



# Navigate the Bill of Materials with SQL Server Shortest Path

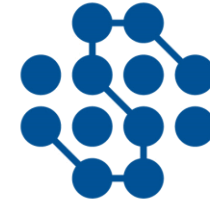
Andrea Martorana Tusa



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UNIVERSITÀ DEGLI STUDI DI PARMA



**DATA SKILLS**  
UNDERSTANDING THE WORLD



CREDEMTEL





# Speaker

- **MVP Data Platform**
- **Product Manager in Pandora**
  - Sharepoint, Power BI governance, security and access management
- Working and living in Denmark
- Speaker for many community driven events: SQL Saturdays, Data Saturdays, PASS Summit, etc; worldwide
- Author for [sqlservercentral.com](http://sqlservercentral.com), [sqlshack.com](http://sqlshack.com), UGISS (User Group Italiano SQL Server)

# Agenda

- Graphs
- Graphs and SQL Server 2017-19
- Query syntax and T-SQL graph extensions in SQL Server 2019
- Shortest Path
  - Navigate through a Bill of Materials
- D365 BOM

DISCLAIMER: This is not an introduction to graph databases. I'm just talking about the features you need to follow the session.

# Graphs

# Graph objects

A graph is a collection of *Nodes* and *Edges*

- ***Nodes*** = Entities (customers, products, territories, ...)
- ***Edges*** = Relationships between entities
- ***Properties*** = Node or Edge attributes

# Graph objects

## ***Node***

- Represents an entity: Product, Customer, Supplier, ...
- Nodes can contain some properties
- Nodes can be labeled with one or more labels
- Stored as physical table in the database

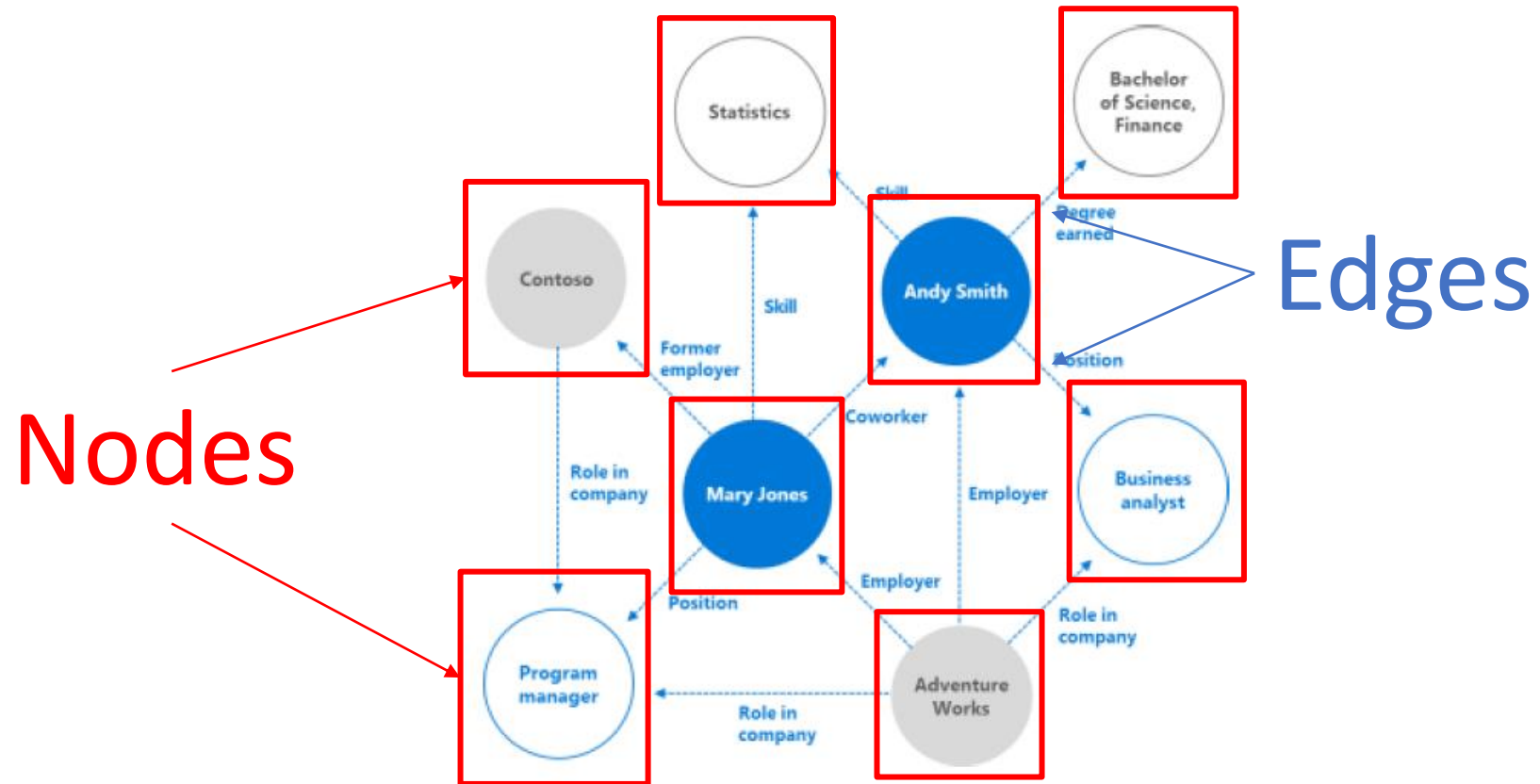
# Graph objects

## ***Edges***

- Relationships between entities
- Relationships are named and directed and always have a start and end node
- Relationship can also contain properties
- Stored as physical table in the database



# Graph objects



# Graphs and SQL Server 2017-2019

# Node and edge tables in SQL Server

Node Properties			Nodes that this edge connects			Edge Properties
\$node_id	Name	Age	\$edge_id	\$from_id	\$to_id	StartDate
{"type":"node","id":0}	John	30	{"type":"edge","id":0}	{"type":"node","id":0}	{"type":"node","id":1}	01/01/2013
"type":"node","id":1}	Mary	28	{"type":"edge","id":1}	{"type":"node","id":1}	{"type":"node","id":2}	05/05/2010
"type":"node","id":2}	Alice	25	{"type":"edge","id":2}	{"type":"node","id":2}	{"type":"node","id":0}	09/09/2016

**Person Node Table** **Friends Edge Table**

# Query syntax and T-SQL graph extensions in SQL Server

# T-SQL extensions

- **CREATE TABLE ... AS NODE / AS EDGE**
- **CREATE EDGE CONSTRAINTS:** enforce specific semantics and maintain data integrity
- **MATCH:** built-in function to support pattern matching and traversal through the graph

# T-SQL extensions

## MATCH

Specifies a search condition for a graph. MATCH can be used only with graph node and edge tables, in the SELECT statement as part of WHERE clause.

```
-- use MATCH in SELECT to find friends of Alice
SELECT Person2.name AS FriendName
FROM Person Person1, friend, Person Person2
WHERE MATCH(Person1-(friend)->Person2)
AND Person1.name = 'Alice';
```

# T-SQL extensions

Syntax: *node-(edge)->node* or *node<-(edge)-node*

From one node to another via an edge

Edge names inside brackets

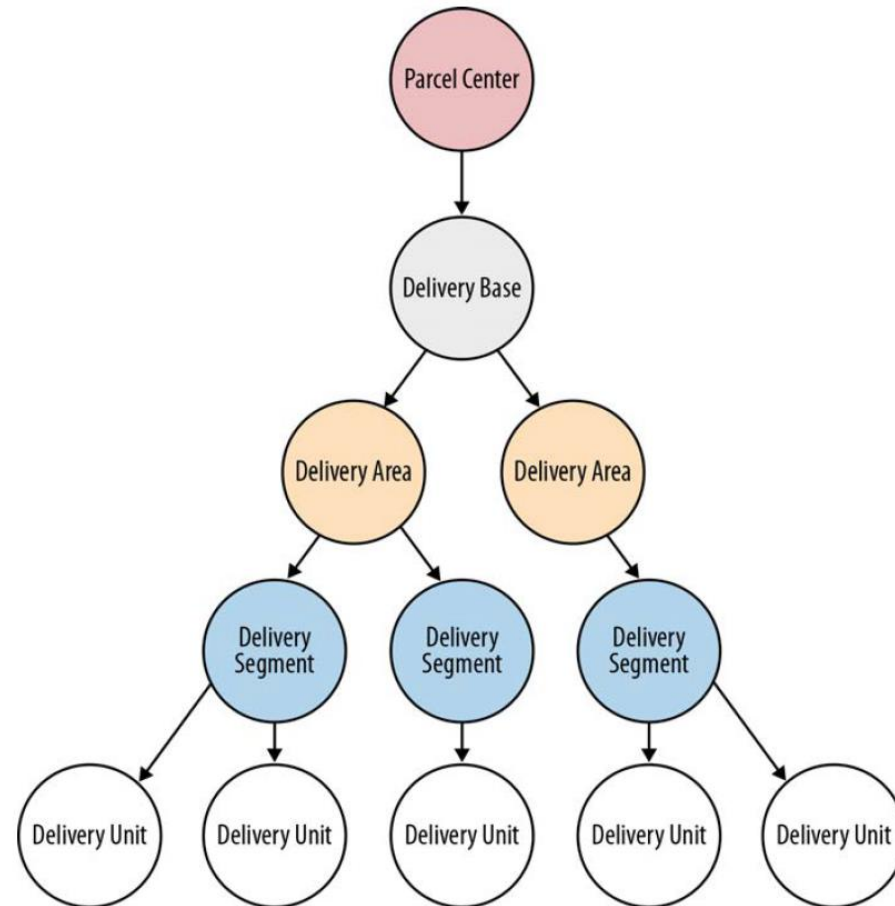
Easier than a relational JOIN

SHORTEST\_PATH



# Route calculation and shortest path

Global Post parcel network



# SQL Server 2019 – SHORTEST\_PATH

The **SHORTEST\_PATH** function:

- Finds a shortest path between two given nodes/entities
- Finds a single source shortest path(s)
- Finds a shortest path from multiple source nodes to multiple target nodes

The function can only be used inside the MATCH clause

# Clauses and patterns to be used in SHORTEST PATH

## **FOR PATH**

Tells the engine that the node or edge table will return an ordered collection representing the list of nodes or edges found along the path traversed.

# Clauses and patterns to be used in SHORTEST PATH

## **Arbitrary Length Pattern**

+ Repeat the pattern 1 or more times. Terminate as soon as the shortest path is found

**(1,n)** Repeat the pattern 1 to n times. Terminate as soon as the shortest is found

# Clauses and patterns to be used in SHORTEST PATH

## **LAST\_NODE**

the node which appears last in the path traversed

# Clauses and patterns to be used in SHORTEST PATH

## **Graph Path Order**

The order of data in the output path

WHITIN GROUP (GRAPH PATH)

# Clauses and patterns to be used in SHORTEST PATH

## Graph Path Aggregate Functions

- **STRING\_AGG**
- **LAST\_VALUE**
- **SUM**
- **COUNT**
- **AVG**
- **MIN**
- **MAX**

# Find shortest path between two people

```
SELECT PersonName, Friends
FROM (
    SELECT
        Person1.name AS PersonName,
        STRING_AGG(Person2.name, '->') WITHIN GROUP (GRAPH PATH) AS Friends,
        LAST_VALUE(Person2.name) WITHIN GROUP (GRAPH PATH) AS LastNode
    FROM
        Node Person AS Person1,
        Edge friendOf FOR PATH AS fo,
        Node Person FOR PATH AS Person2
    WHERE MATCH(SHORTEST_PATH(Person1(-(fo)->Person2)+))
        AND Person1.name = 'Jacob'
) AS Q
WHERE Q.LastNode = 'Alice'
```

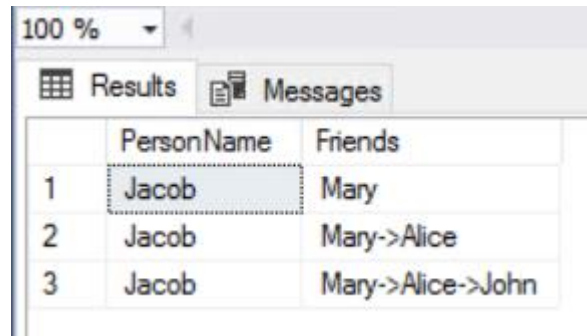
SHORTEST\_PATH  
clauses



# Find shortest path from a given value to all other nodes in graph

```
SELECT
    Person1.name AS PersonName,
    STRING_AGG(Person2.name, '->') WITHIN GROUP (GRAPH PATH) AS Friends
FROM
    Person AS Person1,
    friendOf FOR PATH AS fo,
    Person FOR PATH AS Person2
WHERE MATCH(SHORTEST_PATH(Person1(-(fo)->Person2)+))
AND Person1.name = 'Jacob'
```

Arbitrary length pattern:  
repeat the pattern 1 time



	PersonName	Friends
1	Jacob	Mary
2	Jacob	Mary->Alice
3	Jacob	Mary->Alice->John

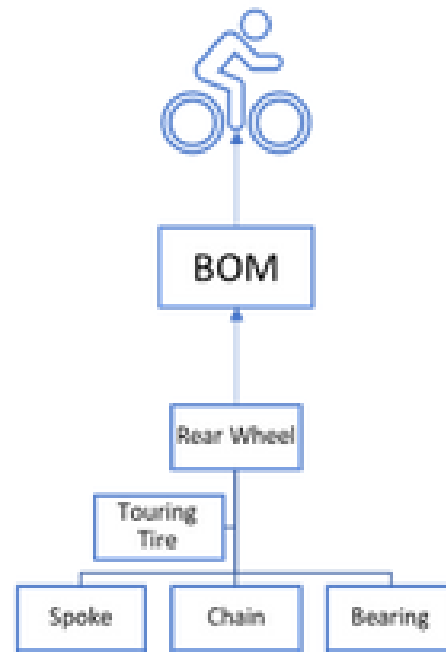
# Count the number of levels traversed to go from one person to another in the graph

```
SELECT PersonName, Friends, levels
FROM (
    SELECT
        Person1.name AS PersonName,
        STRING_AGG(Person2.name, '->') WITHIN GROUP (GRAPH PATH) AS Friends,
        LAST_VALUE(Person2.name) WITHIN GROUP (GRAPH PATH) AS LastNode,
        COUNT(Person2.name) WITHIN GROUP (GRAPH PATH) AS levels
    FROM
        Person AS Person1,
        friendOf FOR PATH AS fo,
        Person FOR PATH AS Person2
    WHERE MATCH(SHORTEST_PATH(Person1(-(fo)->Person2)+))
    AND Person1.name = 'Jacob'
) AS Q
WHERE Q.LastNode = 'Alice'
```

Results			
Messages			
	PersonName	Friends	levels
1	Jacob	Mary->Alice	2

# Shortest path and BOM (Bill of Material) calculation

# BOM in Adventure Works Cycles

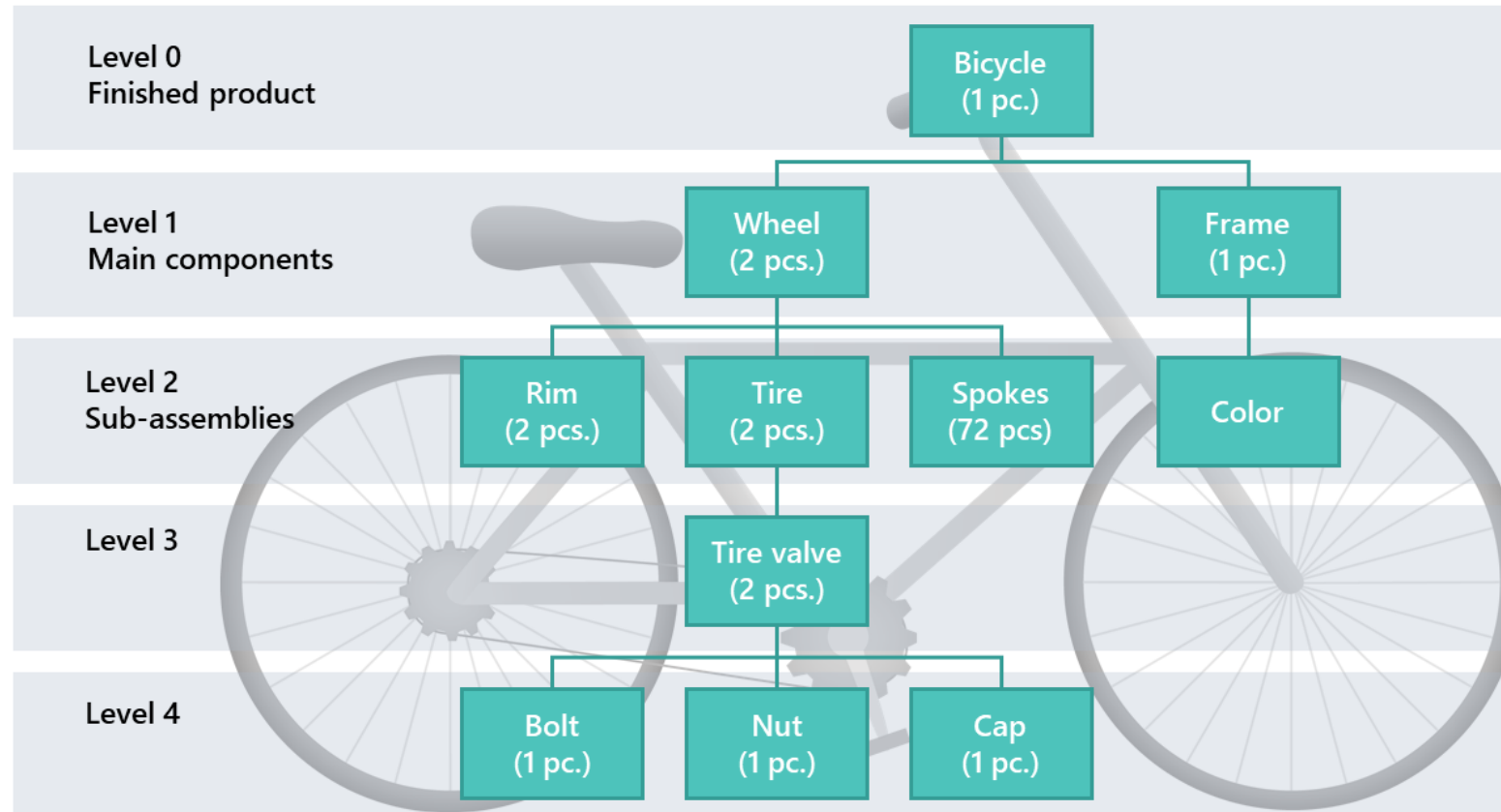


# Find all assemblies where a given product is used

```
SELECT
    P1.ProductID,
    P1.Name,
    STRING_AGG(P2.Name,'->') WITHIN GROUP (GRAPH PATH) AS [Assembly],
    LAST_VALUE(P2.ProductID) WITHIN GROUP (GRAPH PATH) AS [Final ProductID]
FROM
    PRODUCT P1,
    PRODUCT FOR PATH P2,
    ISPARTOF FOR PATH IPO
WHERE
    MATCH(SHORTEST_PATH(P1(-(IPO)->P2)+))
    AND P1.ProductID = 2
ORDER BY P1.ProductID
```

Results		Messages		
	ProductID	Name	Assembly	Final ProductID
1	2	Bearing Ball	BB Ball Bearing->LL Bottom Bracket->Touring-3000 Blue, 62	960
2	2	Bearing Ball	BB Ball Bearing	3
3	2	Bearing Ball	BB Ball Bearing->LL Bottom Bracket	994
4	2	Bearing Ball	BB Ball Bearing->ML Bottom Bracket->Touring-2000 Blue, 46	970
5	2	Bearing Ball	BB Ball Bearing->LL Bottom Bracket->Touring-3000 Yellow, 44	961

# Multilevel BOM



# Demo BOM AdventureWorks

Database: AdventureWorks2014

Setup-BOMGraph.sql

ShortestPath.sql

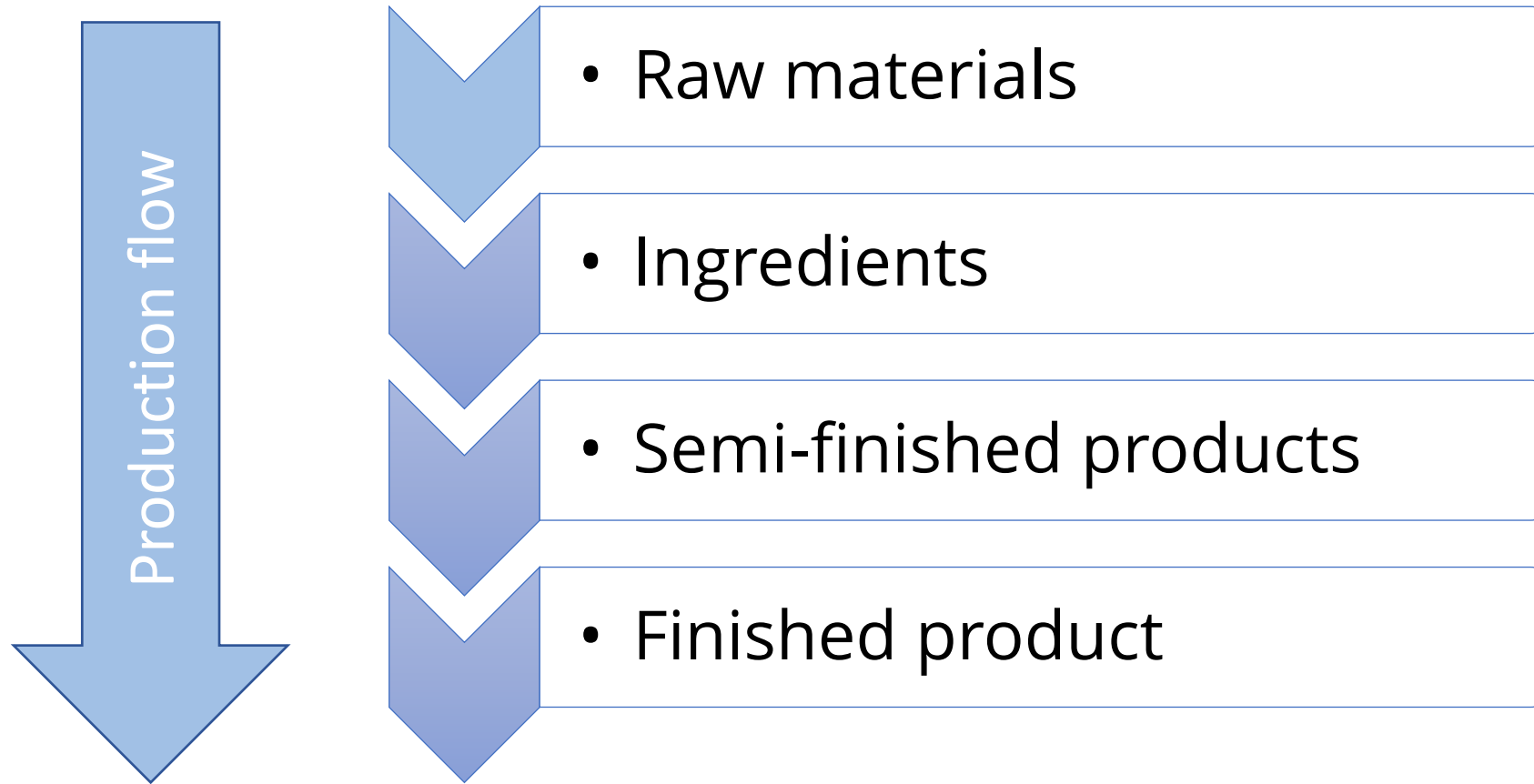
*Public Preview of Shortest Path on SQL Server 2019*

<https://techcommunity.microsoft.com/t5/SQL-Server/Public-Preview-of-Shortest-Path-on-SQL-Server-2019/ba-p/721240>

*Exploding Bill of Materials using Graph Shortest Path*

<https://channel9.msdn.com/Shows/Data-Exposed/Exploding-Bill-of-Materials-using-Graph-Shortest-Path>

# BOM in Dynamics 365





# BOM in Dynamics 365

A BOM is described by the following information:

- BOM ID
- BOM name
- The BOM lines that describe the components and ingredients
- The BOM versions, which define the product and period that the BOM can be used for

# BOM in Dynamics 365

Finance and Operations		Product information management > Products > Released products											
Edit  New  Delete		Product	Purchase	Sell	Manage inventory	Engineer	Plan	Manage projects	Manage costs	Commerce	General	Setup	Options
View		BOM		Configuration		Formula	Product change		Process		Item drawings		
Production orders	Route	BOM versions	Designer	Configuration route		Formula versions	Create case	Associate with case	Report as finished		Drawings		
Batch orders	Kanbans	Active BOM versions	Where-used	Configuration - tree		Designer	All cases	Add to case log	Max. report as finished				
				Maintain configurations		Where-used							

# BOM in Dynamics 365

M0010 : CARAUDIOUNIT

Where-used : **M0010** **ITEM ID**

**BOM lines**

Filter ☐ Show only interval

<input type="radio"/> BOM	Configuration group	Configuration	Size	Color	Style	Site	Warehouse	Quantity	Unit	From date	To date
<input checked="" type="radio"/> 000021			500			1		1.0000	ea		
<input type="radio"/> 000024			500			4		1.0000	ea		
<input type="radio"/> 000025			200			4	41	1.0000	ea		

**BOM ID**

---

**BOM versions**

Where-used Product change ▾

Filter ☐ Show only interval

<input type="radio"/> Item number	Name	Configuration	Size	Color	Style	Site	From date	To date	Active	Construction
<input checked="" type="radio"/> 4401	CarAudio			Silver		1		3/15/2017	✓	
4401	CarAudio			Green		1				
4401	CarAudio			Black		1			✓	
4401	CarAudio			Orange		1	1/1/2017	10/15/2017	✓	
4401	CarAudio			Blue		1	3/1/2017	7/31/2017	✓	
4403	CarAudio			Black		1		4/30/2017	✓	

# BOM in Dynamics 365

[Bills of materials](#) | 000024 : CARAUDIO

Record title

000024 : CarAudio

[Lines](#) Header

Bill of materials header

BOM  
000024

Name  
CarAudio


Site  
4

Item group  
Audio

Approved by  
000001

Approved  
☒ Yes






Use configuration nomenclature  
☐ No







BOM ID

Bill of materials lines



[+ New](#) [Delete](#) [Sorting](#) [Where-used](#) [BOM versions](#) [Configuration](#) [Display dimensions](#) [Product change](#)

Item number	Configuration	Size	Color	Style	Warehouse	Resource cons...	Quantity	Per series	Unit	Configuration group	Ite...	Product name
M0014		1000					1.0000	1	ea			M0014 / Amplifier1000
M0010		500					1.0000	1	ea			M0010 / Car Audio Uni
M0011		4					1.0000	4	ea			M0011 / Door Speaker
M0013							1.0000	1	ea			M0013
M0016							1.0000	1	ea			M0016

# BOM in Dynamics 365


Finance and Operations		Product information management > Products		
 Edit		 New	 Delete	
<b>Bill of materials</b>		Options 		
<b>Maintain</b>		<b>Configuration</b>	<b>Product change</b>	
<b>Designer</b>	Check	Configuration rules	Create case	Associate with case
Approval	Copy		All cases	Add to case log

 	Bills of materials   000024 : CARAUDIO	
	<b>000024 : CarAudio</b>	
	Bill of materials header	
	BOM	Name
	<input type="text" value="000024"/>	<u>CarAudio</u>

# BOM in Dynamics 365

**Finance and Operations**

 Save

BOM lines ▾

BOM ▾


Route ▾



Configurations ▾

View ▾

Setup

Filter

Options 



BOM number: 000024

M0014 / Amplifier

M0010 / Car Audio Unit

M0011 / Door Speaker Unit

M0013 / Subwoofer

M0016 / Sedan Wiring Harness

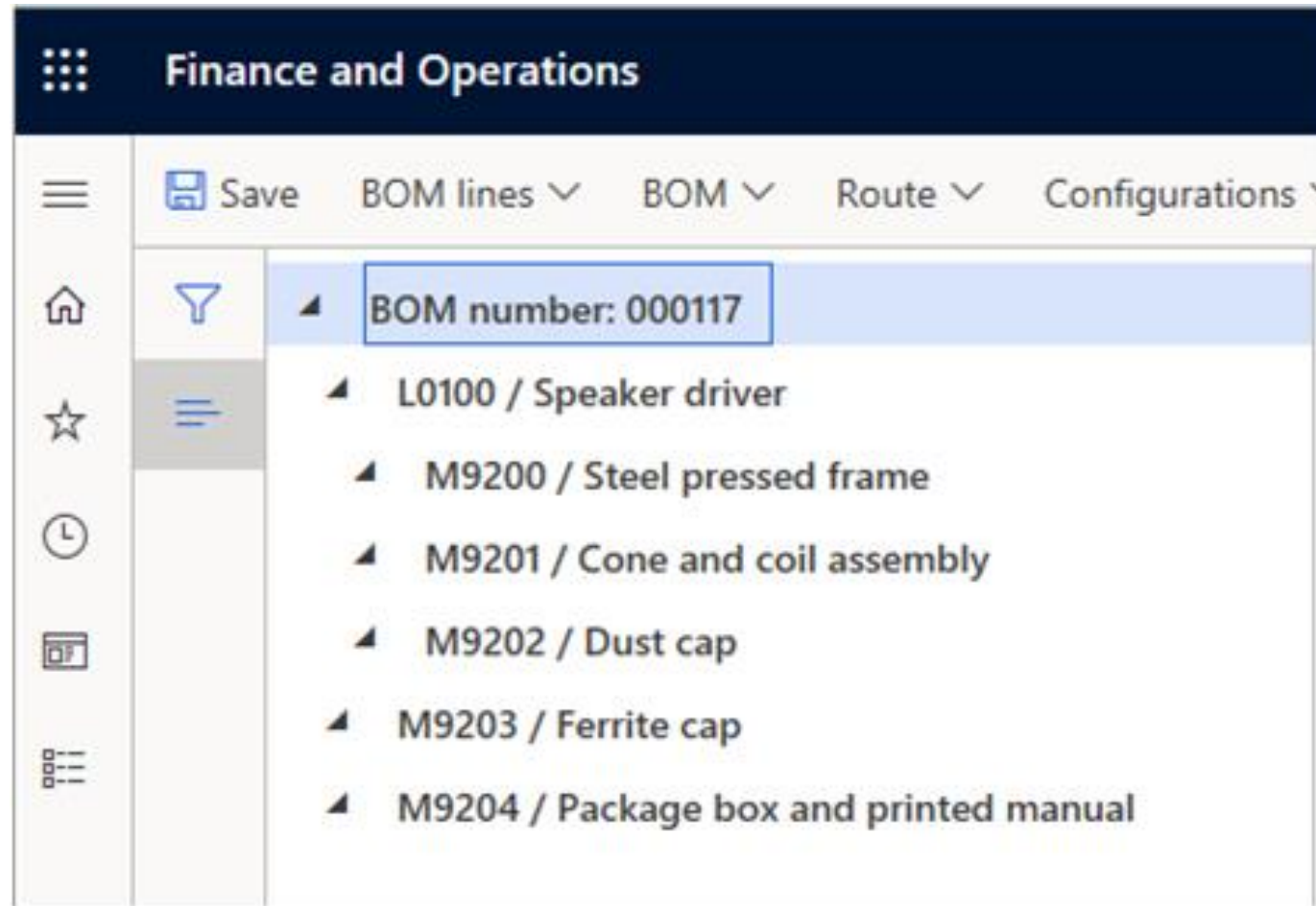
BOM designer / 4 / Active / 11/12/2020 / 1 | 000024 : CARAUDIO

Item number / Name

**BOM line details**

IDENTIFICATION	PRODUCT
Configuration group	Item number
<hr/>	<hr/>

# Multilevel BOM



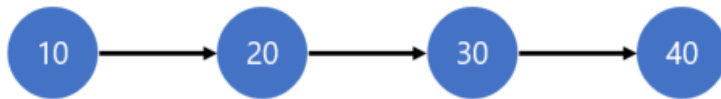
# Routes

A route describes the order of operations that is used to produce a product or product variant.

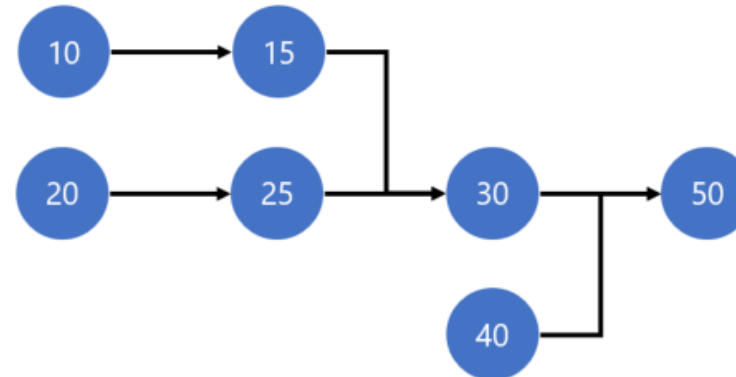
Each operation is assigned an operation number and a successor operation.

The order of operations forms a route network.

Simple route

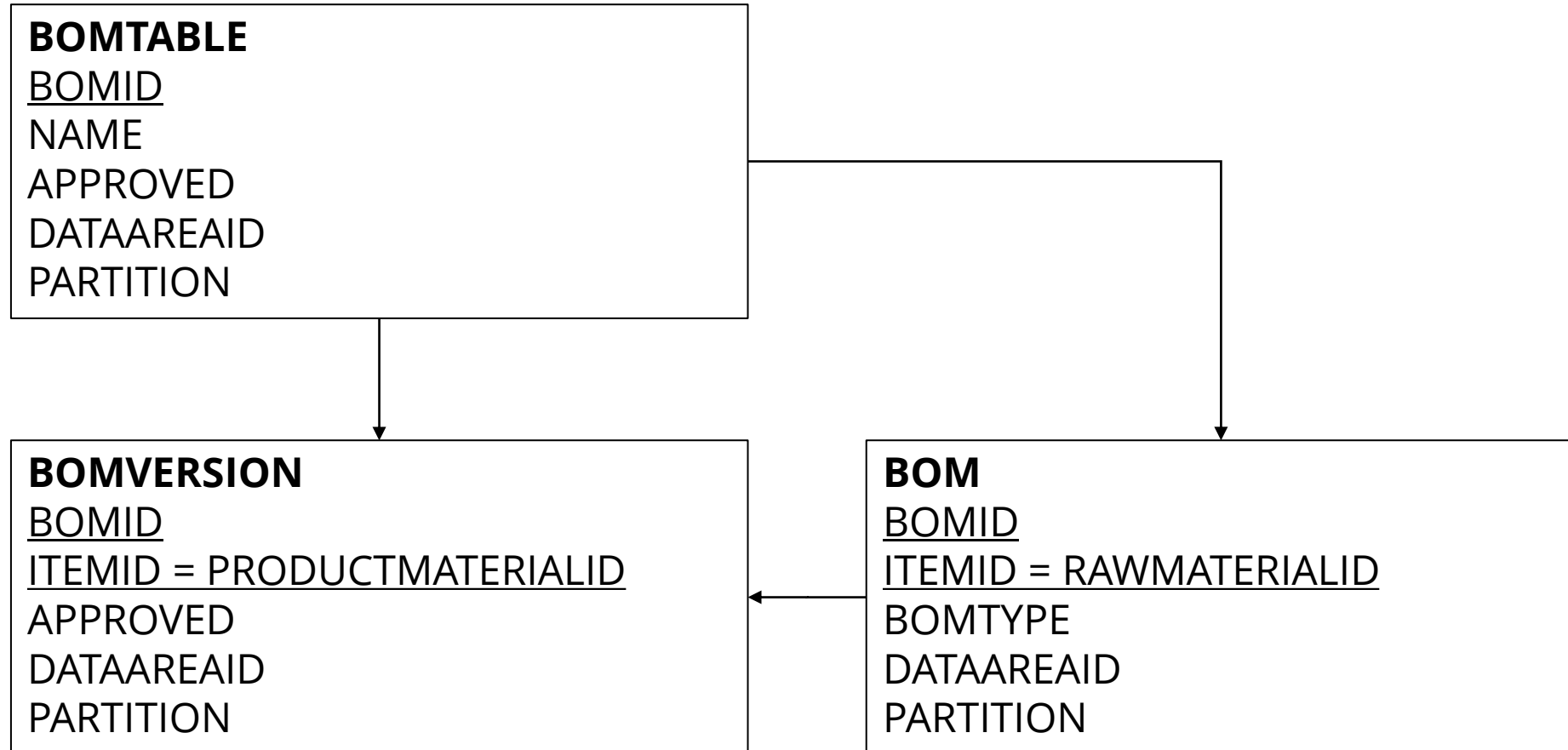


Route network





# Data model in AX/D365



# Demo BOM AX/D365

Database: AXDB

No shortest path. Traditional SQL for reading the BOM:

AX\_Database\_BOM\_loop.sql

Shortest path setup on the AX Database:

AXDB\_BOM\_graph\_setup.sql

# SQL Server 2022 and Graph features





Grazie!!!

