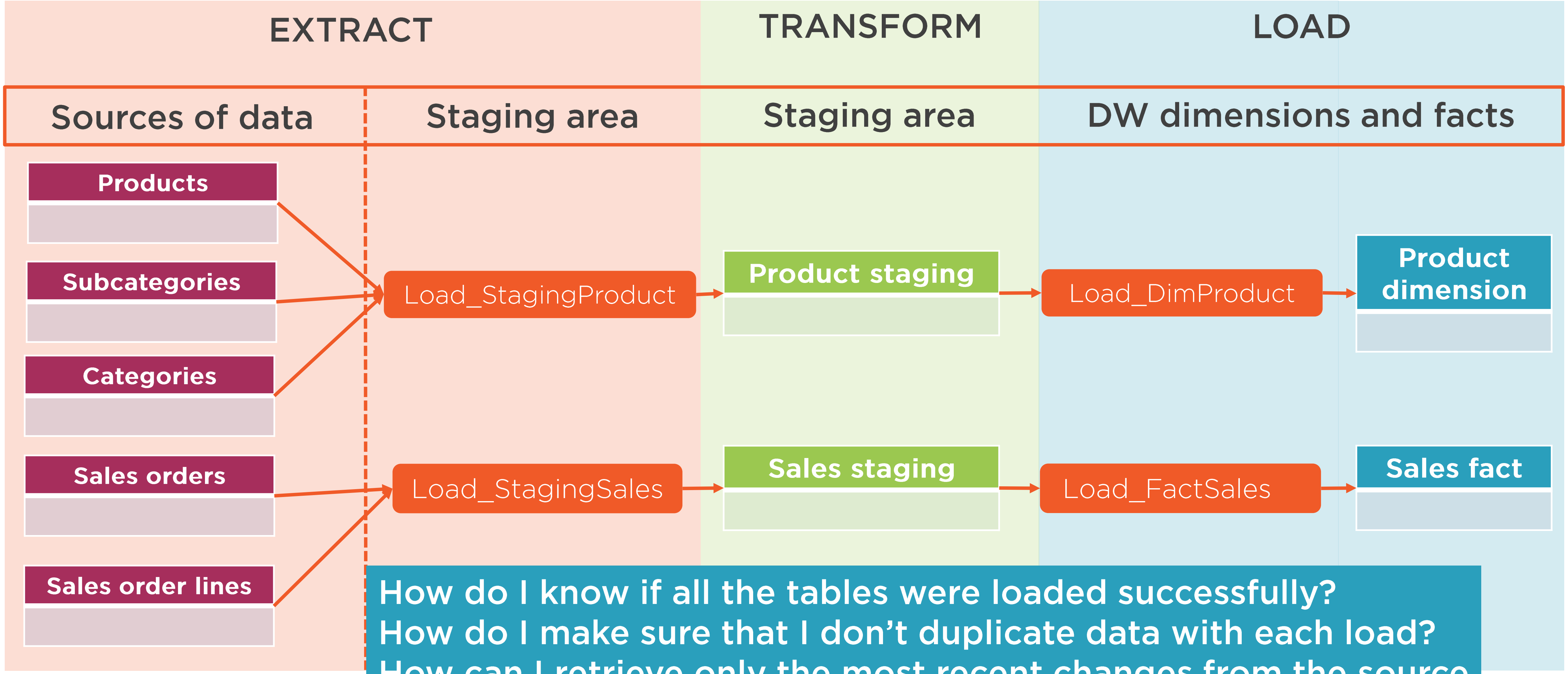
Overview of an ETL System



Overview of an ETL System

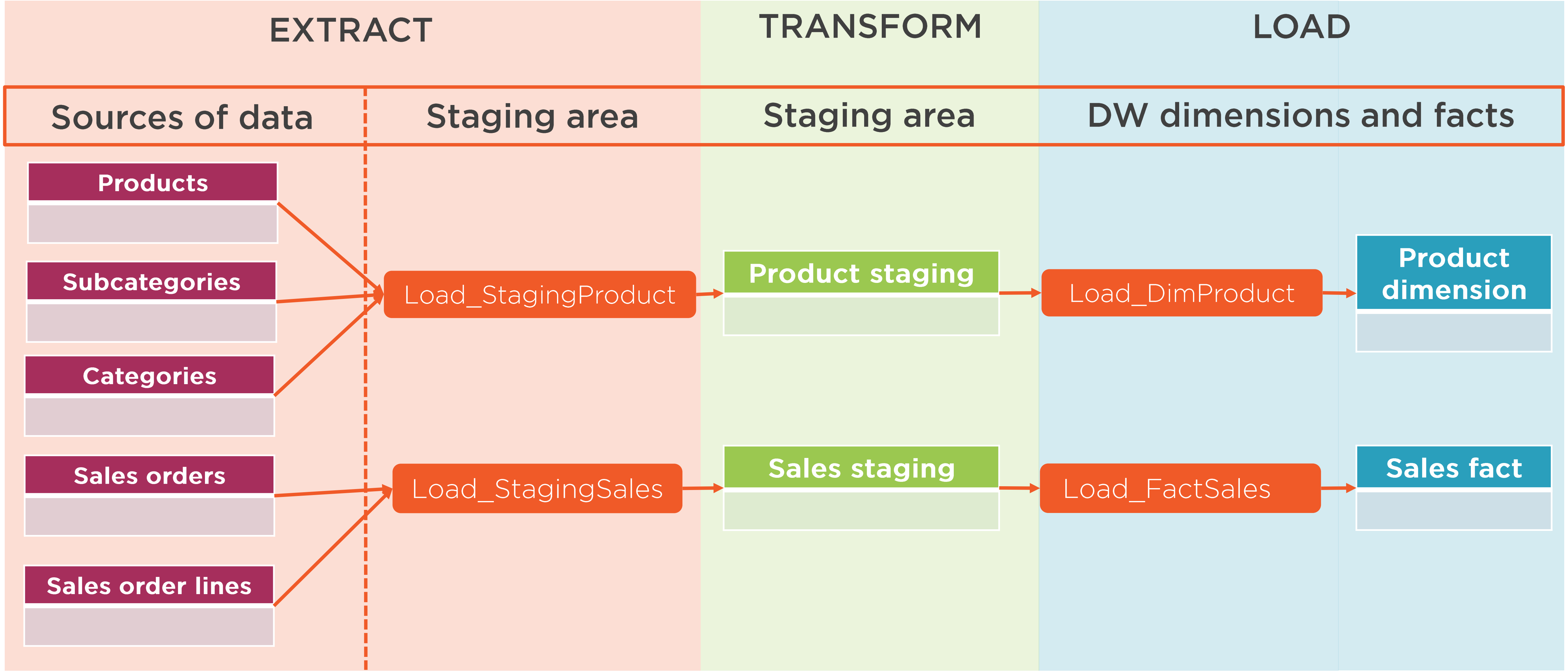


Overview of an ETL System

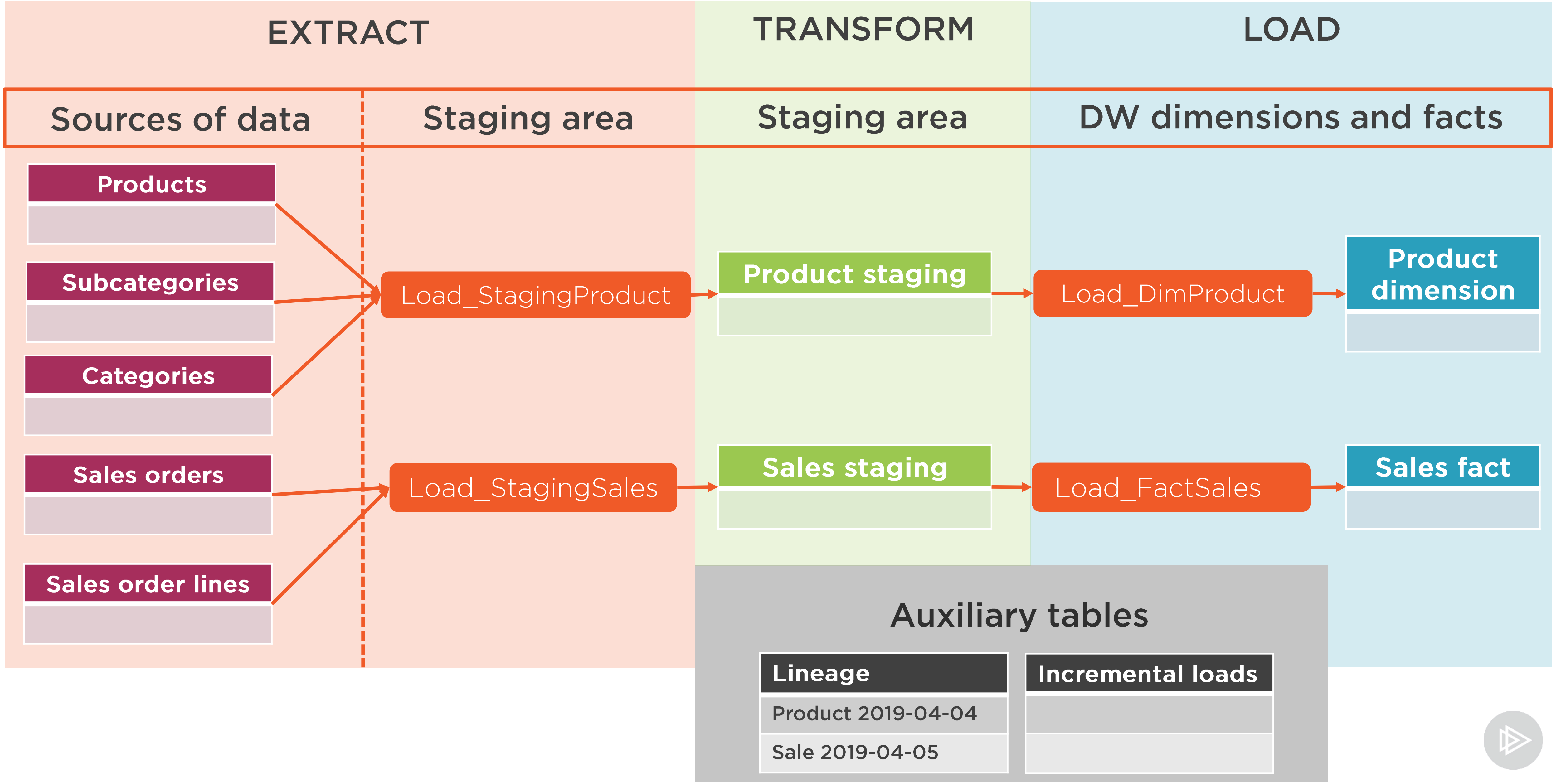


How do I know if all the tables were loaded successfully?
How do I make sure that I don’t duplicate data with each load?
How can I retrieve only the most recent changes from the source systems?

Overview of an ETL System



Overview of an ETL System



Types of Data Warehouse Loads

Types of Data Warehouse Loads

Full/initial load

The process of populating the data warehouse for the first time with data from the operational system

All tables are truncated and reloaded

Old data is lost

Takes a lot of time to finish

Easy to implement

Incremental load

The process of updating the data warehouse with the operational system changes

Tables are updated with new data

Old data is preserved

Takes less time than the initial load

Implementation is more complex

- Keep track of the previous load date
- Store multiple versions of the same row

Incremental Load Elements

_Source key	Name	Valid from	Valid to
387	Cherry toffee	2019-01-01	2019-09-16
387	Super cherry toffee	2019-09-16	9999-12-31
104	Banana bread	2019-01-01	9999-12-31
105	Grape juice	2019-01-01	9999-12-31

The "Valid from" and "Valid to" columns

Load date key	Table name	Load date
1	Dim_Product	2019-04-13
2	Dim_Employee	2019-01-01
...	...	
16	Dim_Product	2019-04-15

The "Incremental loads" table

Incremental Load Elements

_Source key	Name	Valid from	Valid to
387	Cherry toffee	2019-01-01	2019-09-16
387	Super cherry toffee	2019-09-16	9999-12-31
104	Banana bread	2019-01-01	9999-12-31
105	Grape juice	2019-01-01	9999-12-31

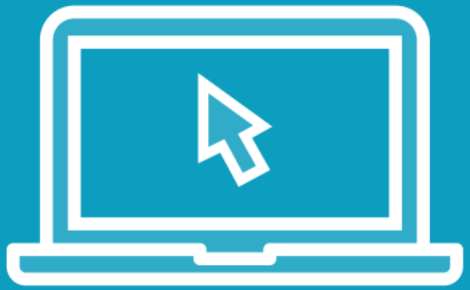
The "Valid from" and "Valid to" columns

Load date key	Table name	Load date
1	Dim_Product	2019-04-13
2	Dim_Employee	2019-01-01
…	…	
16	Dim_Product	2019-04-15

The "Incremental loads" table

```
SELECT *
FROM Products
WHERE
ModifiedDate > '2019-04-13'
AND ModifiedDate <= '2019-04-15'
```

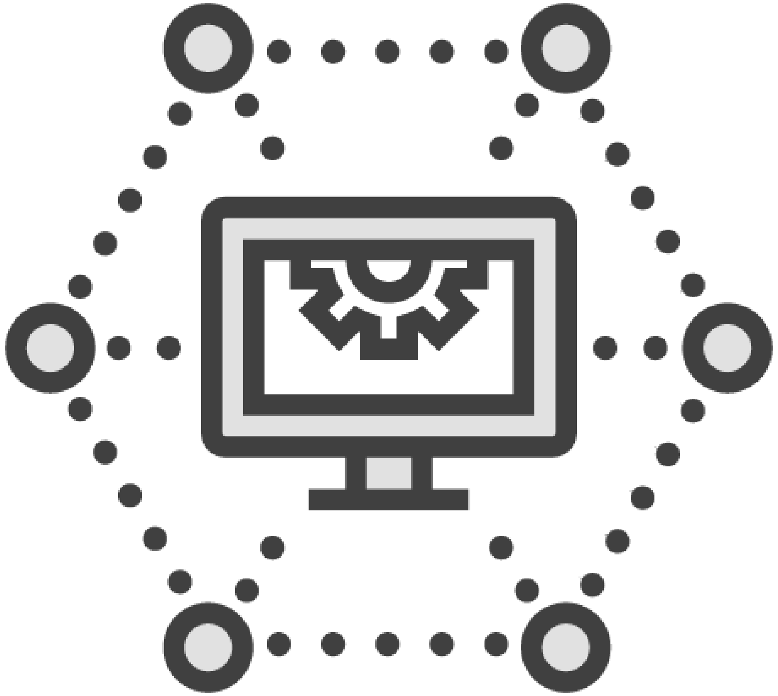
Demo



Creating and working with the "Incremental loads" table

Setting up Data Lineage

What Is Data Lineage?



Data lineage tracks the movement of data

- What are the origins of data
- Where is the data going to
- When was the data loaded or updated
- What transformations are applied to the data

The complexity of data lineage implementations varies

- Depends on the necessities of the project

It is important to set up data lineage in data warehouse projects

Advantages of Data Lineage

Advantages of Data Lineage

Troubleshooting

Advantages of Data Lineage

Troubleshooting

Data warehouse

Sale number	Product
123	Cherry toffee

Source system

Sale number	Product
123	Super cherry toffee

Advantages of Data Lineage

Troubleshooting

Advantages of Data Lineage

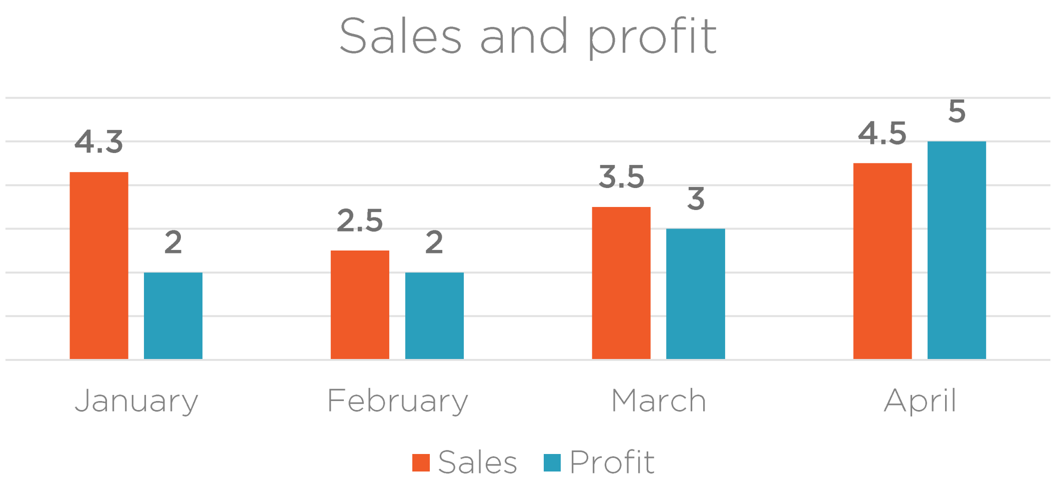
Troubleshooting

Data trust

Advantages of Data Lineage

Troubleshooting

Data trust



Advantages of Data Lineage

Troubleshooting

Data trust

Advantages of Data Lineage

Troubleshooting

Data trust

Transparent business rules

Advantages of Data Lineage

Troubleshooting

Data trust

Transparent business rules

Rate	% of VAT	Applies to
Standard	20%	Mixed ice cream, frozen yogurt
Reduced	5%	Some goods and services
Zero	0%	Herbal tea, pita bread, cold sandwiches, crocodile meat

Advantages of Data Lineage

Troubleshooting

Data trust

Transparent business rules

Advantages of Data Lineage

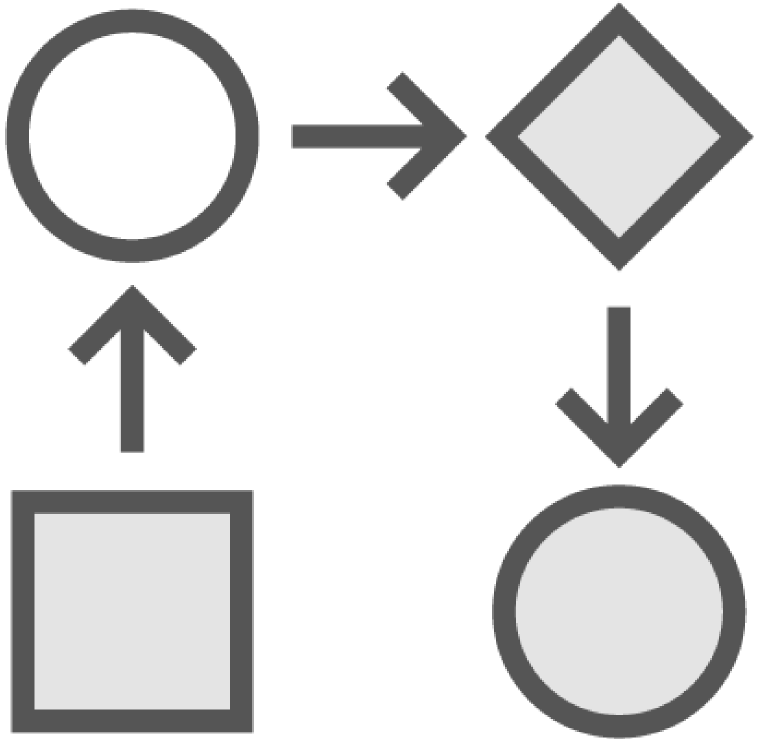
Troubleshooting

Data trust

Transparent business rules

Data audit

Implementing Data Lineage



Ensure row uniqueness

- Use surrogate keys
- Data passes multiple stages from source to destination
- Keeping the same key through all the stages helps tracing back the data

Keep track of the operation that loaded each row

- Create a “Lineage” column in all tables from the data warehouse

Implementing Data Lineage

Lineage key	Table name	Start	End	Type	Status

Implementing Data Lineage

Lineage key	Table name	Start	End	Type	Status

Product key	Product name	...	Lineage key

Employee key	Employee name	...	Lineage key

Implementing Data Lineage

Lineage key	Table name	Start	End	Type	Status
10	Dim_Product	2019-03-04 20:39:10.000	null	F	P

Product key	Product name	...	Lineage key

Employee key	Employee name	...	Lineage key

Implementing Data Lineage

Lineage key	Table name	Start	End	Type	Status
10	Dim_Product	2019-03-04 20:39:10.000	null	F	P

Product key	Product name	...	Lineage key
1	Cotton candy		10
2	Green tea		10

Employee key	Employee name	...	Lineage key

Implementing Data Lineage

Lineage key	Table name	Start	End	Type	Status
10	Dim_Product	2019-03-04 20:39:10.000	2019-03-04 20:54:35.000	F	S

Product key	Product name	...	Lineage key
1	Cotton candy		10
2	Green tea		10

Employee key	Employee name	...	Lineage key

Implementing Data Lineage

Lineage key	Table name	Start	End	Type	Status
10	Dim_Product	2019-03-04 20:39:10.000	2019-03-04 20:54:35.000	F	S
11	Dim_Employee	2019-03-04 20:45:21.000	null	F	P

Product key	Product name	...	Lineage key
1	Cotton candy		10
2	Green tea		10

Employee key	Employee name	...	Lineage key

Implementing Data Lineage

Lineage key	Table name	Start	End	Type	Status
10	Dim_Product	2019-03-04 20:39:10.000	2019-03-04 20:54:35.000	F	S
11	Dim_Employee	2019-03-04 20:45:21.000	null	F	P

Product key	Product name	...	Lineage key
1	Cotton candy		10
2	Green tea		10

Employee key	Employee name	...	Lineage key
1	Mary Baker		11
2	Jack Peanut		11
3	Gigi Knopper		11
...	...		...

Implementing Data Lineage

Lineage key	Table name	Start	End	Type	Status
10	Dim_Product	2019-03-04 20:39:10.000	2019-03-04 20:54:35.000	F	S
11	Dim_Employee	2019-03-04 20:45:21.000	2019-03-04 20:59:12.000	F	S

Product key	Product name	...	Lineage key
1	Cotton candy		10
2	Green tea		10

Employee key	Employee name	...	Lineage key
1	Mary Baker		11
2	Jack Peanut		11
3	Gigi Knopper		11
...	...		...

Implementing Data Lineage

Lineage key	Table name	Start	End	Type	Status
10	Dim_Product	2019-03-04 20:39:10.000	2019-03-04 20:54:35.000	F	S
11	Dim_Employee	2019-03-04 20:45:21.000	2019-03-04 20:59:12.000	F	S
...	...	...	...		...

Product key	Product name	...	Lineage key
1	Cotton candy		10
2	Green tea		10

Employee key	Employee name	...	Lineage key
1	Mary Baker		11
2	Jack Peanut		11
3	Gigi Knopper		11
...	...		...

Implementing Data Lineage

Lineage key	Table name	Start	End	Type	Status
10	Dim_Product	2019-03-04 20:39:10.000	2019-03-04 20:54:35.000	F	S
11	Dim_Employee	2019-03-04 20:45:21.000	2019-03-04 20:59:12.000	F	S
...	...	...	...		...
28	Dim_Product	2019-03-15 20:07:10.000	null	I	P

Product key	Product name	...	Lineage key
1	Cotton candy		10
2	Green tea		10

Employee key	Employee name	...	Lineage key
1	Mary Baker		11
2	Jack Peanut		11
3	Gigi Knopper		11
...	...		...

Implementing Data Lineage

Lineage key	Table name	Start	End	Type	Status
10	Dim_Product	2019-03-04 20:39:10.000	2019-03-04 20:54:35.000	F	S
11	Dim_Employee	2019-03-04 20:45:21.000	2019-03-04 20:59:12.000	F	S
…	…	…	…		…
28	Dim_Product	2019-03-15 20:07:10.000	null	I	P

Product key	Product name	…	Lineage key
1	Cotton candy		10
2	Green tea		10
3	Grape juice		28
4	Banana bread		28

Employee key	Employee name	…	Lineage key
1	Mary Baker		11
2	Jack Peanut		11
3	Gigi Knopper		11
…	…		…

Implementing Data Lineage

Lineage key	Table name	Start	End	Type	Status
10	Dim_Product	2019-03-04 20:39:10.000	2019-03-04 20:54:35.000	F	S
11	Dim_Employee	2019-03-04 20:45:21.000	2019-03-04 20:59:12.000	F	S
...	...	...	...		...
28	Dim_Product	2019-03-15 20:07:10.000	2019-03-15 20:12:33.000	I	S

Product key	Product name	...	Lineage key
1	Cotton candy		10
2	Green tea		10
3	Grape juice		28
4	Banana bread		28

Employee key	Employee name	...	Lineage key
1	Mary Baker		11
2	Jack Peanut		11
3	Gigi Knopper		11
...	...		...

Demo

Creating and working with the Lineage table

Demo

Populating a dimension table with the help of stored procedures

- Load_StagingProduct
- Load_DimProduct

Objects Participating in a Load Process

Object (table/stored procedure)	Was discussed
Fact/dimension tables	✓
Staging tables	✓
SP for loading the staging table	✓
SP for loading the fact/dim table	✓
Lineage table	✓
Incremental loads table	✓
SPs for updating the log tables	✓

Summary

Overview of an ETL system

Types of data warehouse loads

- Full (initial) load
- Incremental load

Setting up data lineage

Demos

- Creating and using the auxiliary tables
  - Lineage
  - Incremental loads
- Populating with data the staging and dimension tables

Setting up an ETL Project in SSIS

Ana Voicu

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Overview

What is an ETL tool

Advantages of using an ETL tool

Overview of SSIS

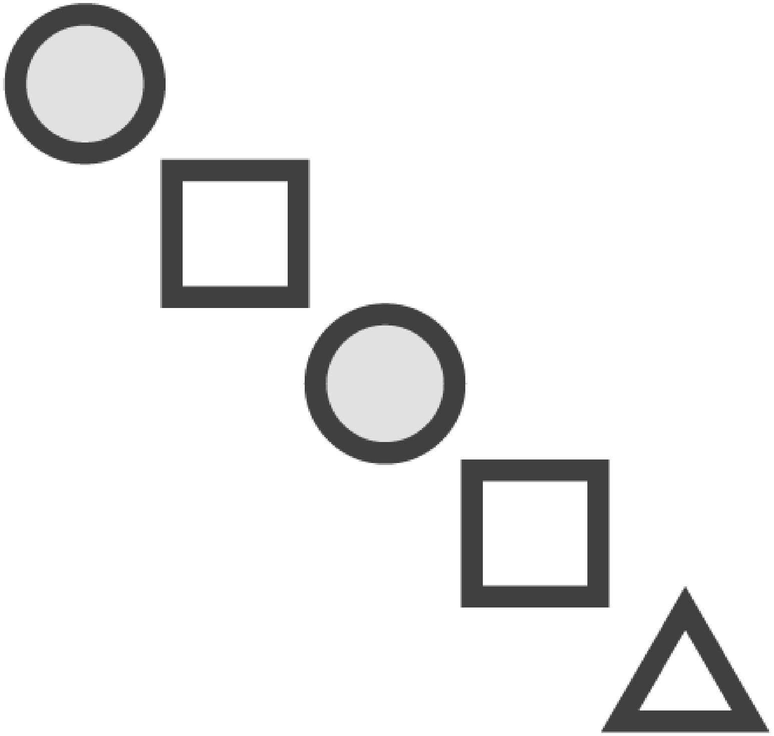
Demos

- Creating a new SSIS project with Visual Studio
- Adding connection managers
- Creating control flow components
- Linking tasks with precedence constraints
- Adding project variables
- Executing SQL tasks with parameters

Disclaimer: This is not an intensive course on SSIS

Advantages of Using an ETL Tool

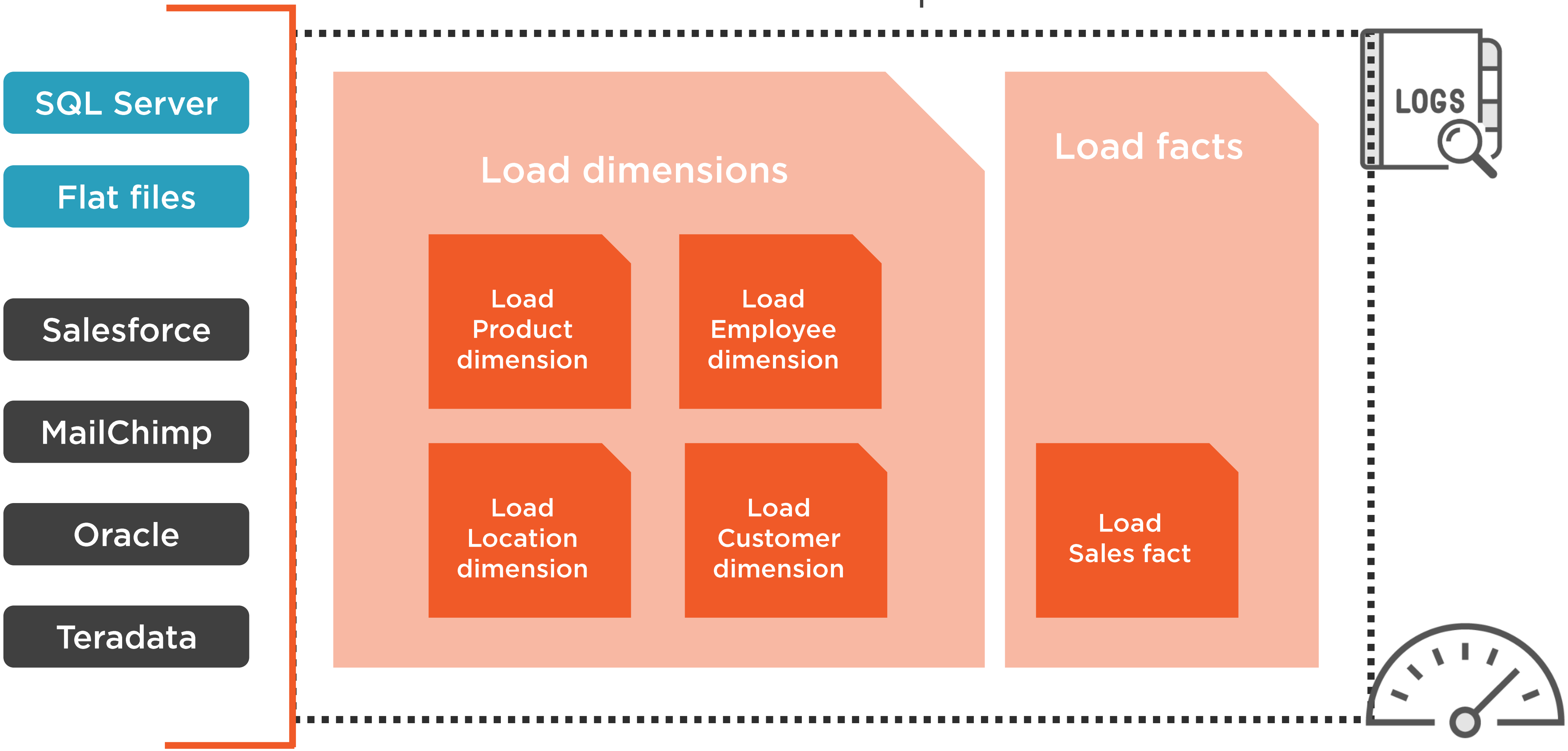
What Are ETL Tools?



Software systems for building and automating ETL processes

Offer an alternative to creating all the code for a DW solution by hand

Loading a Data Warehouse Only Using SQL Scripts



What Is an ETL Tool?

A system comprised of all the components needed to build ETL processes

Components:

- Data flow management
- Connectors to other systems
- Data transformation components
- Logging and auditing
- Debugging
- Deployment

Advantages of Using an ETL Tool

Flexibility

Maintainability

- Easier than working with hundreds of stored procedures
- ETL tools are very graphical and easy to interpret
- Easy to learn and use

Advantages of Using an ETL Tool

Flexibility

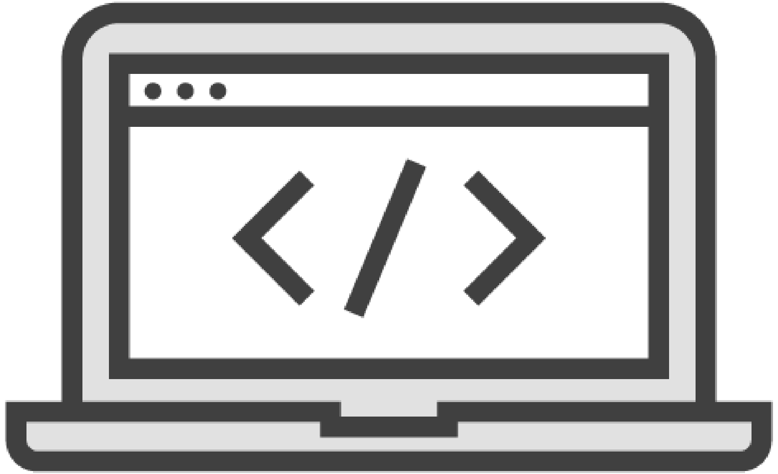
Maintainability

Advantages of Using an ETL Tool

Flexibility	Maintainability
Performance	Logging and audit

Overview of SSIS

What Is SSIS?



Component of SQL Server

Used for data integration and automating processes

Provides all the components necessary for creating an ETL process

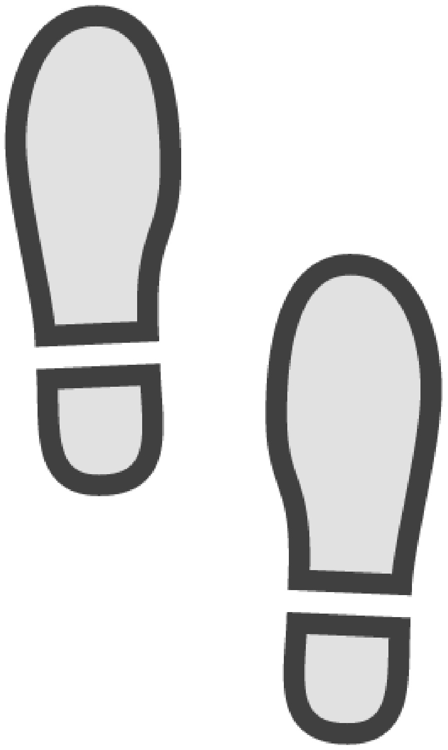
Graphical tool

- Doesn't require writing complex code
- Based on drag and drop actions

The output is a workflow, or pipeline

The unit of work in SSIS is called a package

Steps for Loading the Product Dimension



1. **Save the current load date**
2. **Insert new row in the Lineage table**
3. **Truncate the staging table**
4. **Populate the staging table**
5. **Transfer data from staging to dimension**

These steps are part of a flow or process

- Executed together
- In a specified order
- Executed multiple times

Overview of a SSIS Package

Get date of current load

Overview of a SSIS Package

Get date of current load

@[User::LoadDate] = GETDATE()

Overview of a SSIS Package

Get date of current load

@[User::LoadDate] = GETDATE()

Update Lineage table

Overview of a SSIS Package

Overview of a SSIS Package

Get date of current load — @[User::LoadDate] = GETDATE()

Update Lineage table — EXEC [int].[Get_LineageKey] ?, ?;

Truncate staging

Overview of a SSIS Package

Overview of a SSIS Package

- Get date of current load — @[User::LoadDate] = GETDATE()
- Update Lineage table — EXEC [int].[Get_LineageKey] ?, ?;
- Truncate staging — TRUNCATE TABLE Staging_Product
- Populate staging

Overview of a SSIS Package

Get date of current load — @[User::LoadDate] = GETDATE()

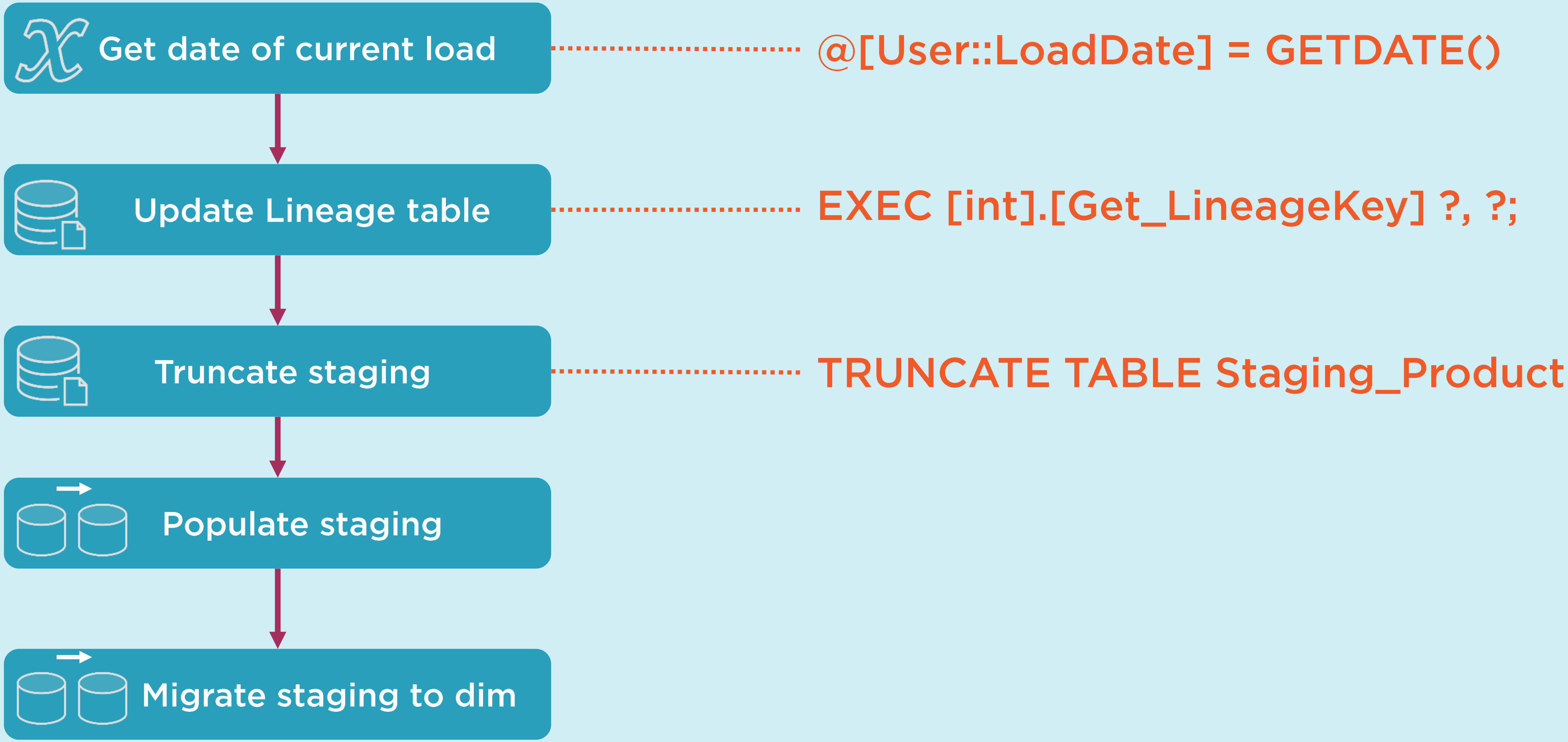
Update Lineage table — EXEC [int].[Get_LineageKey] ?, ?;

Truncate staging — TRUNCATE TABLE Staging_Product

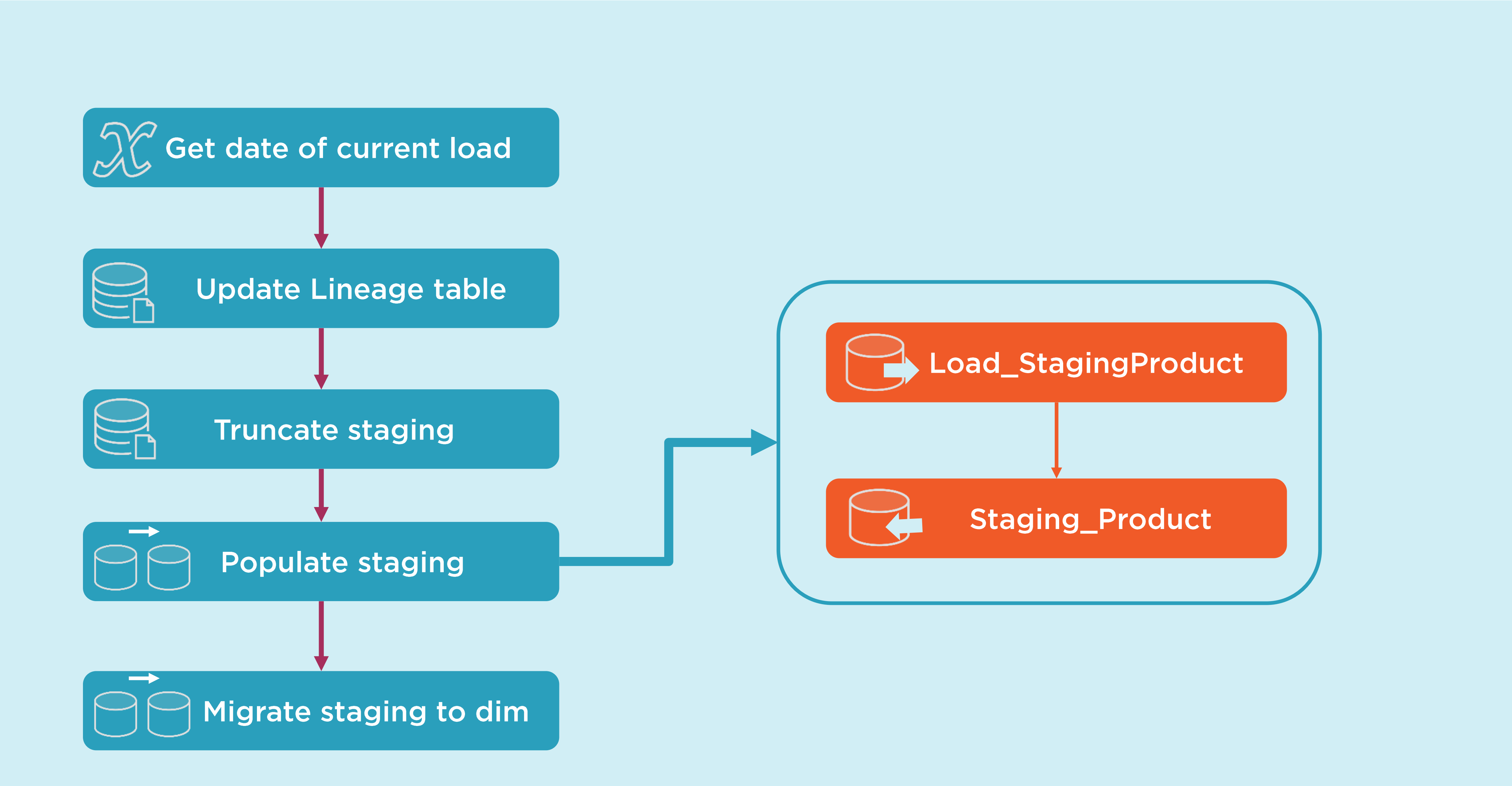
Populate staging

Migrate staging to dim

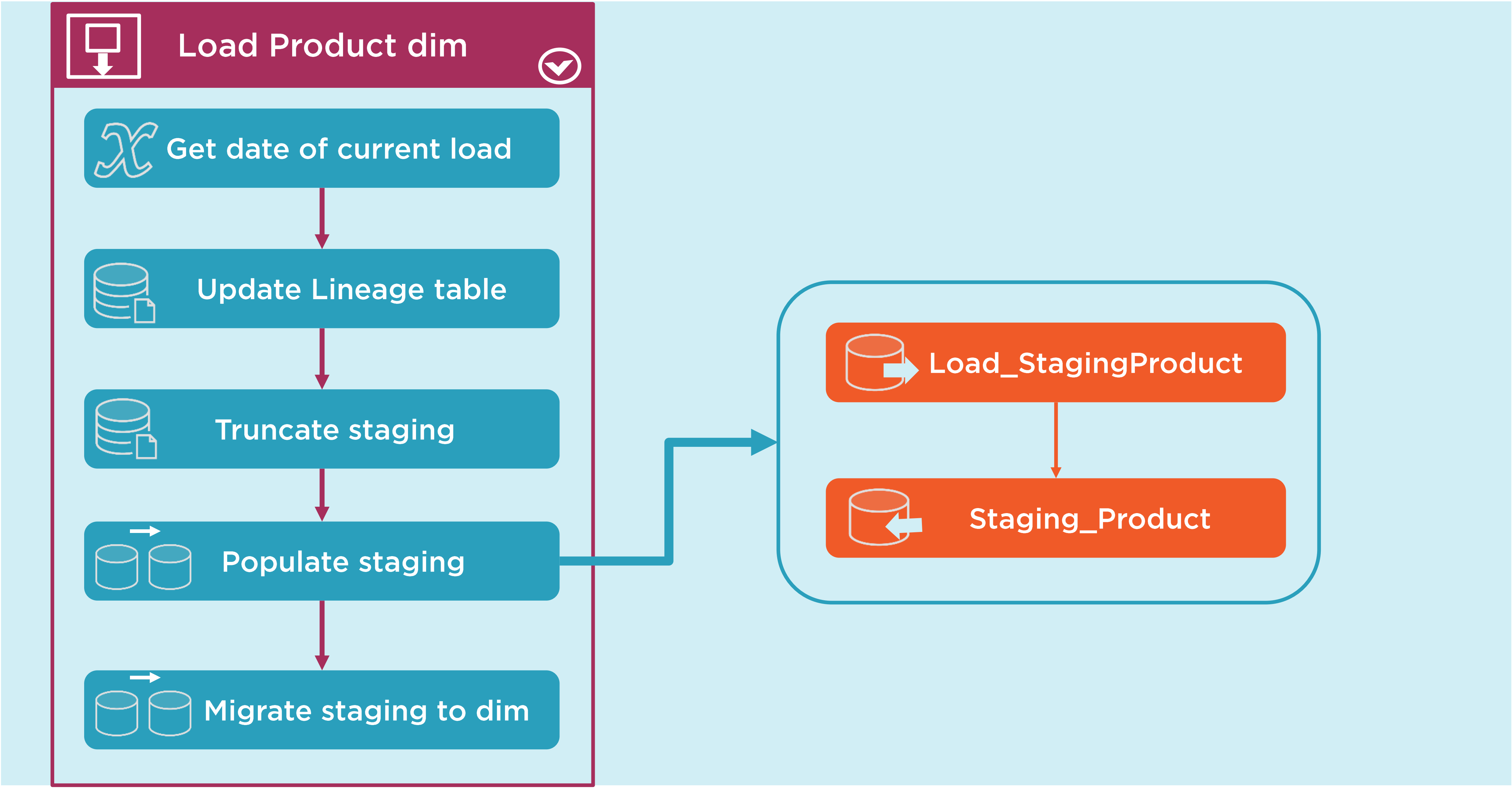
Overview of a SSIS Package



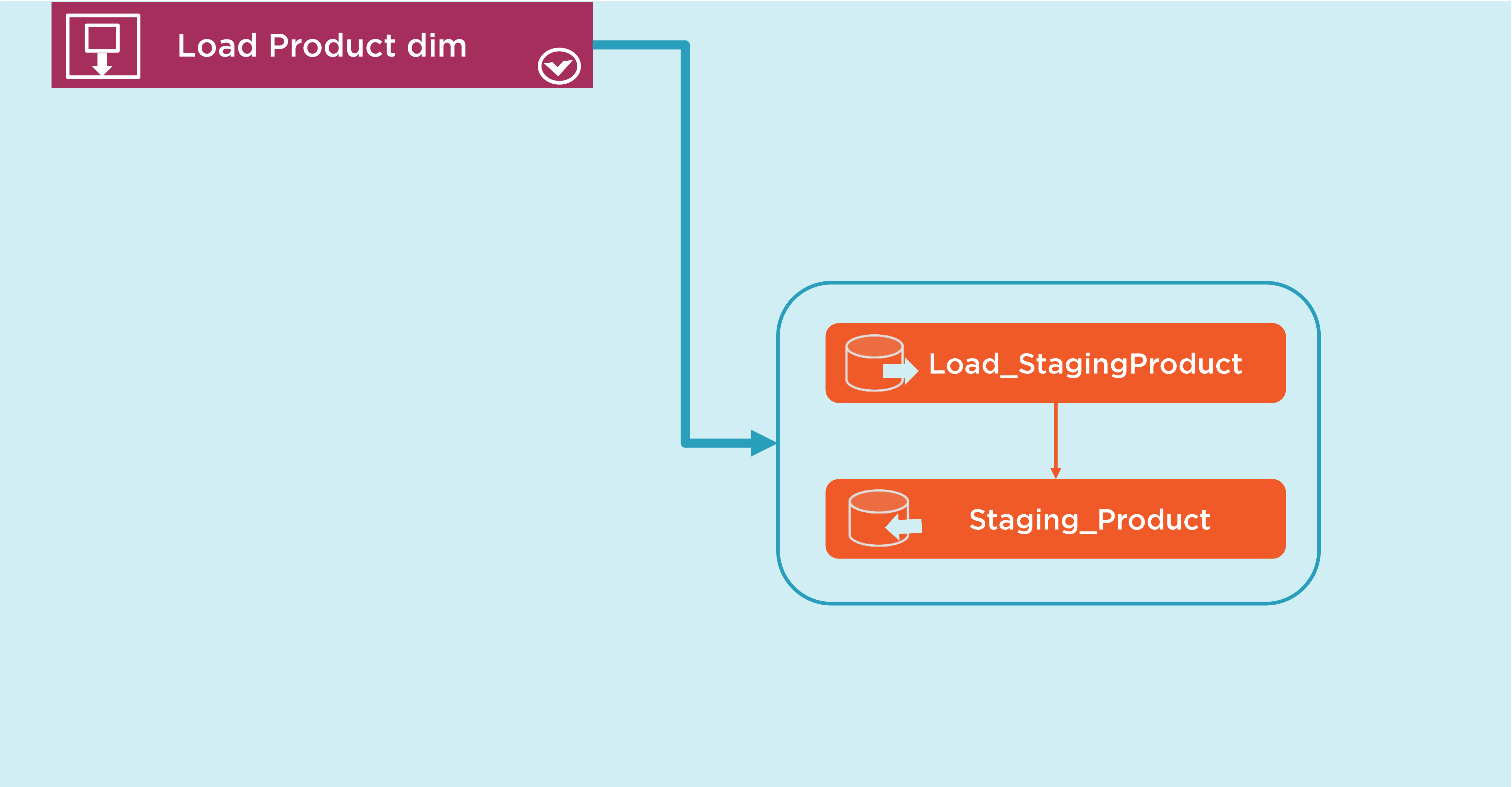
Overview of a SSIS Package



Overview of a SSIS Package



Overview of a SSIS Package



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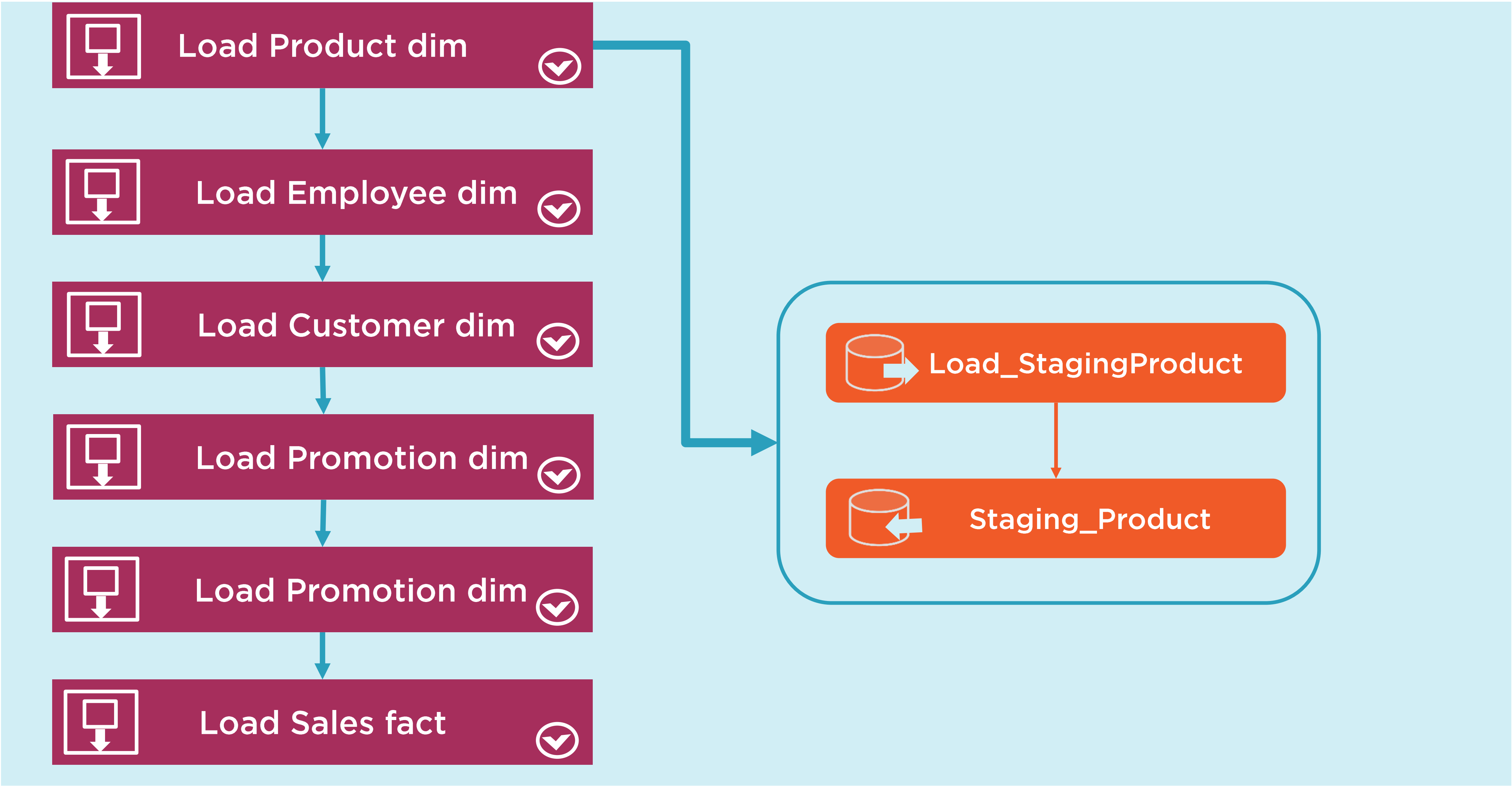

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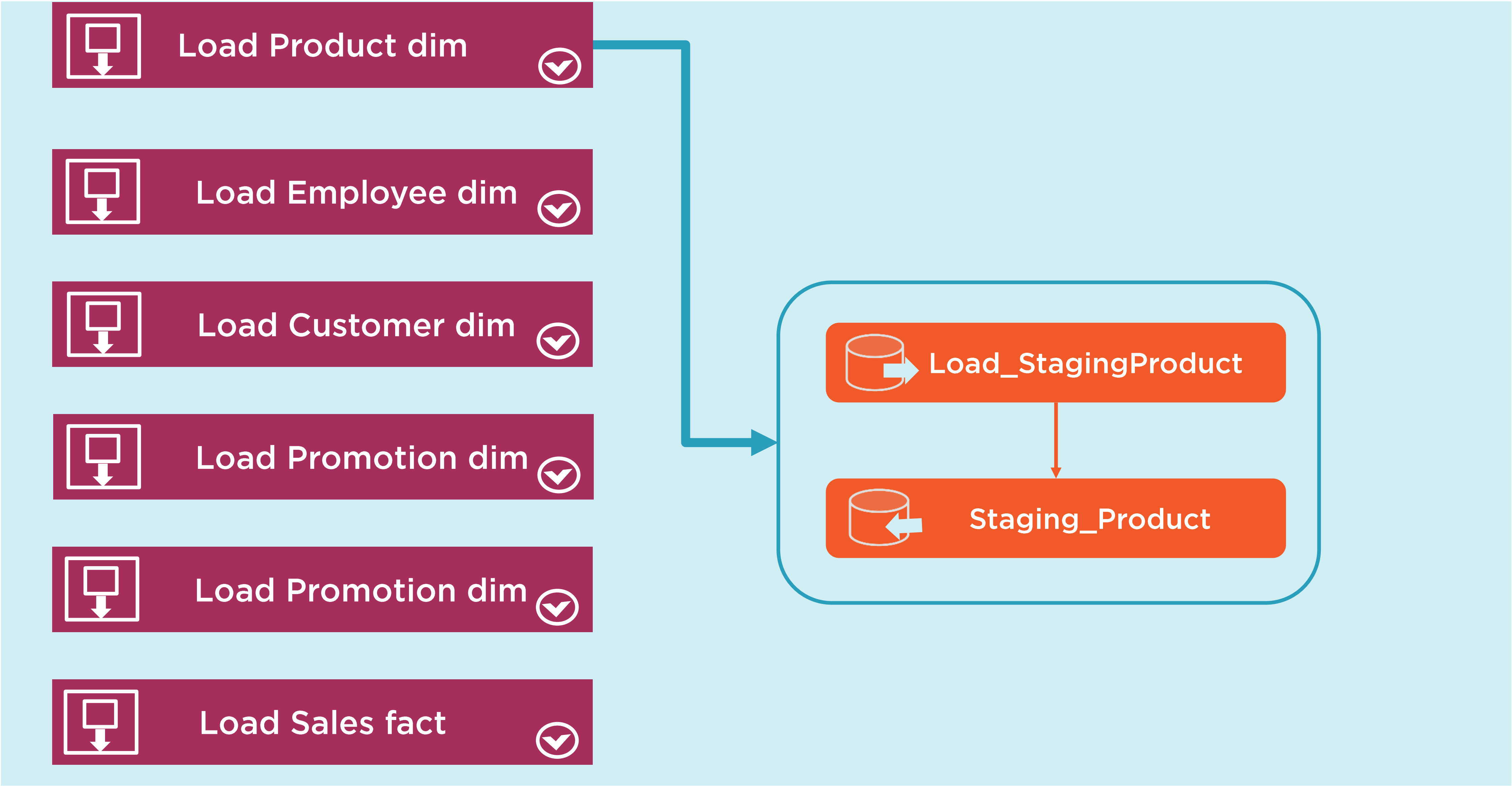
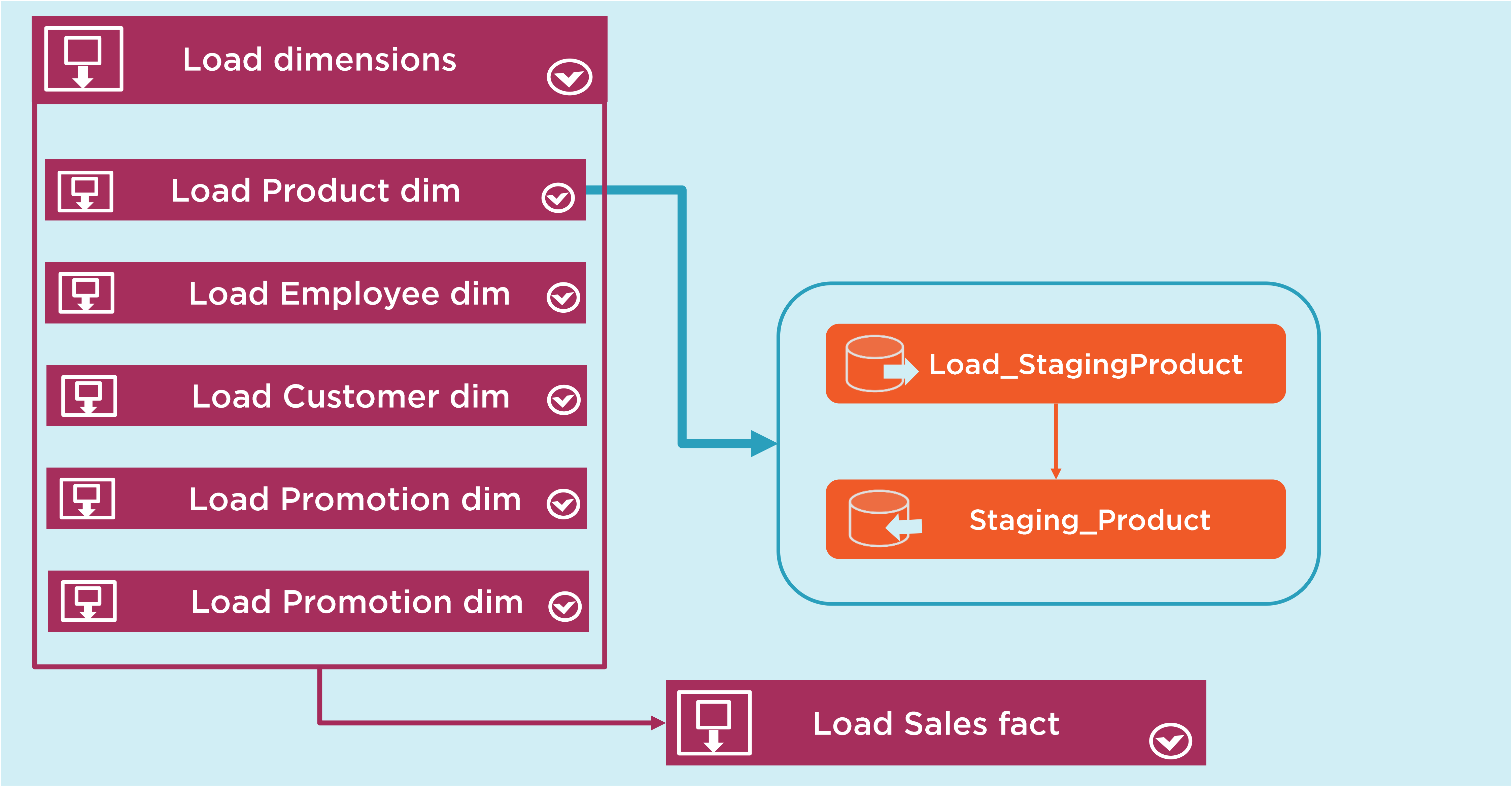


Overview of a SSIS Package



SSIS Terminology

SSIS Terminology

SSIS package	

SSIS Terminology

SSIS package	
Task	

SSIS Terminology

SSIS package	
Task **Control flow task**	

SSIS Terminology

SSIS package	
Task Control flow task Data flow task	

SSIS Terminology

SSIS package	
Task Control flow task Data flow task	
Control flow	

SSIS Terminology

SSIS package	
Task Control flow task Data flow task	
Control flow	
Data flow	

SSIS Terminology

SSIS package	
Task Control flow task Data flow task	
Control flow	
Data flow	
Connection manager	

SSIS Terminology

SSIS package	Container
Task Control flow task Data flow task	
Control flow	
Data flow	
Connection manager	

SSIS Terminology

SSIS package	Container
Task Control flow task Data flow task	Precedence constraint
Control flow	
Data flow	
Connection manager	

SSIS Terminology

SSIS package	Container
Task Control flow task Data flow task	Precedence constraint
Control flow	Variable
Data flow	
Connection manager	

SSIS Terminology

SSIS package	Container
Task Control flow task Data flow task	Precedence constraint
Control flow	Variable
Data flow	Parameter
Connection manager	

Demo

Creating a new SSIS project

Demo

Creating connection managers

- This is one of the first tasks to do in a new project
- Almost all components in SSIS need a connection

Demo

Creating SSIS components for loading Product dimension

- Connection managers
- Tasks
- Precedence constraints
- Containers

The package will do the following:

- Update Lineage and Incremental loads tables
- Transfer data into the staging table
- Update the dimension table

Demo

Creating and working with variables

Demo

Creating precedence constraints

Demo

Executing a SQL task with parameters

Practical Exercise

Retrieve the date of the previous load

- Create a SQL task that executes the stored procedure **[int].[Get_LastLoadedDate]**
- Save the result in the variable: **[User::PreviousLoadDate]**
- Execute the task after the staging table is truncated
- Rename the procedure **“SQL Get date of the previous load”**

Summary

Advantages of using ETL tools

High-level overview of SSIS

Creating an SSIS project

Configuring connections to the data sources

Creating control flow tasks

Setting up the order of execution with precedence constraints

Creating and working with package variables

Loading a Data Warehouse with SSIS

Ana Voicu

@ana_voicu

Overview

Design data flow elements

Organize control flow tasks in containers

Add package parameters

Change the properties of a task using expressions

Deploy and execute the SSIS project in SQL Server

The result is a project that:

- Loads the data warehouse (full or incremental load)
- Can be customized for different customers with parameters
- Can be executed automatically, from a SQL Agent job

Demo

Designing data flow elements

Demo

Organizing data with containers

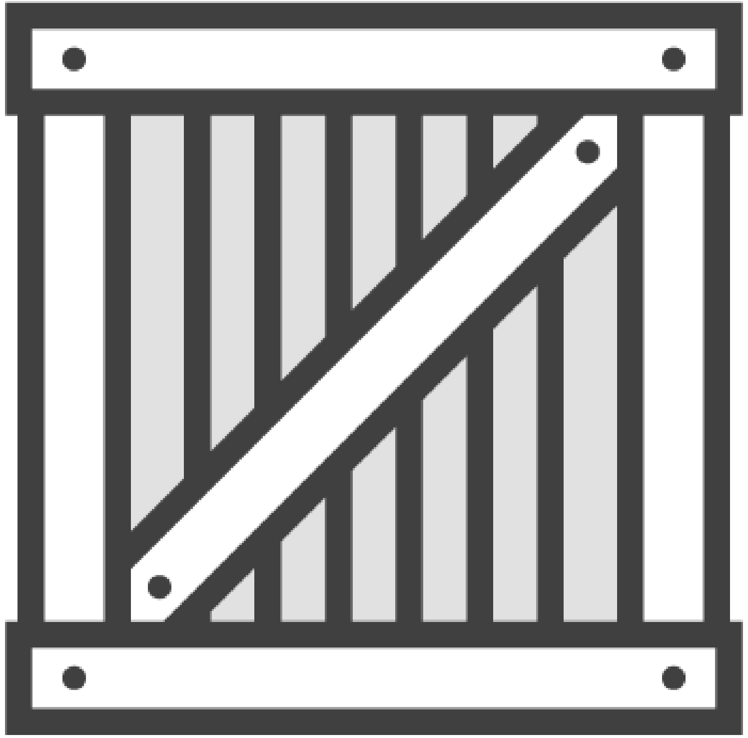
What Are Containers?

SSIS components that organize tasks into units

Three types of containers:

- For loop
- Foreach loop
- Sequence container

Description of Each Container Type



For loop

- The tasks are executed repeatedly, based on an expression

Foreach loop

- Iterate through a collection of objects

Sequence container

- Treats the elements as a whole
- If a task fails, the entire container fails
- You cannot add a precedence constraint between a task from the container and a task outside of it
- "All for one and one for all" behavior

Demo

Working with package parameters

- What are parameters?
- Types of parameters
- How to create parameters?
- The difference between parameters and variables

SSIS Parameters

Assign values to properties at package execution

Can be set:

- At package level
- At project level

Choosing what type to use depends on the deployment strategy for the project

Create the link between the outside world and the content within SSIS

Examples:

- Database server name
- Type of load (full or incremental)

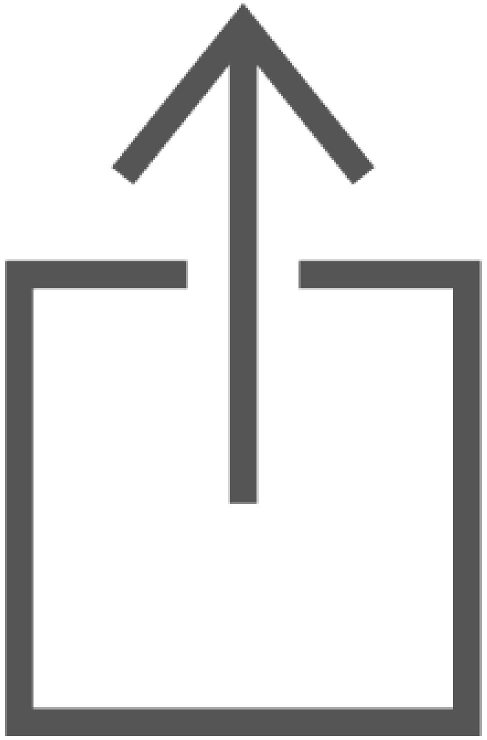
Demo

Adding expressions to tasks

Demo

Deploying and configuring a SSIS project

SSIS Deployment Model



The current deployment model is available starting with SQL Server 2012

Everything SSIS-related is centralized in one place

- Project and package parameters
- Execution runtime values
- Execution status and other troubleshooting information
- General information about SSIS

The centralized location is called SSISDB catalog

Summary

Understand the difference between control flow and data flow

Created data flow components

Created tasks to load all the dimensions and fact tables

Organized tasks in containers

Added package parameters

Used expressions to change the properties of a task at package execution

Deployed an SSIS project in SQL Server

Visualizing Data from the Data Warehouse

Ana Voicu
@ana_voicu

Project Status Update

Task	Status

Project Status Update

Task	Status
Create data warehouse	Done

Project Status Update

Task	Status
Create data warehouse	Done
Create load process in SSIS	Done

Project Status Update

Task	Status
Create data warehouse	Done
Create load process in SSIS	Done
Expose data and reports to end-users	Not done

Overview

Adding a semantic layer on top of the data warehouse

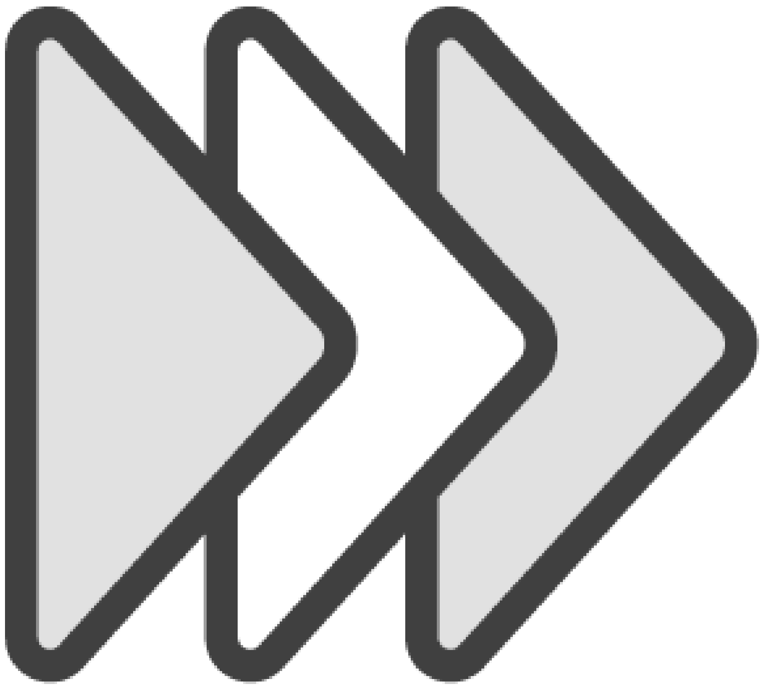
- A semantic layer is a structure that:
  - Reduces the complexity of the data warehouse
  - Shows only what is relevant
  - Creates pre-calculated measures, to improve performance
- SQL Server Analysis Services is used
  - Multidimensional model
  - Tabular model

Microsoft reporting tools:

- SQL Server Reporting Services
- Power BI
- Power BI Report Server

Creating a Semantic Layer

Stages of Creating a BI Solution



Summary of the previous steps

- Gathered business requirements
- Created the dimensional model
- Implemented the data warehouse in SQL Server
- Extended the DW with auxiliary tables
- Created the load process

Options to move forward

a) Create the visualization layer directly from the data warehouse

b) Create a semantic layer

Semantic layer

"It is a business representation of corporate data that helps end-users access data autonomously using common business terms.

A semantic layer maps complex data into familiar business terms such as product, customer, or revenue to offer a unified, consolidated view of data across the organization." (Wikipedia)

Clarifying the Confusion

Isn’t that what the dimensional design is doing?

- Yes, it is

The dimensional design

- Is an abstraction layer on top of different data sources
- Can be extended and simplified even more with a semantic model on top of it
- There are some advantages for creating the semantic model

Advantages of Using a Semantic Layer

Advantages of Using a Semantic Layer

Sales

Advantages of Using a Semantic Layer

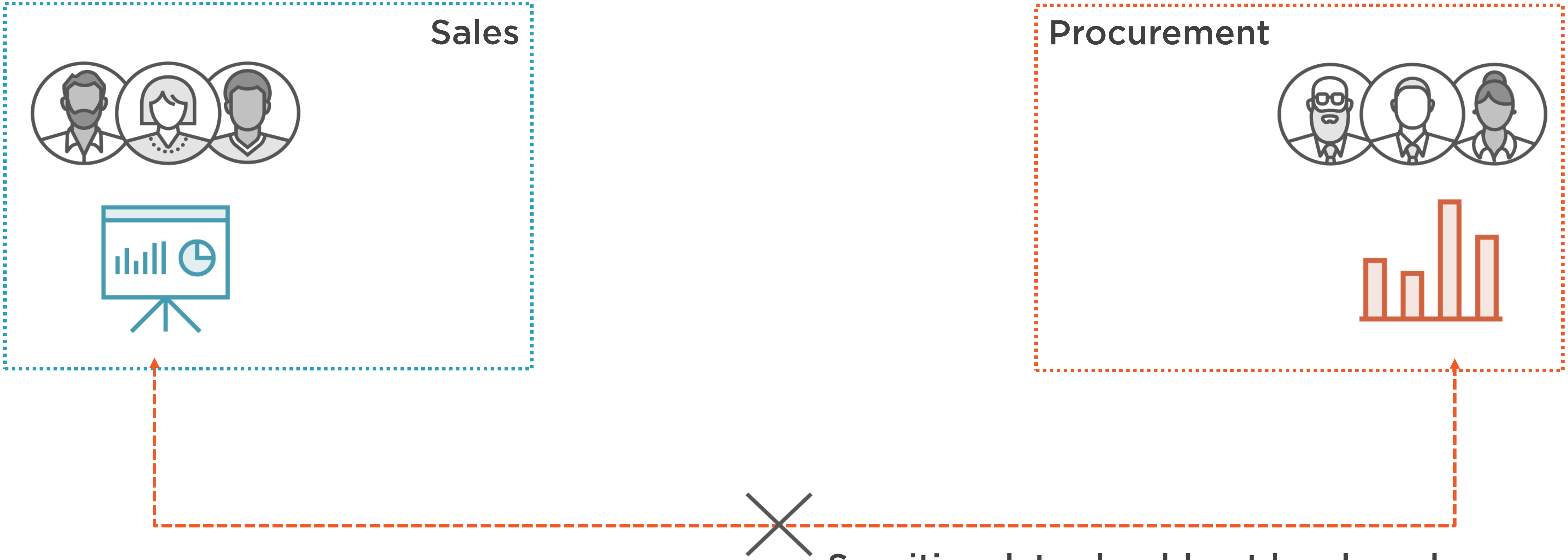
Advantages of Using a Semantic Layer

Advantages of Using a Semantic Layer

Sales

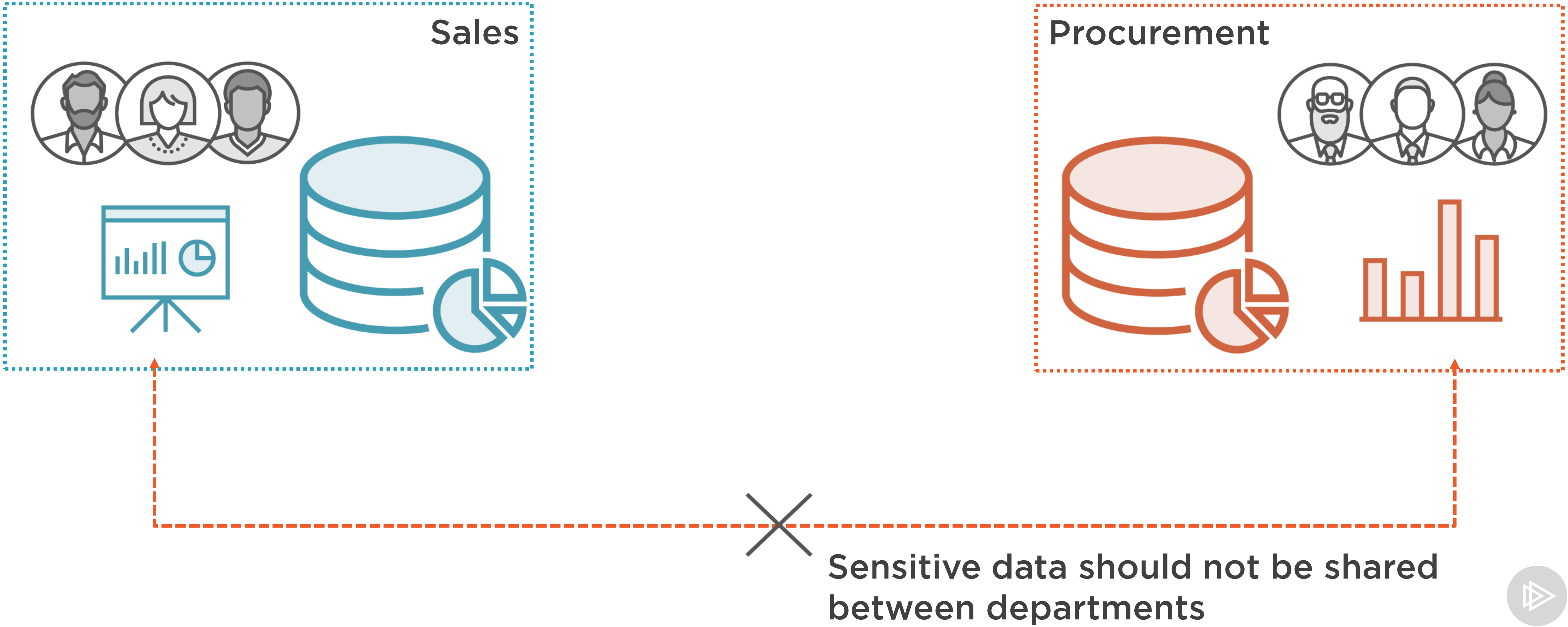
Procurement

Advantages of Using a Semantic Layer

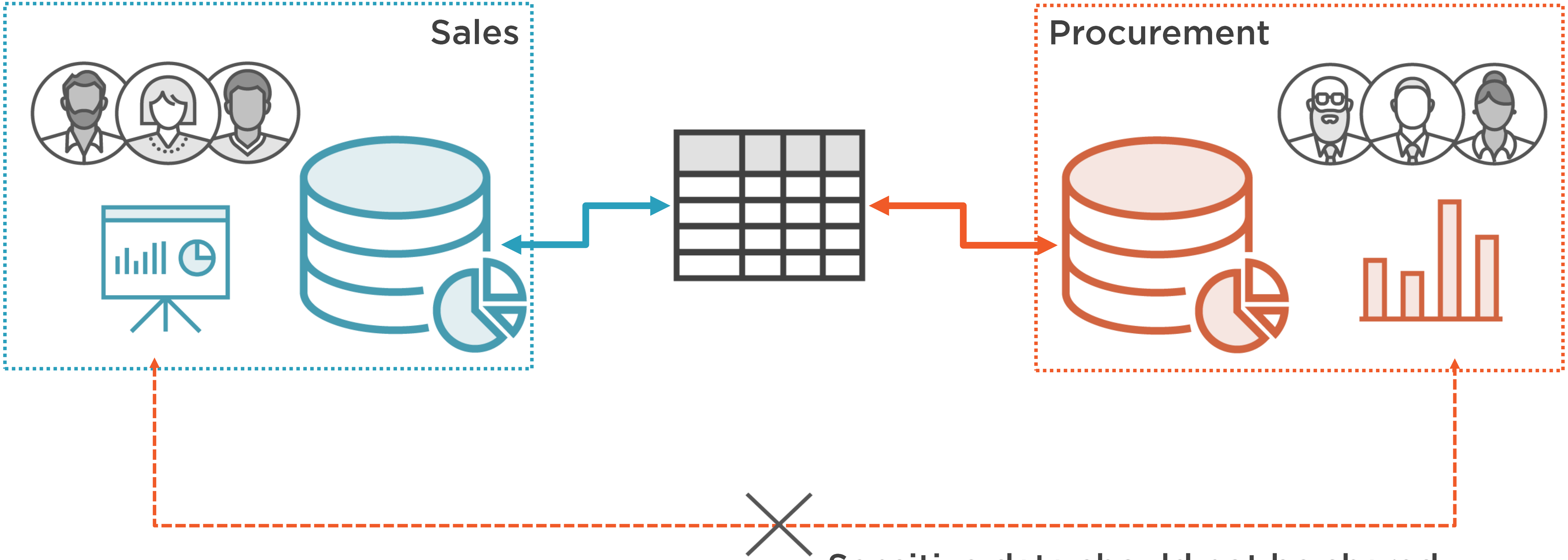


Sensitive data should not be shared between departments

Advantages of Using a Semantic Layer

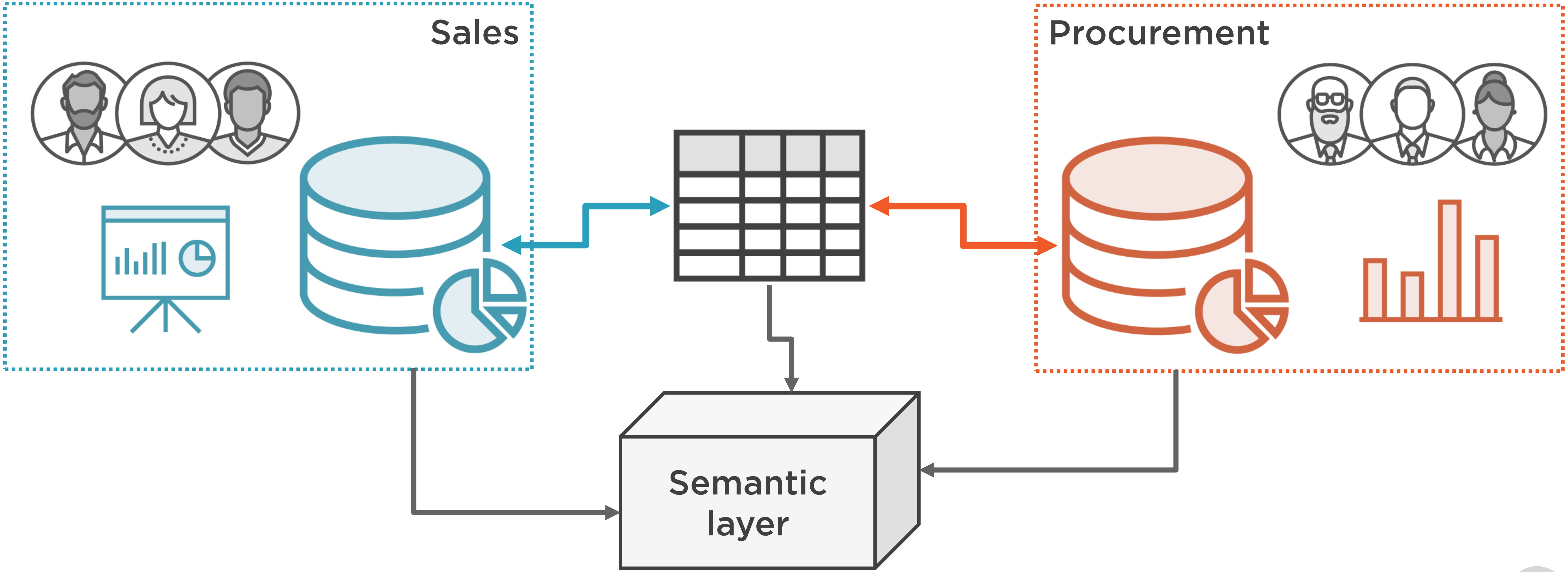


Advantages of Using a Semantic Layer

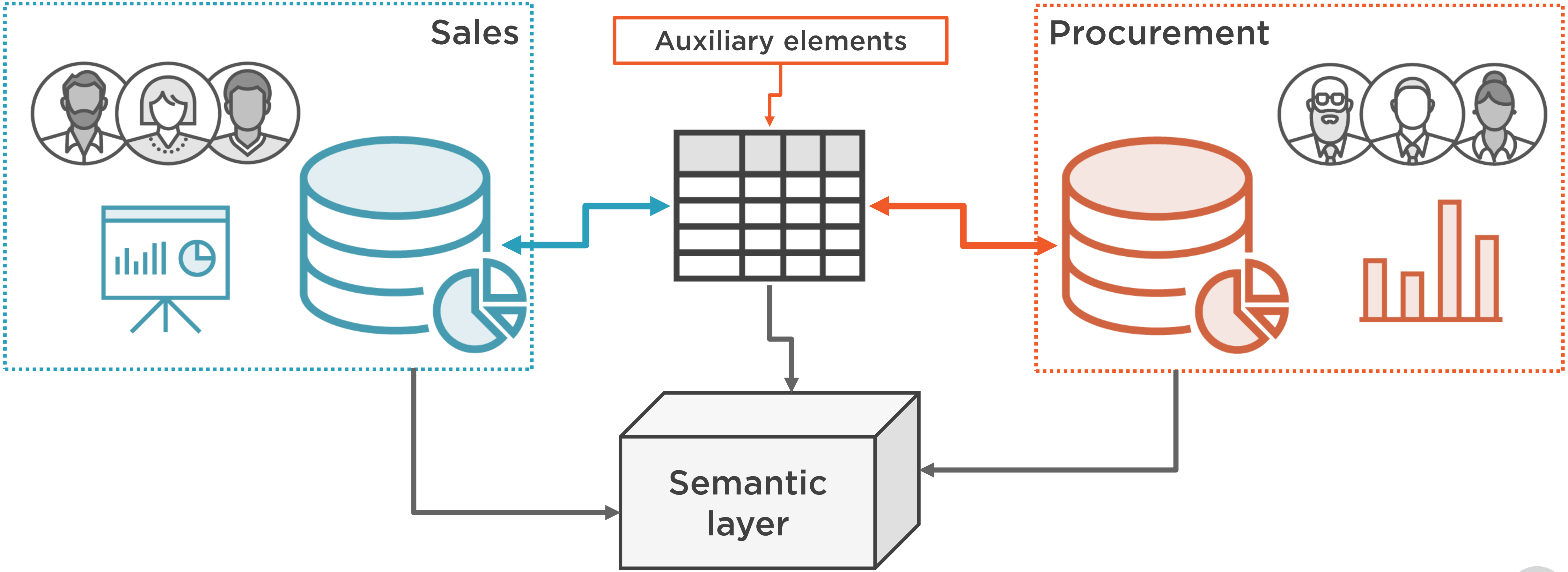


Sensitive data should not be shared between departments

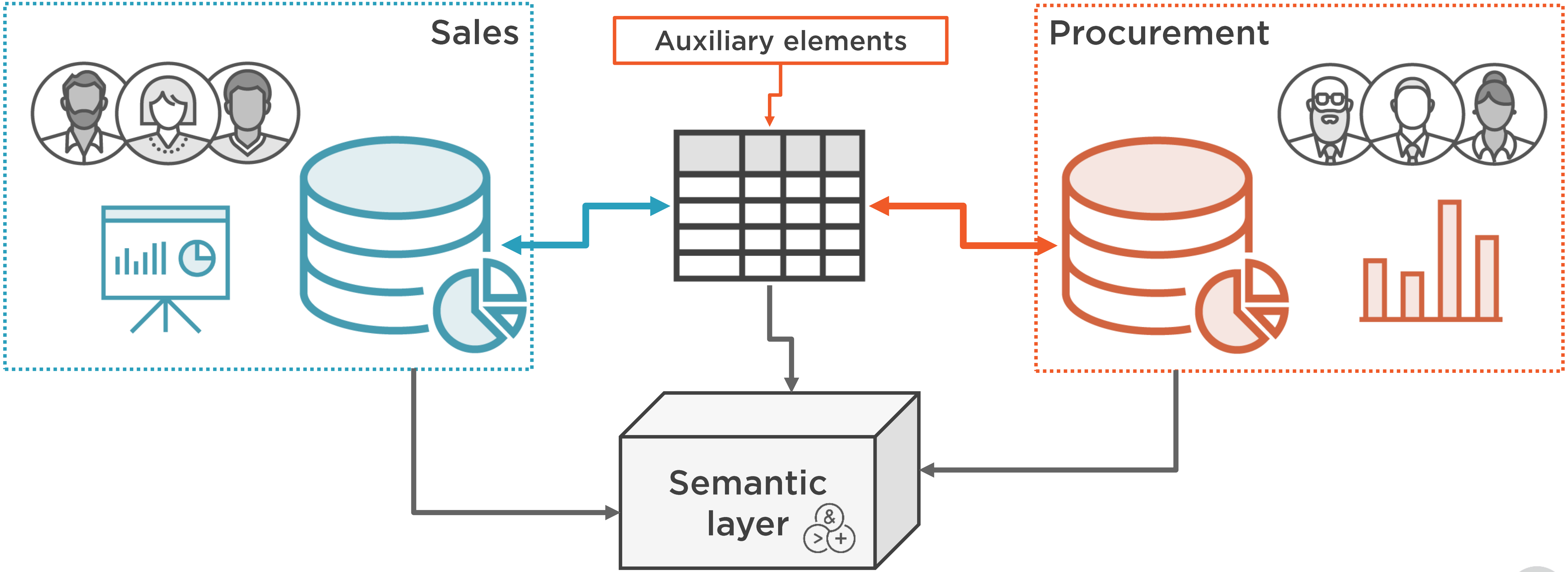
Advantages of Using a Semantic Layer



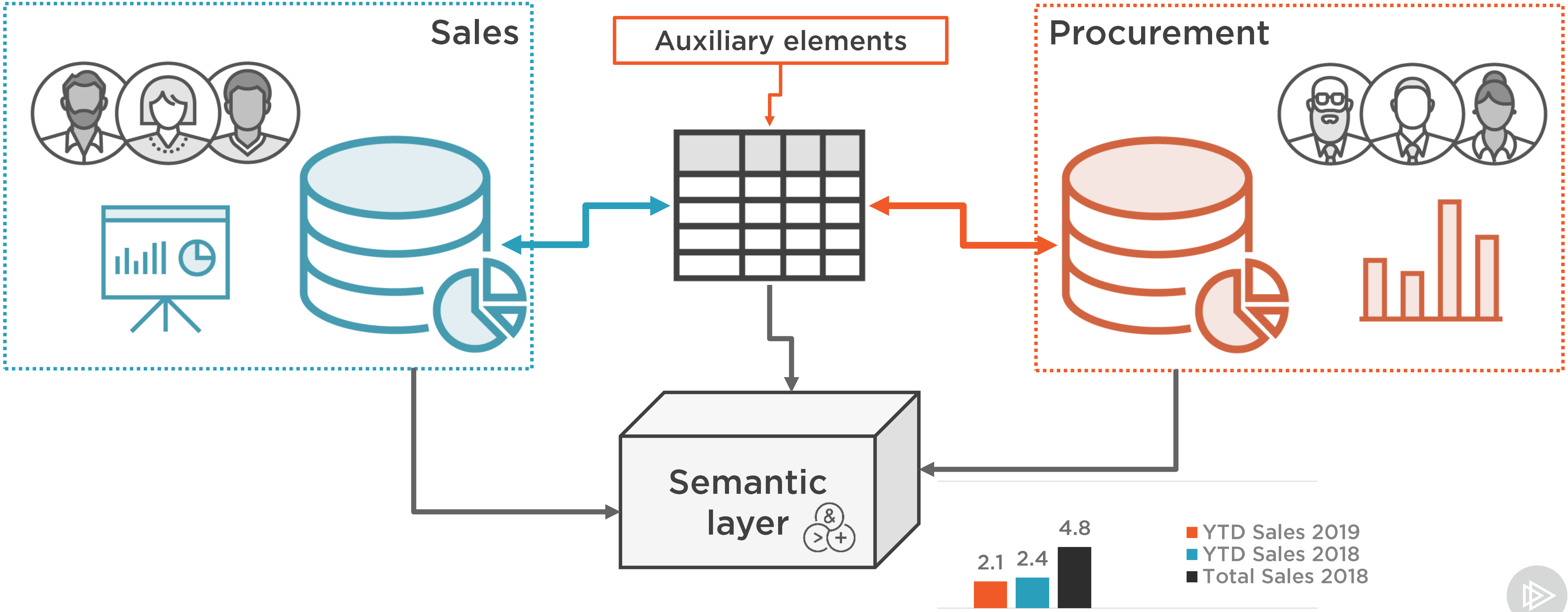
Advantages of Using a Semantic Layer



Advantages of Using a Semantic Layer



Advantages of Using a Semantic Layer



Advantages of Using a Semantic Layer

Show only relevant data

Faster query performance

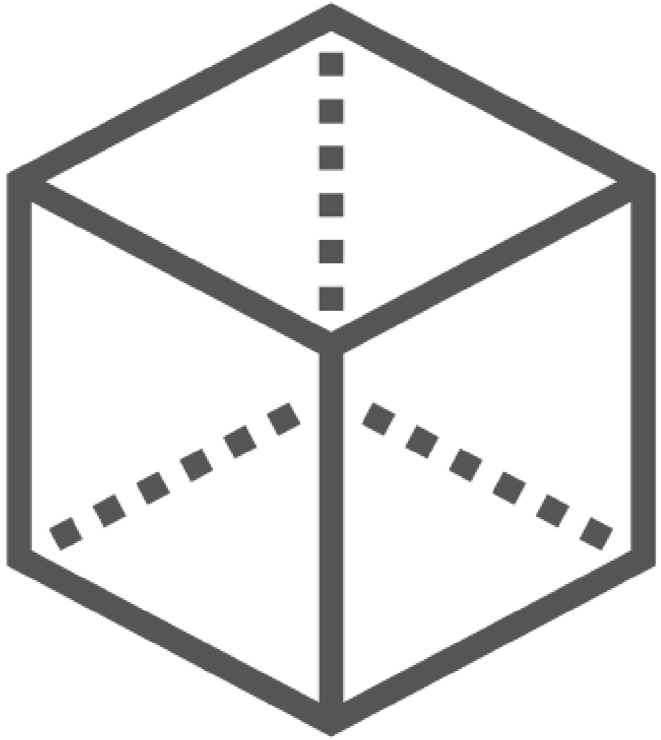
Complex aggregations

Readable names for objects

Consolidate data from multiple source

Integration with many BI tools

Types of Models in SSAS

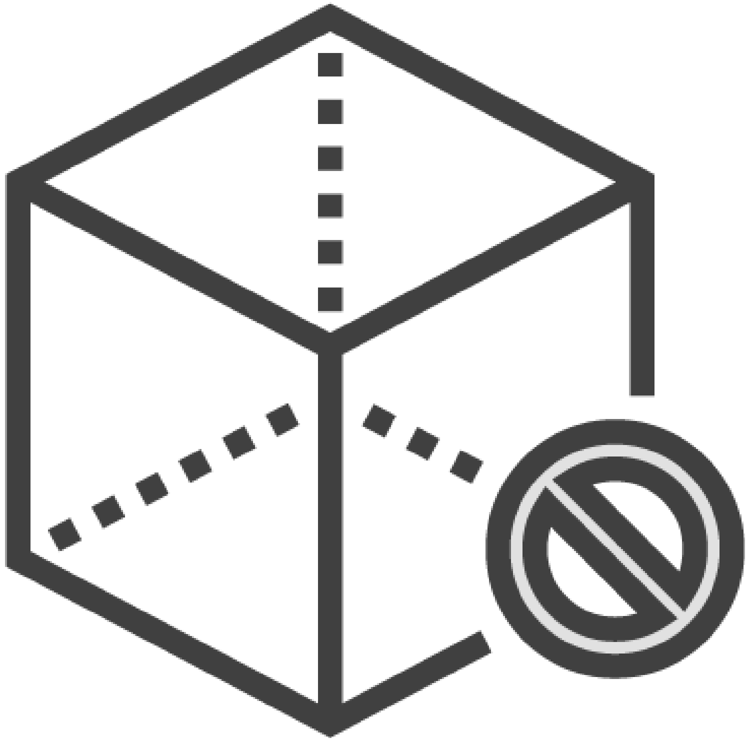


Multidimensional model

Tabular model

The Multidimensional and Tabular Models

The Multidimensional Model



Similar to the star schema design

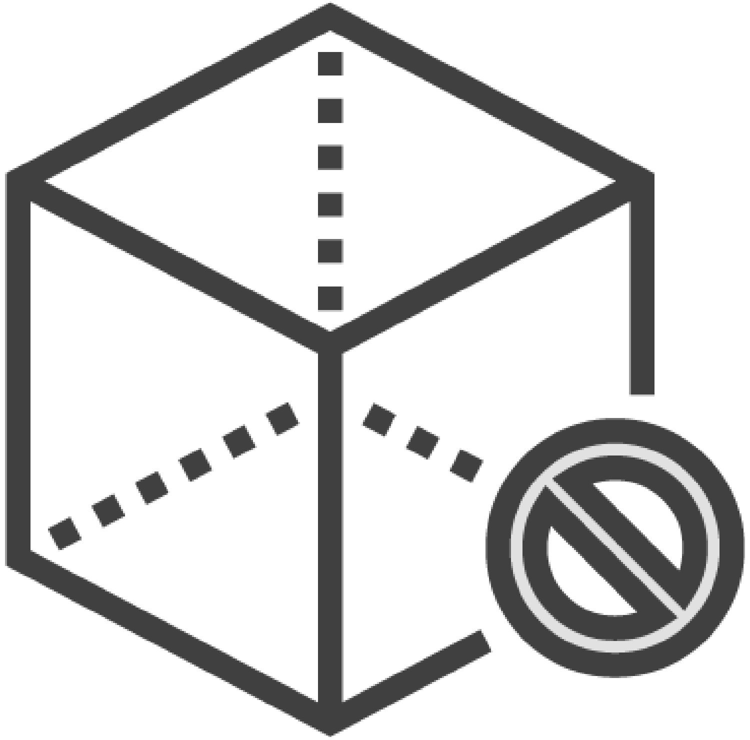
The main structure used for data analysis is the cube

A cube consists of

- Dimensions
- Measure groups

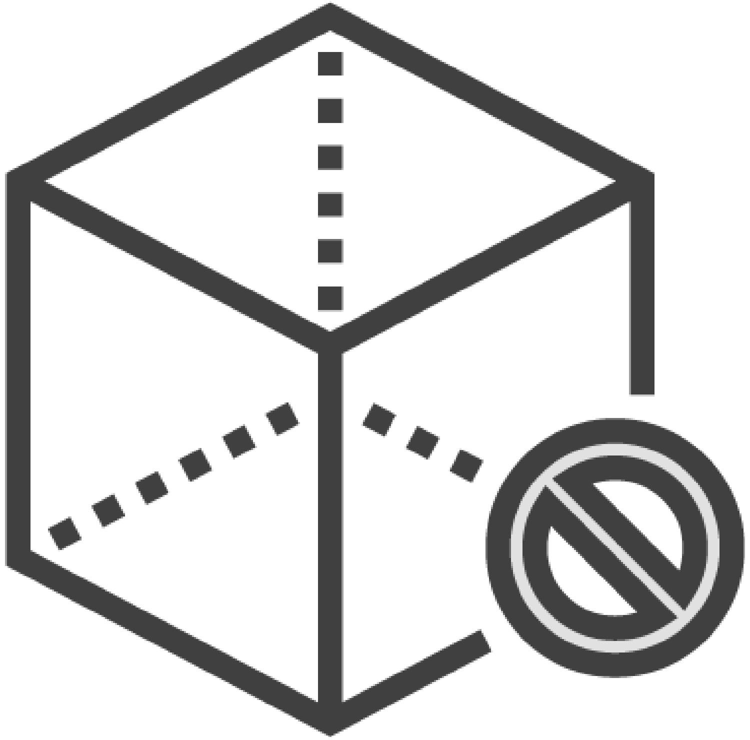
Data sources must be defined before creating other elements

The Multidimensional Model



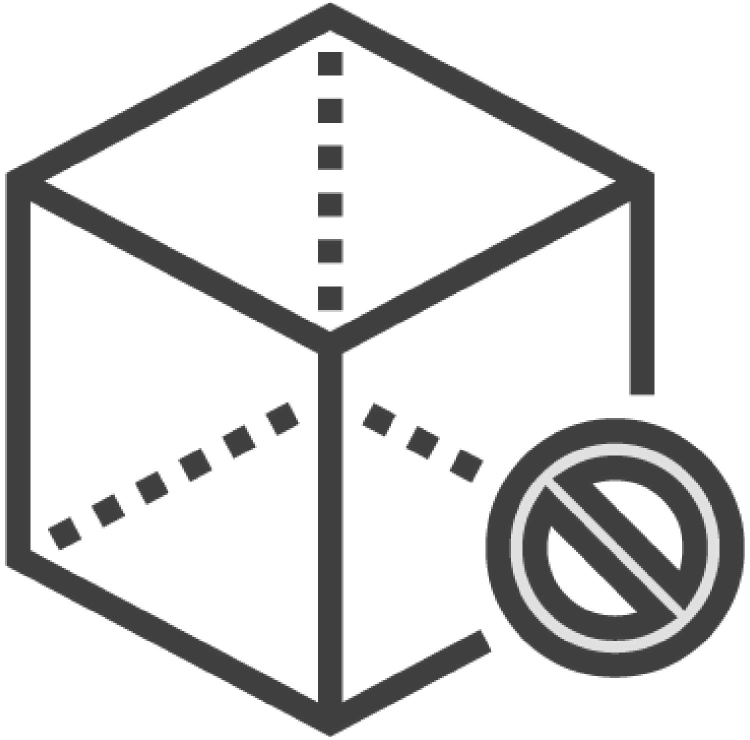
Multidimensional object	Data warehouse object
Dimension	Dimension table

The Multidimensional Model



Multidimensional object	Data warehouse object
Dimension	Dimension table
Measure group	Fact table

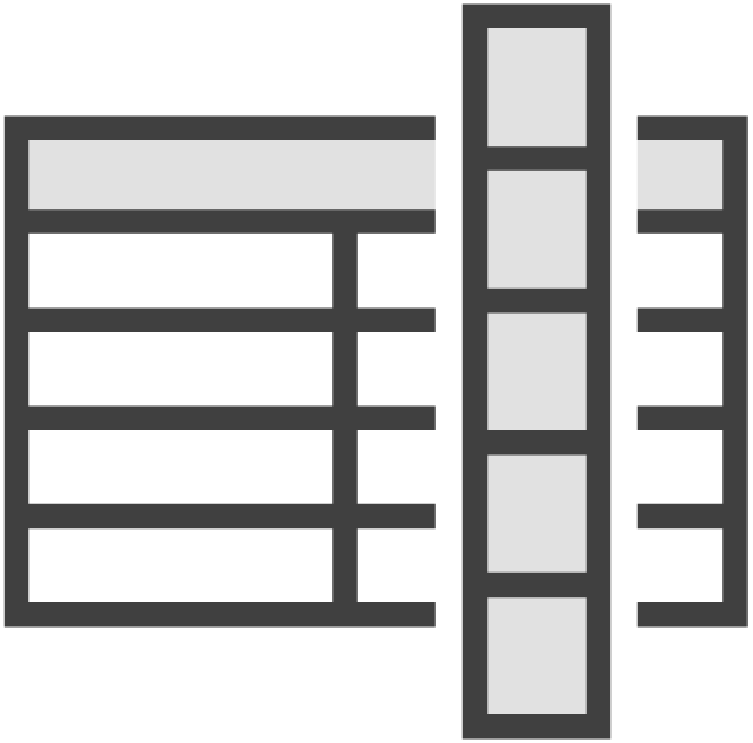
The Multidimensional Model



Multidimensional object	Data warehouse object
Dimension	Dimension table
Measure group	Fact table
Measure	Column in the fact table

New measures can be calculated in this database

The Tabular Model



In-memory database

Connects directly to a relational source of data

Similar to both SQL Server relational databases and a SSAS cube

- Consists of tables and relationships between tables
- You can also create measures and KPIs

The database can be used in Excel, Reporting Services, Power BI, etc.

Multidimensional vs. Tabular Model

Multidimensional

Better option when working with large amounts of data

Better performance in terms of scalability

Easily create and work with parent-child hierarchies

Writeback capabilities

Tabular

Easier for developers to understand and implement the model

DAX language

Doesn’t require strong hardware (disk) capabilities. It is only memory-dependent

The database is much smaller than the original source of data

Demo

Creating a multidimensional database in SSAS

- This is a separate type of database

Prerequisite for this demo

- Install SQL Server Analysis Services in multidimensional mode

Demo

Analyzing data from a SSAS database

Creating Interactive Reports

SQL Server Reporting Services

Paginated reports

- The "traditional" reports
- Data is organized in tables, spread on multiple pages
- Optimized for printing or saving as Word or PDF

Mobile reports

- Compatible with several mobile devices
- Connect to different data sources (including SQL Server and SSAS)
- The visualizations are not very diverse, but they still have a modern look and feel

Web portal

- The portal can be accessed from any browser
- Types of reports: Power BI, mobile, paginated, KPIs, Excel files
- The data sets used in reports can be accessed from the portal

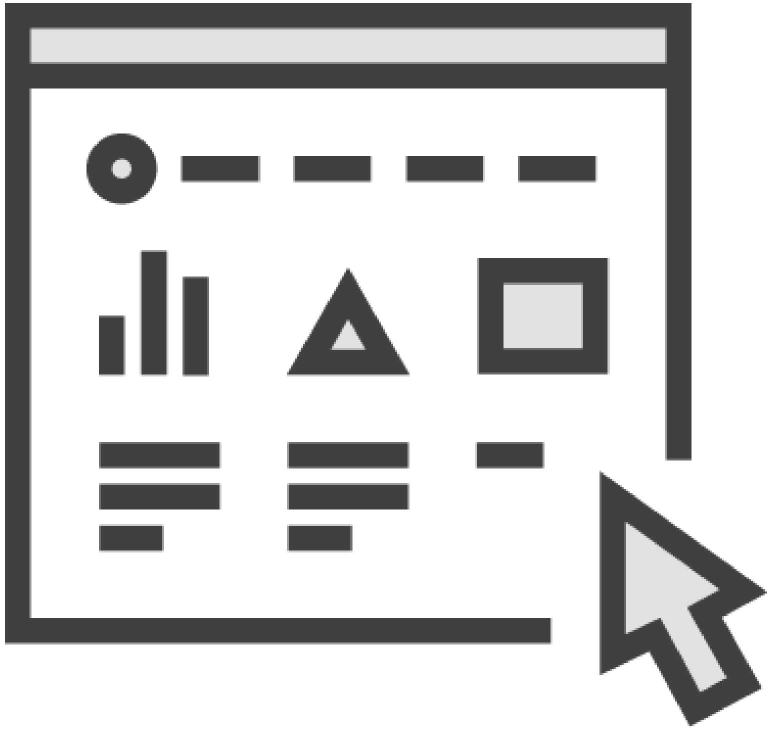
Power BI

Tool used to create rich and interactive reports

Components:

- **Power BI Desktop**
  - Download and use for free, to create reports
  - Collaborative editing is not supported
- **Power BI Service**
  - Cloud service
  - Share reports with people within/external to the organization
- **Power BI mobile app**

Power BI Report Server



Reporting capabilities of Power BI

Data remains on-premises

Users can visualize the reports

- In the web portal
- On mobile devices
- Shared by email

Available in SQL Server Enterprise Edition, or with Power BI Premium license

Demo

Creating and publishing a report with Power BI Report Server

You need to install two components

- Power BI Report Server
- Power BI Desktop for Report Server
- Download them from the Microsoft Download Center

Power BI Report Server is available in

- SQL Server Enterprise Edition
- SQL Server Developer Edition

Course Summary

Fundamental concepts of a data warehouse

- Purpose of a data warehouse
- Facts and fact tables
- Dimensions and dimension tables
- Steps of the dimensional design process

Dimension table techniques

Hierarchies

Fact tables

- Difference between fact and dimension tables
- Common types of fact tables

Course Summary

Creating the SQL scripts for loading a dimension table

- Create the Lineage and Incremental loads tables
- Create the stored procedures for loading data

Implementing a load process in SSIS

- Create a new SSIS project in Visual Studio
- Work with control flow and data flow tasks
- Add parameters
- Deploy the project in SQL Server
- Create a SQL Agent job to run the project automatically

Multidimensional and tabular models

Creating reports on top of the data warehouse

Thank you!