



## Introduction to Association Rule Mining - Market Basket Analysis (MBA)

- Association rules are **if-then** statements that show **the probability of relationships** between data items within large data sets in various types of databases.
- At a basic level, association rule mining involves the use of machine learning models to analyze data for patterns, called **co-occurrences**, in a database.
- It identifies **frequent if-then associations**, which themselves are the association rules.
- For example, if 75% of people who buy cereal also buy milk, then there is an evidence for pattern in the transactional data that customers who buy cereal often buy milk.

For example, the rule:

$$\{\text{cereal}\} \Rightarrow \{\text{milk}\}$$

Such information can be used as the basis for decisions about marketing activities such as, e.g., promotional pricing or product placements.

# Market Basket Analysis



للاستفسار فُرعي 108 - 06/5814168			
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رقم الفاتة 62464		الرقم الضريبي: 16650476	
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كاش 6			
التاريخ 28/05/2025		الساعة : 3:34:00 pm	
ف المادة	الكمية	السعر	المجموع
ارم اند همر الدفاتس	1	1.350	1.350
ارم اند همر معجون اسنان	1	1.350	1.350
معجون اورل بي 123	1	1.390	1.390
المراعي لبنة 500 غم	1	2.250	2.250
صابون حمام نابلسي حبة و	1	0.550	0.550
عصير الربيع اناناس 1 لتر	1	1.400	1.400
عصير الربيع كوكتيل 1 لتر	1	1.400	1.400
هاربيك سبترس 495 مل	1	1.200	1.200
هاربيك لافندر 495 مل	1	1.200	1.200
كفوف لاتيكس اسود وسط*	1	2.490	2.490
تشيرورز غسل 375 غم	1	3.750	3.750
رايس كيك طبيعي 100 غم	2	0.950	1.900
رايس كيك سمسم 100 غم	1	0.950	0.950
غاستو مناديل مبللة 96	1	0.990	0.990
ساتينو معجون اسنان الحس	1	0.990	0.990
جبنة برمران ايطالي	0.166	12.990	2.156
جبنة برمران ايطالي	0.354	12.990	4.598
فلل قرن الغزال	0.552	0.650	0.359
بندورة عناليد كبيرة	0.7	1.100	0.770
مخلل هلابينو	0.284	1.990	0.565
خيار	0.44	0.790	0.348
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المجموع النهائي:			31.956
فيزا :			31.956
المدفوع:			0.000
الباقي			0.000
عدد المواد :			22
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للاستفسار فُرعي 108 - 06/5814168			
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رقم الفاتة 62465		الرقم الضريبي: 16650476	
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كاش 6			
التاريخ 28/05/2025		الساعة : 3:35:00 pm	
ف المادة	الكمية	السعر	المجموع
نبيل دجاج تندر 900 غم	1	3.750	3.750
نبيل اصابع سمك محمد 40	2	2.390	4.780
خضار مشكلة السنبلة 450	2	1.600	3.200
السنبلة بامية اكسترا 400	2	2.590	5.180
سباتخ السنبلة 400 غم	2	0.900	1.800
جبنة فاكيوم روابي جرش 3	1	3.550	3.550
مكدوس بلدي التميمي 1 كغ	1	3.650	3.650
بردايس خبز طابون 4*	1	0.600	0.600
غيث خبز مسخن 5*	1	0.850	0.850
مخلل هلابينو	0.494	1.990	0.983
ديلايت قشقوان	0.3	8.190	2.457
مشمش حموي سوبر	0.796	1.750	1.393
سمسمية مصرية	0.816	1.750	1.428
مفروم عجل + خاروف	0.335	8.490	2.844
مفروم عجل + خاروف	0.355	8.490	3.014
دجاج تندوري مقطع متبل لا	0.98	3.250	3.185
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المجموع النهائي:			42.664
فيزا :			42.664
المدفوع:			0.000
الباقي			0.000
عدد المواد :			20
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شكرا لزيارتكم

لا يتم تبديل البضاعة الا بوجود فاتورة شراء خلال 24 ساعة

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لا يتم تبديل البضاعة الا بوجود فاتورة شراء خلال 24 ساعة



## ✖ Association Rule Use Cases and Domains

Association rule mining can be applied in various domains beyond market basket analysis. Here are some examples:

### 1. Healthcare

- **Disease Diagnosis:** Identifying associations between symptoms and diseases. For example, a rule like  $\{fever, cough\} \rightarrow \{flu\}$  can help predict diseases.
- **Drug Interactions:** Discovering relationships between medications that are frequently prescribed together or identifying combinations that lead to adverse reactions.

## 2. Web Usage Mining

- **Website Optimization:** Analyzing user navigation patterns to determine common paths or clicks, e.g.,  $\{homepage \rightarrow product\ page\} \rightarrow \{checkout\}$ .
- **Recommendation Systems:** Suggesting content or products based on frequently co-accessed items, e.g.,  $\{clicked\ 'smartphone'\} \rightarrow \{clicked\ 'smartphone\ accessories'\}$ .

## 3. Education

- **Student Behavior Analysis:** Discovering patterns in course enrollment, such as  $\{math101, cs101\} \rightarrow \{stat101\}$ .
- **Learning Paths:** Identifying sequences of topics that students study, helping design better curricula.

## 4. Telecommunications

- **Customer Churn Analysis:** Detecting combinations of usage patterns that are associated with customers leaving the service, e.g.,  $\{low\ data\ usage, few\ calls\} \rightarrow \{churn\}$ .
- **Service Bundling:** Identifying services that are commonly purchased together, like  $\{broadband, mobile\} \rightarrow \{TV\ subscription\}$ .

## 5. Banking and Finance

- **Fraud Detection:** Uncovering patterns associated with fraudulent transactions, e.g.,  $\{high\ transaction\ frequency, odd\ hours\} \rightarrow \{fraud\}$ .
- **Loan Approvals:** Identifying attributes of successful loan applications, such as  $\{high\ income, good\ credit\ score\} \rightarrow \{loan\ approved\}$ .

## 6. Manufacturing

- **Fault Detection:** Identifying combinations of machine conditions that frequently result in faults, e.g.,  $\{high\ temperature, low\ pressure\} \rightarrow \{equipment\ failure\}$ .
- **Supply Chain Optimization:** Discovering patterns in material usage, e.g.,  $\{material\ A, material\ B\} \rightarrow \{product\ C\}$ .

## 7. Retail Beyond Market Basket

- **Shelf Placement:** Finding products that are often bought together to optimize store layout.
- **Customer Segmentation:** Identifying customer groups with similar purchasing behaviors, e.g.,  $\{frequent\ discount\ purchases\} \rightarrow \{low\ brand\ loyalty\}$ .

## 8. Social Media Analysis

- **Trending Topics:** Discovering associations between hashtags, e.g.,  $\{\#climatechange, \#sustainability\} \rightarrow \{\#renewableenergy\}$ .
- **User Behavior Patterns:** Understanding engagement behaviors, such as  $\{likes\ post, comments\ on\ post\} \rightarrow \{shares\ post\}$ .

## 9. Energy Sector

- **Usage Patterns:** Identifying associations in energy usage, like  $\{high\ A/C\ usage, weekend\} \rightarrow \{peak\ energy\ consumption\}$ .
- **Smart Grid Analysis:** Detecting patterns for predictive maintenance, e.g.,  $\{low\ voltage, high\ demand\} \rightarrow \{power\ outage\}$ .

## 10. Transportation and Logistics

- **Traffic Analysis:** Discovering patterns in traffic conditions, e.g.,  $\{morning\ rush\ hour, bad\ weather\} \rightarrow \{traffic\ jam\}$ .
- **Route Optimization:** Identifying frequently used delivery routes, such as  $\{route\ A, route\ B\} \rightarrow \{delivered\ faster\}$ .

## 11. E-commerce

- **User Preferences:** Identifying patterns in user preferences for personalized recommendations.
- **Cross-Selling:** Suggesting related products based on purchase history.

## 12. Sports Analytics

- **Performance Metrics:** Discovering combinations of player actions that lead to victories, e.g.,  $\{high\ possession, accurate\ passes\} \rightarrow \{win\}$ .
- **Injury Prevention:** Identifying conditions that precede injuries, such as  $\{high\ training\ load, lack\ of\ rest\} \rightarrow \{injury\ risk\}$ .

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## ✓ The Apriori Algorithm

Apriori is the most common algorithm used for MBA. It identifies frequent itemsets and builds association rules from them by leveraging the principle that **subsets of frequent**

**itemsets must also be frequent.**

## Key Notes:

- Apriori is an algorithm for identifying frequent item-sets and association rule learning over relational databases.
- It was proposed by Agrawal and Srikant in 1994.
- Apriori is designed to operate on databases containing transactions (for example, collections of items bought by customers, or details of a website frequentation or IP addresses).
- It proceeds by identifying the frequent individual items in the database and extending them to larger and larger item sets as long as those item sets appear sufficiently often in the database.
- The frequent item sets determined by Apriori can be used to determine association rules which highlight general trends in the database.
- This has applications in domains such as market basket analysis.
- Apriori uses a "bottom up" approach, where frequent subsets are extended one item at a time (a step known as candidate generation), and groups of candidates are tested against the data.
- The algorithm terminates when no further successful extensions are found.

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## ✓ Creating Association Rules

To create association rules, we use 3 metrics:

1. Support: finds the popular items and builds initial rules.
2. Confidence: Enhance initial rules by finding true relationships.
3. Lift: Enhance rules by acomodating for popular items effect (x -> y where x is popular e.g. bread in a bakery)

### 1. Support:

Support is a measure that represents the frequency or proportion of transactions in the dataset that contain a given item set or pattern. In other words, it measures how often a particular combination of items appears together in the dataset. Support is a **Probability Based** measure that has a value between 0 and 1.

$$\text{Support}(X) = \frac{\text{Number of transactions containing } X}{\text{Total transactions}}$$

## Valid Values for Support:

- **Range:** The value of support ranges from **0% to 100%**:
- **0%:** The itemset does not appear in any transaction.
- **100%:** The itemset appears in all transactions.

## Interpreting Support:

- **High support:** The itemset is common and may represent a strong association.
- **Low support:** The itemset is rare and might not provide actionable insights.

## Thresholds in Practice

- In practice, a minimum support threshold is specified to filter out infrequent itemsets, ensuring only itemsets that appear frequently in the dataset are considered for further analysis.
- Generally speaking, the minimum values for **support**, **confidence**, and **lift** depend on the specific dataset and the business context, but here are some common guidelines and starting points:
- Setting a very high support threshold can exclude less frequent but potentially interesting itemsets.
- If support is too low, the rule may represent rare occurrences, which might not be meaningful or actionable.
- **Typical Threshold:**
  - **5-10%:** Frequently used in retail datasets where only a small fraction of products are bought together.
  - **Higher Thresholds (20-30%):** For smaller datasets or when focusing on very popular combinations.

## ✓ Example

Let's assume that we have a small dataset with 12 transactions:

Transaction ID	Item 1	Item 2	Item 3	Item 4	Item 5
1	Milk	Egg	Bread	Butter	
2	Milk	Butter	Egg	Ketchup	
3	Bread	Butter	Ketchup		
4	Milk	Bread	Butter		
5	Bread	Butter	Cookies		
6	Milk	Bread	Butter	Cookies	
7	Milk	Cookies			
8	Milk	Bread	Butter		

Transaction ID	Item 1	Item 2	Item 3	Item 4	Item 5
9	Bread	Butter	Egg	Cookies	
10	Milk	Butter	Bread		
11	Milk	Bread	Butter		
12	Milk	Bread	Cookies	Ketchup	

First, we set out the **Minimum Support** value to:

- 50% (focus on items present in at least half of the transactions), this value can be set to 5% or 10% in real-life situations with large datasets.

**Step 1: Dataset Transformation** Convert the dataset into a binary format:

Transaction	Milk	Egg	Bread	Butter	Ketchup	Cookies
1	1	1	1	1	0	0
2	1	1	0	1	1	0
3	0	0	1	1	1	0
4	1	0	1	1	0	0
5	0	0	1	1	0	1
6	1	0	1	1	0	1
7	1	0	0	0	0	1
8	1	0	1	1	0	0
9	0	1	1	1	0	1
10	1	0	1	1	0	0
11	1	0	1	1	0	0
12	1	0	1	0	1	1

## Step 2: Identify Frequent 1-Itemsets

The algorithm starts by calculating the support for each single item.

Item	Support Count	Support (%)	Frequent?
Milk	9	75%	Yes
Egg	3	25%	No
Bread	10	83%	Yes
Butter	10	83%	Yes
Ketchup	3	25%	No
Cookies	5	42%	No

**Frequent 1-itemsets:** {Milk}, {Bread}, {Butter}.

## Step 3: Generate 2-Itemsets

Now, combine frequent 1-itemsets into 2-itemsets and calculate their support.



Itemset	Support Count	Support (%)	Frequent?
{Milk, Bread}	7	58%	Yes
{Milk, Butter}	7	58%	Yes
{Bread, Butter}	9	75%	Yes

**Frequent 2-itemsets:** {Milk, Bread}, {Milk, Butter}, {Bread, Butter}.

#### Step 4: Generate 3-Itemsets

Combine frequent 2-itemsets into 3-itemsets and calculate their support.

Itemset	Support Count	Support (%)	Frequent?
{Milk, Bread, Butter}	6	50%	Yes

**Frequent 3-itemset:** {Milk, Bread, Butter}.

#### Step 5: No Larger Itemsets Can Be Created

Since there are no frequent 4-itemsets (support would drop below 50%), we stop here.

#### Step 6: Generate Initial Association Rules

Now, use the frequent itemsets to generate association rules, we will focus on the largest item set, we can create rules from smaller ones if needed.

Rules from {Milk, Bread, Butter}:

##### 1. Rule 1:

Milk, Bread  $\rightarrow$  Butter

$$\text{Support} = P(\text{Milk, Bread, Butter}) = 6/12 = 50\%$$

##### 1. Rule 2:

Milk, Butter  $\rightarrow$  Bread

$$\text{Support} = P(\text{Milk, Bread, Butter}) = 6/12 = 50\%$$

##### 2. Rule 3:

Bread, Butter  $\rightarrow$  Milk

$$\text{Support} = P(\text{Milk, Bread, Butter}) = 6/12 = 50\%$$

#### The Problem with Support

Support is useful, but it has a limitation: it is **symmetric**.

$\text{Support}(\text{milk} \cap \text{diapers})$  is exactly the same whether we write the rule as (Milk  $\rightarrow$  Diapers) or (Diapers  $\rightarrow$  Milk). It only tells us **how often the two items appear together**, not in which direction the rule should go.

In our example with 1,000 transactions, milk and diapers appear together in 100 of them, so  $\text{support}(\text{milk} \cap \text{diapers}) = 100/1000 = 10$

That 10% tells us the pair is reasonably common, but it does **not** answer a key business question: *Should we recommend milk to customers who buy diapers, or recommend diapers to customers who buy milk, or both?*

Support alone cannot distinguish between these options because it treats the pair (milk, diapers) the same in both directions.

This is why we need **confidence**, which is directional and based on **conditional probability**.

From the raw data: 500 customers bought milk, 150 bought diapers, and 100 bought both. If we look at the rule (Diapers  $\rightarrow$  Milk), the confidence is:

$$\text{conf}(\text{Milk} \mid \text{Diapers}) = 100/150 \approx 66$$

meaning 66% of diaper-buyers also buy milk. For the opposite rule (Milk  $\rightarrow$  Diapers), the confidence is:

$$\text{conf}(\text{Diapers} \mid \text{Milk}) = 100/500 = 20$$

so only 20% of milk-buyers also buy diapers.

Now we can clearly see that **Diapers  $\rightarrow$  Milk** is the more useful rule. In short: support tells us that the pair is common, but because it is **symmetric**, it cannot guide us on *direction*; confidence is needed to decide which way the rule should go.

More Examples about The Asymmetry of Association Rules:

Domain	Rule A $\rightarrow$ B (Strong)	Rule B $\rightarrow$ A (Weak or Misleading)
Retail	Buys Smartphone $\rightarrow$ Buys Phone Case	Buys Phone Case $\rightarrow$ Buys Smartphone
Web Analytics	Visits Product Page $\rightarrow$ Adds to Cart	Adds to Cart $\rightarrow$ Visits Product Page
Healthcare	Diagnosed with Diabetes $\rightarrow$ Prescribed Insulin	Prescribed Insulin $\rightarrow$ Diagnosed with Diabetes
Fraud Detection	Unusual Login $\rightarrow$ Account Lock	Account Lock $\rightarrow$ Unusual Login
E-Learning	Watches Lecture Video $\rightarrow$ Submits Homework	Submits Homework $\rightarrow$ Watches Lecture
Streaming Services	Subscribes to Premium Plan $\rightarrow$ Watches Exclusive Shows	Watches Exclusive Shows $\rightarrow$ Subscribes to Premium Plan
Finance	Misses Loan Payment $\rightarrow$ Credit Score Drops	Credit Score Drops $\rightarrow$ Misses Loan Payment
HR / Workforce	Attends Training $\rightarrow$ Improved Job Performance	Improved Job Performance $\rightarrow$ Attends Training

## ✓ 2 Confidence:

In order to validate which rule is correct, we need to examine the confidence of the rule, for example, we might have a frequent item set that have two items (Milk, Bread), we can

establish two rules from that set:

Milk  $\rightarrow$  Bread

Bread  $\rightarrow$  Milk

To determine which rule is correct for that frequent item set (the rule that says when  $x$  occurs  $y$  also most probably occurs), we can use to confidence establish that assertion.

**Confidence** in Apriori is a measure that calculates the **probability** of the rule being true, in other words, it measures the reliability of the rule. Having higher confidence means that when the antecedent occurs, the consequent is likely to follow.

$$\text{Confidence}(X \rightarrow Y) = \frac{\text{Support}(X \cap Y)}{\text{Support}(X)}$$

### Valid Values for Confidence

- **Range:** Confidence values range from **0 to 1**:
  - **0:** The rule  $X \rightarrow Y$  never holds true.
  - **1:** The rule  $X \rightarrow Y$  always holds true (perfect confidence).

### Interpreting Confidence

#### 1. High Confidence ( $\approx 1$ ):

- Indicates that  $Y$  almost always occurs when  $X$  occurs.
- Example: If  $X = \{\text{bread}\}$  and  $Y = \{\text{butter}\}$ , a high confidence implies that customers buying bread are very likely to buy butter.

#### 2. Low Confidence ( $\approx 0$ ):

- Indicates that  $Y$  rarely occurs when  $X$  occurs.
- Example: If  $X = \{\text{bread}\}$  and  $Y = \{\text{cereal}\}$ , a low confidence implies that buying bread is not strongly associated with buying cereal.

### Thresholds in Practice

The minimum values for **confidence** depend on the specific dataset and the business context, but here are some common guidelines and starting points:

- **Typical Threshold:**
  - **70-80%:** Commonly used as a starting point for reliable rules.
  - Adjust based on your use case:
    - Lower threshold (50-60%) for exploratory insights.
    - Higher threshold (90%+) for high-accuracy recommendations.
- **Reason:** Rules with low confidence may not reliably predict the consequent item, making them less actionable.

**Example:**

A rule with 30% confidence means that only 30% of the time, the consequent is bought when the antecedent is bought. This may not justify a marketing strategy.

**Step 7: Validate the Rules using Confidence**

First, let us set the **Minimum Confidence** value to: 70%.

Rules from {Milk, Bread, Butter}:

**1. Rule 1:**

Milk, Bread  $\rightarrow$  Butter

$$\text{Confidence} = P(\text{Butter}|\text{Milk, Bread}) = \frac{P(\text{Milk, Bread, Butter})}{P(\text{Milk, Bread})} = \frac{6}{7} = 85$$

**1. Rule 2:**

Milk, Butter  $\rightarrow$  Bread

$$\text{Confidence} = P(\text{Bread}|\text{Milk, Butter}) = \frac{P(\text{Milk, Bread, Butter})}{P(\text{Milk, Butter})} = \frac{6}{7} = 85$$

**1. Rule 3:**

Bread, Butter  $\rightarrow$  Milk

$$\text{Confidence} = P(\text{Milk}|\text{Bread, Butter}) = \frac{P(\text{Milk, Bread, Butter})}{P(\text{Bread, Butter})} = \frac{6}{9} \approx 66$$

✓ **2.3. Lift Metric**

**Confidence alone can be misleading**, especially when the consequent (Y) is very frequent in the dataset. In that case, a rule ( $X \rightarrow Y$ ) may have high confidence simply because (Y) is common, not because there is a strong dependency between (X) and (Y).

**Example (bakery: cake and bread)**

Suppose we analyze orders in a bakery and find:

- 80% of all orders contain **bread**.
- 20% of all orders contain **cake**.
- 16% of all orders contain **both cake and bread**.

Then the confidence of the rule  $\text{cake} \Rightarrow \text{bread}$  is:

$$\text{conf}(\text{cake} \Rightarrow \text{bread}) = \frac{P(\text{cake} \cap \text{bread})}{P(\text{cake})} = \frac{0.16}{0.20} = 0.8.$$

A confidence of **80%** sounds strong, but notice that **bread is already in 80% of all orders**. So customers who buy cake are **not more likely** to buy bread than an average customer—bread is just very common in the bakery.

To address this limitation, we use additional measures such as **lift** alongside confidence.

**Lift** compares  $P(Y | X)$  to the overall frequency  $P(Y)$ :

$$\text{Lift}(X \Rightarrow Y) = \frac{\text{Confidence}(X \Rightarrow Y)}{\text{Support}(Y)} = \frac{P(Y|X)}{P(Y)}.$$

In other words, Lift measures how likely  $Y$  is when  $X$  happens, compared to how likely  $Y$  is in general.

Equivalently, in terms of supports:

$$\text{Lift}(X \Rightarrow Y) = \frac{\text{Support}(X \cap Y)}{\text{Support}(X) \times \text{Support}(Y)}.$$

In the example:

$$\text{lift}(\text{cake} \Rightarrow \text{bread}) = \frac{P(\text{bread}|\text{cake})}{P(\text{bread})} = \frac{0.8}{0.8} = 1,$$

which indicates **no real association** beyond what we'd expect by chance.

So lift tells us whether items co-occur more (or less) frequently than chance, making it a useful complement to confidence.

## Interpreting Lift

Lift measures how strongly two items or itemsets are associated:

- (lift > 1): items occur together **more often than expected** (positive association).
- (lift = 1): items occur together **as often as expected** under independence (no association).
- (lift < 1): items occur together **less often than expected** (negative association).

So lift tells us whether items co-occur more (or less) frequently than expected under independence, making it a useful complement to confidence.

## Step 8: Validate Rules using the Lift

First, we set the **Lift > 1** for actionable rules

### 1. Rule 1:

Milk, Bread  $\rightarrow$  Butter

$$\text{Lift} = \frac{P(\text{Butter}|\text{Milk, Bread})}{P(\text{Butter})} = \frac{0.85}{0.83} \approx 1.02$$

## 2. Rule 2:

Milk, Butter  $\rightarrow$  Bread

$$\text{Lift} = \frac{P(\text{Bread}|\text{Milk, Butter})}{P(\text{Bread})} = \frac{0.85}{0.83} \approx 1.02$$

## 3. Rule 3:

Bread, Butter  $\rightarrow$  Milk

$$\text{Lift} = \frac{P(\text{Milk}|\text{Bread, Butter})}{P(\text{Milk})} = \frac{0.66}{0.75} \approx .88$$

## Final Results

Frequent Itemsets:

- **1-itemsets:** {Milk}, {Bread}, {Butter}
- **2-itemsets:** {Milk, Bread}, {Milk, Butter}, {Bread, Butter}
- **3-itemset:** {Milk, Bread, Butter}

Rules:

Rule	Support	Confidence	Lift	Actionable?
Milk, Bread $\rightarrow$ Butter	50%	85%	1.02	Yes
Milk, Butter $\rightarrow$ Bread	50%	85%	1.02	Yes
Bread, Butter $\rightarrow$ Milk	50%	66%	.88	No

## Interpretation and Actionable Insights

Rule	Explanation
Milk, Bread $\rightarrow$ Butter	Customers buying Milk and Bread are highly likely (85%) to also buy Butter. Consider bundling.
Milk, Butter $\rightarrow$ Bread	Strong association; placing these items together could increase sales.
Bread, Butter $\rightarrow$ Milk	Suggests that Milk is a complementary product to Bread and Butter, Weak lift though.

## Python Example

We will implement the **Apriori algorithm** using the `mlxtend` library for frequent itemset mining and rule generation.

**a. Install Required Libraries** Make sure you have the required libraries installed:

```
pip install pandas mlxtend
```

**b. Load the Dataset** We will represent the dataset as a **binary transaction matrix** where each row is a transaction, and each column is an item (1 = purchased, 0 = not purchased).

```
1 import pandas as pd
2
3 # Define the dataset
4 data = {
5     "Milk":    [1, 1, 0, 1, 0, 1, 1, 1, 0, 1, 1, 1],
6     "Egg":     [1, 1, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0],
7     "Bread":   [1, 0, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1],
8     "Butter":  [1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0],
9     "Ketchup": [0, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 1],
10    "Cookies": [0, 0, 0, 0, 1, 1, 1, 0, 1, 0, 0, 1],
11 }
12
13 # Create a DataFrame
14 df = pd.DataFrame(data)
15 print("Transaction Dataset:")
16 df
```

Transaction Dataset:

	Milk	Egg	Bread	Butter	Ketchup	Cookies
0	1	1	1	1	0	0
1	1	1	0	1	1	0
2	0	0	1	1	1	0
3	1	0	1	1	0	0
4	0	0	1	1	0	1
5	1	0	1	1	0	1
6	1	0	0	0	0	1
7	1	0	1	1	0	0
8	0	1	1	1	0	1
9	1	0	1	1	0	0
10	1	0	1	1	0	0
11	1	0	1	0	1	1

**c. Apply the Apriori Algorithm** We will use the `mlxtend` library to find frequent itemsets and generate association rules.

```
1 ! pip install mlxtend
```

Collecting mlxtend

Downloading mlxtend-0.23.4-py3-none-any.whl.metadata (7.3 kB)

Requirement already satisfied: scipy>=1.2.1 in /home/me/myenv/lib/python3.12/sit

Requirement already satisfied: numpy>=1.16.2 in /home/me/myenv/lib/python3.12/si

Requirement already satisfied: pandas>=0.24.2 in /home/me/myenv/lib/python3.12/s

Requirement already satisfied: scikit-learn>=1.3.1 in /home/me/myenv/lib/python3

Requirement already satisfied: matplotlib>=3.0.0 in /home/me/myenv/lib/python3.1

Requirement already satisfied: joblib>=0.13.2 in /home/me/myenv/lib/python3.12/s

Requirement already satisfied: contourpy>=1.0.1 in /home/me/myenv/lib/python3.12

Requirement already satisfied: cycler>=0.10 in /home/me/myenv/lib/python3.12/sit

Requirement already satisfied: fonttools>=4.22.0 in /home/me/myenv/lib/python3.1

Requirement already satisfied: kiwisolver>=1.3.1 in /home/me/myenv/lib/python3.1

Requirement already satisfied: packaging>=20.0 in /home/me/myenv/lib/python3.12/

Requirement already satisfied: pillow>=8 in /home/me/myenv/lib/python3.12/site-p

Requirement already satisfied: pyparsing>=2.3.1 in /home/me/myenv/lib/python3.12

Requirement already satisfied: python-dateutil>=2.7 in /home/me/myenv/lib/python

Requirement already satisfied: pytz>=2020.1 in /home/me/myenv/lib/python3.12/sit

Requirement already satisfied: tzdata>=2022.7 in /home/me/myenv/lib/python3.12/s

Requirement already satisfied: threadpoolctl>=3.1.0 in /home/me/myenv/lib/python

Requirement already satisfied: six>=1.5 in /home/me/myenv/lib/python3.12/site-pa

Downloading mlxtend-0.23.4-py3-none-any.whl (1.4 MB)

1.4/1.4 MB 5.5 MB/s eta 0:00:00[36mC

Installing collected packages: mlxtend

Successfully installed mlxtend-0.23.4

```
1 from mlxtend.frequent_patterns import apriori, association_rules
2
3 # Step 1: Generate frequent itemsets with Apriori
4 frequent_itemsets = apriori(df, min_support=0.5, use_colnames=True)
5
6 # Display frequent itemsets
7 print("\nFrequent Itemsets:")
8 print(frequent_itemsets)
```

Frequent Itemsets:

	support	itemsets
0	0.750000	(Milk)
1	0.833333	(Bread)
2	0.833333	(Butter)
3	0.583333	(Bread, Milk)
4	0.583333	(Milk, Butter)
5	0.750000	(Bread, Butter)
6	0.500000	(Bread, Milk, Butter)

/home/me/myenv/lib/python3.12/site-packages/mlxtend/frequent\_patterns/fpcommon.p  
warnings.warn(



## d. Generate Association Rules We generate rules based on **confidence** and calculate **lift**.

Generate rules based on confidence

```
1 # Step 2: Generate association rules based on confidence
2 rules = association_rules(frequent_itemsets, num_itemsets=len(df), metric='
3
4 # Display the rules
5 print("\nAssociation Rules:")
6 print(rules[['antecedents', 'consequents', 'support', 'confidence', 'lift']])
```

Association Rules:

	antecedents	consequents	support	confidence	lift
0	(Bread)	(Milk)	0.583333	0.700000	0.933333
1	(Milk)	(Bread)	0.583333	0.777778	0.933333
2	(Butter)	(Milk)	0.583333	0.700000	0.933333
3	(Milk)	(Butter)	0.583333	0.777778	0.933333
4	(Butter)	(Bread)	0.750000	0.900000	1.080000
5	(Bread)	(Butter)	0.750000	0.900000	1.080000
6	(Milk, Bread)	(Butter)	0.500000	0.857143	1.028571
7	(Butter, Milk)	(Bread)	0.500000	0.857143	1.028571

We can also generate rules based on lift

```
1 # Step 2: Generate association rules based on lift
2 rules = association_rules(frequent_itemsets, num_itemsets=len(df), metric='
3
4 # Display the rules
5 print("\nAssociation Rules:")
6 print(rules[['antecedents', 'consequents', 'support', 'confidence', 'lift']])
```

Association Rules:

	antecedents	consequents	support	confidence	lift
0	(Butter)	(Bread)	0.75	0.900000	1.080000
1	(Bread)	(Butter)	0.75	0.900000	1.080000
2	(Milk, Bread)	(Butter)	0.50	0.857143	1.028571
3	(Butter, Milk)	(Bread)	0.50	0.857143	1.028571
4	(Bread)	(Butter, Milk)	0.50	0.600000	1.028571
5	(Butter)	(Milk, Bread)	0.50	0.600000	1.028571

## e. Filter and Interpret Rules You can filter rules for high lift or specific itemsets.

```

1 # Filter rules with Lift > 1
2 filtered_rules = rules[rules['lift'] > 1]
3 print("\nFiltered Rules with Lift > 1:")
4 print(filtered_rules[['antecedents', 'consequents', 'support', 'confidence']

```

Filtered Rules with Lift > 1:

	antecedents	consequents	support	confidence	lift
0	(Butter)	(Bread)	0.75	0.900000	1.080000
1	(Bread)	(Butter)	0.75	0.900000	1.080000
2	(Milk, Bread)	(Butter)	0.50	0.857143	1.028571
3	(Butter, Milk)	(Bread)	0.50	0.857143	1.028571
4	(Bread)	(Butter, Milk)	0.50	0.600000	1.028571
5	(Butter)	(Milk, Bread)	0.50	0.600000	1.028571

## Interpretation

### 1. Milk, Bread → Butter

- Support = 58%, Confidence = 87.5%, Lift = 1.05.
- Suggest bundling these items for promotions.

### 2. Milk, Butter → Bread

- Similar metrics as above, showing strong relationships.

### 3. Bread, Butter → Milk

- High confidence but slightly weaker lift, still actionable.

## Two-Item Rules

If desired, we can focus on association rules where the antecedent (X) contains just **one item** (i.e., 1-item antecedent, 2 items in the rule overall).

Consider the rule:

Milk → Bread

Suppose we have **12 transactions**, and we observe:

- **Milk** appears in **9** transactions.
- **Milk and Bread together** appear in **7** transactions.

Then:

- **Support** of the rule is the fraction of all transactions that contain both Milk and Bread:  $\text{supp}(\text{Milk} \rightarrow \text{Bread}) = \frac{7}{12} \approx 58\%$

- **Confidence** of the rule is the fraction of Milk-transactions that also contain Bread:  
 $\text{conf}(\text{Milk} \rightarrow \text{Bread}) = \frac{7}{9} \approx 78$

So we can write the rule as:

$\text{Milk} \rightarrow \text{Bread} \{S = 58\%, C = 78\%\}.$

## 2-Item Rules vs 3-Item Rules

### 2-Item Rules (e.g., $\text{Milk} \rightarrow \text{Bread}$ )

- **Simplicity**: Easy to read, explain, and act on.
- **Higher support and confidence (typically)**: Fewer items need to co-occur, so these rules tend to appear more often in the data.
- **Broad applicability**: Capture general trends such as  $\text{Milk} \rightarrow \text{Bread}$ , which can inform store layout (placing items nearby) or simple promotions.

### 3-Item Rules (e.g., $\text{Milk, Bread} \rightarrow \text{Butter}$ )

– 3-Item Rules are more complex and harder to explain than 2-Item Rules