

smart_substitution_model

September 18, 2025

1 Smart Substitution Model - Clustering Approach (KMeans)

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The clustering approach using KMeans, groups similar products into clusters using feature vectors and then swap within clusters to the cheapest viable option based on product price.

1.1 Feature Selection and Preprocessing:

For the clustering the below features were selected:

- 'product_code'
 - 'name'
 - 'brand'
 - 'brand_tier'
 - 'category'
 - 'subcategory'
 - 'original_price'
 - 'sale_price'
 - 'std_item_size'
 - 'std_item_size_unit'
 - 'item_size'
 - 'price_per_unit'
 - 'unit_type'
-

Since KMeans clustering approach cannot handle missing values, important missing values were imputed while other missing values were dropped.

```
[ ]: # mount the drive
from google.colab import drive
drive.mount('/content/drive')
```

Mounted at /content/drive

```
[ ]: %cd /content/drive/MyDrive/smart_substitution/

/content/drive/MyDrive/smart_substitution
```

```
[ ]: # import libraries
import pandas as pd
import numpy as np
```

```
[ ]: # read final dataset
data = pd.read_csv('smart_substitution_dataset.csv')
```

```
[ ]: data.head()
```

```
[ ]:
product_code          name  brand \
0      8371390    coles hot cross buns traditional fruit  coles
1      7473849              coles hot cross buns choc chip  coles
2      5726070    coles hot cross buns traditional fruit mini  coles
3      7107738  cadbury dairy milk chocolate easter egg hunt c...  cadbury
4      4885191    cadbury dairy milk easter chocolate eggs bag  cadbury

brand_confidence  brand_tier  category  subcategory  original_price \
0      store_brand      store    easter      easter           4.4
1      store_brand      store    easter      easter           4.4
2      store_brand      store    easter      easter           4.4
3      raw_at_start  branded    easter      easter           8.0
4      raw_at_start  branded    easter      easter           6.7

sale_price  std_item_size  std_item_size_unit  item_size  price_per_unit \
0          3.0           6.0                pack    6.02740           0.7300
1          3.0           6.0                pack    6.02740           0.7300
2          3.0           9.0                pack    8.97959           0.4900
3          8.0          306.0                  g   306.51341           0.0261
4          6.7          114.0                  g   113.94558           0.0588

unit_type  size_band          tags \
0      each    mixed      ['coles', 'cross', 'buns', 'fruit']
1      each    mixed      ['coles', 'cross', 'buns', 'choc', 'chip']
2      each    mixed      ['coles', 'cross', 'buns', 'fruit']
3         g    large  ['cadbury', 'dairy', 'milk', 'chocolate', 'eas...
4         g    small  ['cadbury', 'dairy', 'milk', 'easter', 'chocol...

similarity_score
0          0.179609
1          0.179609
2          0.179609
3          0.212367
4          0.208974
```

```
[ ]: data.shape
```

```
[ ]: (24897, 17)
```

```
[ ]: data.dtypes
```

```
[ ]: product_code      int64
      name             object
      brand            object
      brand_confidence object
      brand_tier       object
      category         object
      subcategory      object
      original_price   float64
      sale_price       float64
      std_item_size    float64
      std_item_size_unit object
      item_size        float64
      price_per_unit   float64
      unit_type        object
      size_band        object
      tags             object
      similarity_score  float64
      dtype: object
```

```
[ ]: # check for missing values
      data.isna().sum()
```

```
[ ]: product_code      0
      name             9
      brand            22
      brand_confidence 0
      brand_tier       0
      category         0
      subcategory      0
      original_price   0
      sale_price       0
      std_item_size    19830
      std_item_size_unit 19830
      item_size        1140
      price_per_unit   1140
      unit_type        1140
      size_band        1140
      tags             0
      similarity_score  0
      dtype: int64
```

```
[ ]: # drop unnecessary columns
      drop_columns = ['size_band', 'tags', 'similarity_score', 'brand_confidence']
      data.drop(drop_columns, axis=1, inplace=True)
```

```
[ ]: data.columns
```

```
[ ]: Index(['product_code', 'name', 'brand', 'brand_tier', 'category',  
          'subcategory', 'original_price', 'sale_price', 'std_item_size',  
          'std_item_size_unit', 'item_size', 'price_per_unit', 'unit_type'],  
          dtype='object')
```

```
[ ]: data = data.dropna(subset=["item_size", "price_per_unit", "unit_type"],  
                        how="all")
```

```
[ ]: data.isna().sum()
```

```
[ ]: product_code      0  
     name              9  
     brand            22  
     brand_tier        0  
     category          0  
     subcategory       0  
     original_price    0  
     sale_price        0  
     std_item_size    18959  
     std_item_size_unit 18959  
     item_size         0  
     price_per_unit    0  
     unit_type         0  
     dtype: int64
```

```
[ ]: data[data['std_item_size'].isna() & data['std_item_size_unit'].isna()]
```

```
[ ]:      product_code      name      brand \  
150      1010087      colby cheese block      colby  
151      3842193      haloumi      haloumi  
152      6138179      ginger      ginger  
153      6127365      pads organic day regular      pads  
154      6126690      tampons 100 organic cotton regular      tampons  
...      ...      ...      ...  
24892      6131974      shredded meals beef dog food      shredded  
24893      9113356      complete care adult dog food with lamb      complete  
24894      4505836      grainfree chicken mince cat food      grainfree  
24895      3822899      deodorant aerosol africa      deodorant  
24896      6322859      heart shape brioche with choc chips      heart  
  
      brand_tier      category      subcategory      original_price \  
150      branded      cheese dairy      cheese blocks      10.30  
151      branded      cheese dairy      mixed      6.60  
152      branded      medicinal products      mixed      5.50  
153      branded      sanitary protection      mixed      5.90
```

154	branded	sanitary protection	tampons	5.90
...
24892	branded	pet food	dog food	1.90
24893	branded	pet food	dog food	3.00
24894	branded	pet food	cat food	2.75
24895	branded	mens deos & grooming	mixed	0.00
24896	branded	bakery snacks	bakery snacks	0.00

	sale_price	std_item_size	std_item_size_unit	item_size	\
150	9.0	NaN	NaN	572.222220	
151	5.8	NaN	NaN	204.841710	
152	4.5	NaN	NaN	12.222220	
153	4.5	NaN	NaN	13.111110	
154	4.5	NaN	NaN	21.071430	
...	
24892	1.3	NaN	NaN	146.153850	
24893	2.4	NaN	NaN	500.000000	
24894	2.2	NaN	NaN	500.000000	
24895	11.5	NaN	NaN	250.000000	
24896	9.9	NaN	NaN	349.823322	

	price_per_unit	unit_type
150	0.01800	g
151	0.03222	g
152	0.45000	each
153	0.45000	each
154	0.28000	each
...
24892	0.01300	g
24893	0.00600	g
24894	0.00550	g
24895	0.04600	ml
24896	0.02830	g

[18959 rows x 13 columns]

```
[ ]: # fill na
data['std_item_size'] = data['std_item_size'].fillna(data['item_size'])
data['std_item_size_unit'] = data['std_item_size_unit'].
    ↪fillna(data['unit_type'])
```

```
[ ]: data.isna().sum()
```

```
[ ]: product_code    0
      name           9
      brand          22
      brand_tier      0
```

```

category          0
subcategory       0
original_price    0
sale_price       0
std_item_size    0
std_item_size_unit 0
item_size        0
price_per_unit   0
unit_type       0
dtype: int64

```

```
[ ]: data[data['brand'].isna()]
```

```

[ ]:      product_code      name brand \
9379      3942609      NaN  NaN
12387     1050219      NaN  NaN
13938     8183323      NaN  NaN
14104     9038046      NaN  NaN
18131     4161668  nan supremepro 1 infant formula for newborns s...  NaN
18132     4161690  nan supremepro 2 followon baby formula 612 mon...  NaN
18133     4161840      nan supremepro 3 toddler milk drink from 1 year  NaN
18134     4161872      nan supremepro 4 toddler milk drink stage 4  NaN
18135     4161883  nan optipro 1 infant formula for newborns suit...  NaN
18136     4161974  nan optipro 2 followon baby formula from 6 to ...  NaN
18137     4161996      nan optipro 3 toddler milk drink stage 3  NaN
18138     4162398  nan comfort newborn formula stage 1 suitable f...  NaN
18139     4162536  nan comfort 2 followon baby formula from 612 m...  NaN
18140     4162616      nan comfort 3 toddler milk drink from 1 year  NaN
18141     4163346  nan expertpro reflux formula for regurgitation...  NaN
18202     6251717  nan expertpro sensipro infant formula premium ...  NaN
19028     8851668      NaN  NaN
20157     7061444  nan care probiotic drops for everyday infant g...  NaN
20446     5116160      NaN  NaN
21943     9046011      NaN  NaN
22923     7024867      NaN  NaN
24525     8331919      NaN  NaN

```

```

      brand_tier      category      subcategory  original_price \
9379    branded      spirits      mixed          0.0
12387    branded  seasonal events  seasonal events          0.0
13938    branded      kitchenware      kitchenware          0.0
14104    branded  seasonal events  seasonal events          0.0
18131    branded      infant formula      infant formula          0.0
18132    branded      infant formula      infant formula          0.0
18133    branded      infant formula      infant formula          0.0
18134    branded      infant formula      infant formula          0.0
18135    branded      infant formula      infant formula          0.0

```

18136	branded	infant formula	infant formula	0.0
18137	branded	infant formula	infant formula	0.0
18138	branded	infant formula	infant formula	0.0
18139	branded	infant formula	infant formula	0.0
18140	branded	infant formula	infant formula	0.0
18141	branded	infant formula	infant formula	0.0
18202	branded	infant formula	infant formula	0.0
19028	branded	chilled healthfoods	chilled healthfoods	0.0
20157	branded	infant personal	mixed	0.0
20446	branded	spirits	mixed	0.0
21943	branded	instore cake	instore cake	0.0
22923	branded	international foods	international foods	0.0
24525	branded	spirits	mixed	55.0

	sale_price	std_item_size	std_item_size_unit	item_size \
9379	19.9	750.000000	ml	750.094233
12387	6.0	4.000000	pk	1.000000
13938	13.5	1.000000	each	1.000000
14104	12.0	2.000000	pack	1.000000
18131	38.0	1.000000	infant	800.000000
18132	38.0	2.000000	follow	800.000000
18133	30.0	3.000000	toddler	800.000000
18134	30.0	4.000000	toddler	800.000000
18135	29.0	1.000000	infant	798.898072
18136	29.0	2.000000	follow	798.898072
18137	25.0	3.000000	toddler	798.722045
18138	21.0	1.000000	suitable	798.479087
18139	21.0	2.000000	follow	798.479087
18140	21.0	3.000000	toddler	798.479087
18141	29.0	0.000000	to	798.898072
18202	35.0	799.086758	g	799.086758
19028	8.0	452.000000	g	451.977401
20157	30.0	10.000000	ml	10.000000
20446	44.0	700.000000	ml	699.968183
21943	20.0	750.000000	g	749.063670
22923	2.2	95.000000	g	94.827586
24525	47.0	700.000000	ml	819.183800

	price_per_unit	unit_type
9379	0.02653	ml
12387	1.50000	each
13938	4.50000	each
14104	6.00000	each
18131	0.04750	g
18132	0.04750	g
18133	0.03750	g
18134	0.03750	g

18135	0.03630	g
18136	0.03630	g
18137	0.03130	g
18138	0.02630	g
18139	0.02630	g
18140	0.02630	g
18141	0.03630	g
18202	0.04380	g
19028	0.01770	g
20157	3.00000	ml
20446	0.06286	ml
21943	0.02670	g
22923	0.02320	g
24525	0.06714	ml

```
[ ]: # drop products that do not have a product name or brand
data = data.dropna(subset=['name', 'brand'])
```

```
[ ]: data.isna().sum()
```

```
[ ]: product_code      0
name                  0
brand                 0
brand_tier            0
category              0
subcategory           0
original_price        0
sale_price            0
std_item_size         0
std_item_size_unit    0
item_size             0
price_per_unit        0
unit_type             0
dtype: int64
```

```
[ ]: data['subcategory'].unique()
```

```
[ ]: array(['easter', 'footy's back', 'bonus credit products',
        'meat & seafood', 'fruit & vegetables', 'dairy, eggs & fridge',
        'bakery', 'deli', 'pantry', 'dietary & world foods',
        'chips, chocolates & snacks', 'drinks', 'frozen', 'household',
        'health & beauty', 'cheese blocks', 'mixed', 'tampons',
        'nut butters', 'baby cereals', 'bakery packaged cake',
        'picnic pool bbq acc', 'continental', 'diffusers', 'pain relief',
        'cold & flu', 'frozen desserts', 'shampoo', 'international foods',
        'surface cleaners', 'chilled spreads', 'colas', 'instant noodles',
        'poultry (mt)', 'chips/crisps', 'seafood deli',
```


'bread rolls & fbread', 'lemonades', 'condiments',
 'apples & pears', 'value added fp', 'smallgoods dy',
 'desserts (gr)', 'pickled vegetables', 'gourmet cheese',
 'kitchen needs/bags', 'pork', 'paper towels', 'rice', 'biscuits',
 'water', 'instore bread', 'facial tissues', 'spec/fresh cheese',
 'frozen world foods', 'chilled healthfoods', 'tuna', 'lamb',
 'grocery milk', 'jerky', 'ready to eat protein', 'dishwashing',
 'bbq meat', 'cookies', 'breakfast cereal', 'beauty/trial travel',
 'processed cheese', 'soft drinks', 'pods & capsules',
 'frozen seafood', 'black tea', 'herbal tea', 'green tea',
 'tea bags', 'beef', 'instore cake', 'hair removal',
 'ice cream tubs', 'candles', 'beans', 'toilet paper',
 'convenience meals', 'dog treats', 'jams & preserves', 'juices',
 'air fresheners', 'shoe care', 'supplements', 'pasta', 'salmon',
 'conditioner', 'infant nappies', 'frozen vegetables', 'popcorn',
 'entertainment', 'dried fruit/nuts', 'canned veg',
 'specific vitamins', 'minerals', 'body wash', 'toothbrush',
 'bakery snacks', 'trail mix', 'kitchenware', 'kiwi fruit',
 'value added', 'sauces', 'avocado & mango', 'citrus',
 'bunch lines', 'mexican foods', 'mints', 'canned meals',
 'sunscreen', 'sliced meats', 'chocolate', 'fruit-shelf stable',
 'protein snacks', 'fruit drinks', 'nuts/dried', 'hot cereal',
 'salad dressings', 'smoked & cured fish', 'deodorants',
 'bakery bought in', 'sweet biscuits', 'disposable tableware',
 'noodles', 'moisturiser', 'pest control', 'poultry (dl)',
 'smallgoods', 'vine vegetables', 'soft vegetables', 'tomatoes',
 'gum', 'chocolate spreads', 'eggs', 'toothpaste', 'spices',
 'liquid soap', 'energy drinks', 'mouthwash', 'hair treatments',
 'cold drink', 'ground coffee', 'boxed chocolates', 'dry dog food',
 'dental floss', 'fresh herbs', 'soap bars', 'dried herbs',
 'cat treats', 'flour', 'marinades', 'prepackaged seafood', 'oils',
 'game', 'herbs & chillies', 'cherries', 'hard vegetables',
 'potatoes', 'organic fruit & veg', 'mushrooms',
 'melons & tropical', 'melons', 'berries & cherries', 'bananas',
 'grapes', 'cream cheese', 'pudding', 'antip/olive/dip/pate',
 'milk alternatives', 'soft cheese', 'fruit juices', 'grab & go',
 'pies and quiches', 'mousse', 'milk additives',
 'bought in seasonal', 'bbq', 'dl prepared foods', 'gravy/stock',
 'sugar/sweeteners', 'protein bars', 'cake mixes', 'vinegar',
 'snacks', 'gluten free', 'rice paper', 'dessert mixes',
 'hot sauces', 'rice & grains', 'mackerel', 'sardines',
 'bread mixes', 'vegan', 'ready to drink', 'canned soup',
 'better for you', 'beer', 'gin', 'infant formula', 'tequila',
 'sparkling wine', 'white wine', 'red wine', 'energy/sport/icedtea',
 'whisky', 'candy', 'fresh pet food dy', 'liquor rtd', 'liqueurs',
 'frozen finger foods', 'cordials', 'rum', 'vodka', 'pretzels',
 'christmas gr food', 'nuts', 'frozen appetizers', 'detergents',

```
'electrical', 'brushware', 'household gloves', 'hardware', 'auto',
'bleach & stain removers', 'seasonal events', 'best buys',
'party goods', 'ironing', 'linen', 'allergy', 'serum',
'multivitamins', 'body lotion', 'shaving', 'makeup', 'nail care',
'cleansers', 'skincare cosmetics', 'first aid',
'continence products', 'masks', 'hair styling',
'dental accessories', 'hair accessories', 'baby wipes', 'purees',
'baby lotions', 'diapers', 'wet cat food', 'dry cat food',
'pet accessories', 'wet dog food', 'bird food', 'liquorland',
'ready meals', 'bh bought in easter', 'cat food', 'stone fruit',
'bakery easter', 'sausages', 'organic meat', 'hams',
'vegetable juices', 'dairy world foods', 'cheesecake',
'gel desserts', 'dog food'], dtype=object)
```

```
[ ]: len(data['subcategory'].unique())
```

```
[ ]: 271
```

```
[ ]: len(data['category'].unique())
```

```
[ ]: 184
```

```
[ ]: data['brand_tier'].unique()
```

```
[ ]: array(['store', 'branded'], dtype=object)
```

```
[ ]: data['unit_type'].unique()
```

```
[ ]: array(['each', 'g', 'ml', 'm', 'kgm'], dtype=object)
```

1.2 Implementation of KMeans Clustering

The process of applying KMeans clustering for a smart substitution model involves the below steps:

1. Cluster each product using the feature vector.
2. Find alternative products for a given cluster within the same cluster with appropriate conditions. (`find_alternatives()` method).
3. Optimize Cart by showing all alternative products with total savings and optimized amount.

KMeans Clustering:

- Elbow method to find the optimal number of clusters.
- Silhouette Score to observe the quality of clusters.

The Process of Finding Alternatives:

It finds the cheaper alternatives in the same cluster.

- Find the cluster assignment of the product of interest.
- Find other products under the same cluster (excluding the product itself).

- Filter for cheap options where `sale_price` is lower than the target product's sale price.

```
[ ]: import pandas as pd
import numpy as np
from sklearn.cluster import KMeans, HDBSCAN
from sklearn.preprocessing import StandardScaler, LabelEncoder, OneHotEncoder
from sklearn.decomposition import PCA
from sklearn.metrics import silhouette_score
import matplotlib.pyplot as plt
import seaborn as sns
from typing import List, Dict, Tuple, Optional
import warnings
warnings.filterwarnings('ignore')

class ProductClusteringOptimizer:
    """
    Groups similar products into clusters using feature vectors,
    then recommends cheapest viable alternatives within clusters.
    """

    def __init__(self, clustering_method: str = 'kmeans', n_clusters: int = 50,
        random_state: int = 42):
        """
        Initialize the optimizer.

        Args:
            clustering_method: 'kmeans' or 'hdbscan'
            n_clusters: Number of clusters for K-means (ignored for HDBSCAN)
        """
        self.clustering_method = clustering_method
        self.n_clusters = n_clusters
        self.random_state = random_state

        # Model components
        self.scaler = StandardScaler()
        self.onehot_encoder = None
        self.cluster_model = None
        self.label_encoders = {}
        self.feature_columns = []
        self.df = None
        self.feature_matrix = None
        self.clusters = None
        # self.pipeline = None

    def _encode_categorical_features(self, df: pd.DataFrame) -> pd.DataFrame:
        """One-hot encode subcategory and encode other categorical features."""
        df_encoded = df.copy()
```

```

drop_columns = ['product_code', 'name']
df_encoded.drop(drop_columns,axis=1, inplace=True)

# One-hot encode subcategory
one_hot_cols = ['brand', 'category', 'new_subcategory']
self.onehot_encoder = OneHotEncoder(handle_unknown="ignore",
↳sparse_output=False)
    one_hot_encoded = self.onehot_encoder.
↳fit_transform(df_encoded[one_hot_cols].astype(str))
    one_hot_df = pd.DataFrame(one_hot_encoded,
                                columns = self.onehot_encoder.
↳get_feature_names_out(one_hot_cols),
                                index=df_encoded.index)

# append one hot encoded columns
df_encoded = pd.concat([df_encoded, one_hot_df], axis=1)

# Label encode other categorical features
categorical_cols = ['unit_type', 'brand_tier', 'std_item_size_unit']
for col in categorical_cols:
    if col in df_encoded.columns:
        le = LabelEncoder()
        df_encoded[f'{col}_encoded'] = le.fit_transform(df_encoded[col].
↳astype(str))
        self.label_encoders[col] = le

# Drop the original raw categorical columns now
df_encoded.drop(one_hot_cols + categorical_cols, axis=1, inplace=True)

return df_encoded

def _create_feature_vector(self, df_encoded: pd.DataFrame) -> np.ndarray:
    """Create feature matrix from encoded dataframe."""
    categorical_features = [col for col in df_encoded.columns
                            if any(col.startswith(c) for c in ["brand_",
↳"category_", "new_subcategory_", "unit_type_", "std_item_size_unit_",
↳"brand_tier_"])]
    # Add numerical features
    numerical_features =
↳['original_price', 'sale_price', 'std_item_size', 'price_per_unit',]

    self.feature_columns = numerical_features + categorical_features

    # Scale numeric features
    X_numeric = df_encoded[numerical_features].values
    X_categorical = df_encoded[categorical_features].values

```

```

        return np.hstack([X_numeric, X_categorical]), numerical_features,
↪ categorical_features

def prepare_features(self, df:pd.DataFrame) -> 'ProductClusteringOptimizer':
    self.df = df.copy().reset_index(drop=True)

    # Encode categorical features
    df_encoded = self._encode_categorical_features(self.df)

    # Create feature matrix (unscaled)
    self.feature_matrix, numerical_features, categorical_features = self.
↪ _create_feature_vector(df_encoded)

    # Scale only numeric features
    scaled_numeric = self.scaler.fit_transform(self.df[numerical_features])
    X = np.hstack([scaled_numeric, df_encoded[categorical_features].values])

    # Save scaled matrix
    self.feature_matrix_scaled = X

    return self

def fit(self) -> 'ProductClusteringOptimizer':
    """
    Fit the clustering model on the product data.

    Args:
        df: DataFrame with product information

    Returns:
        self for method chaining
    """
    if self.feature_matrix_scaled is None:
        raise ValueError("Must preprocess data.")

    # Apply clustering
    if self.clustering_method.lower() == 'kmeans':
        self.cluster_model = KMeans(n_clusters=self.n_clusters,
↪ random_state=42, n_init=10)
    elif self.clustering_method.lower() == 'hdbscan':
        self.cluster_model = HDBSCAN(min_cluster_size=3, min_samples=2)
    else:
        raise ValueError("clustering_method must be 'kmeans' or 'hdbscan'")

    self.clusters = self.cluster_model.fit_predict(self.
↪ feature_matrix_scaled)

```

```

self.df['cluster'] = pd.Series(self.clusters, index=self.df.index)

return self

def plot_elbow_method(self, max_k: int=50) -> None:
    """
    Use the ELbow method to find a good number of clusters for KMeans
    """
    if self.feature_matrix_scaled is None:
        raise ValueError("Must preprocess data.")

    inertias = []
    K = range(2, max_k+1)
    for k in K:
        model = KMeans(n_clusters=k, random_state=self.random_state,
↪n_init=5)
        model.fit(self.feature_matrix_scaled)

        inertias.append(model.inertia_)
    # Plot
    plt.figure(figsize=(8,5))
    plt.plot(K, inertias, 'bo-', markersize=6)
    plt.xlabel("Number of Clusters (k)")
    plt.ylabel("Inertia (WCSS)")
    plt.title("ELbow Method for Optimal k")
    plt.show()

def get_cluster_quality_metrics(self) -> Dict[str, float]:
    """Calculate clustering quality metrics."""
    if self.clusters is None:
        raise ValueError("Model must be fitted first")

    # Silhouette score
    silhouette = silhouette_score(self.feature_matrix_scaled, self.clusters)

    # Number of clusters
    n_clusters = len(np.unique(self.clusters[self.clusters >= 0])) #↵
↪Exclude noise points for HDBSCAN

    # Cluster size statistics
    cluster_sizes = pd.Series(self.clusters).value_counts()
    avg_cluster_size = cluster_sizes.mean()

    return {
        'silhouette_score': silhouette,
        'n_clusters': n_clusters,
        'avg_cluster_size': avg_cluster_size,
    }

```

```

        'min_cluster_size': cluster_sizes.min(),
        'max_cluster_size': cluster_sizes.max()
    }

def visualize_clusters(self, figsize: Tuple[int, int] = (12, 8)) -> None:
    """Visualize clusters using PCA dimensionality reduction."""
    if self.clusters is None:
        raise ValueError("Model must be fitted first")

    # Apply PCA for visualization
    pca = PCA(n_components=2, random_state=42)
    features_2d = pca.fit_transform(self.feature_matrix_scaled)

    plt.figure(figsize=figsize)

    # Plot clusters
    unique_clusters = np.unique(self.clusters)
    colors = plt.cm.Set3(np.linspace(0, 1, len(unique_clusters)))

    for cluster_id, color in zip(unique_clusters, colors):
        mask = self.clusters == cluster_id
        label = f'Cluster {cluster_id}' if cluster_id >= 0 else 'Noise'
        plt.scatter(features_2d[mask, 0], features_2d[mask, 1],
                    c=[color], label=label, alpha=0.7, s=50)

    plt.title(f'Product Clusters ({self.clustering_method.upper()})\n'
             f'Silhouette Score: {self.
get_cluster_quality_metrics()["silhouette_score"]:.3f}')
    plt.xlabel(f'PC1 ({pca.explained_variance_ratio_[0]:.1%} variance)')
    plt.ylabel(f'PC2 ({pca.explained_variance_ratio_[1]:.1%} variance)')
    plt.legend(bbox_to_anchor=(1.05, 1), loc='upper left')
    plt.tight_layout()
    plt.show()

def find_alternatives(self, product_code: str, max_alternatives: int = 5) -> List[Dict]:
    """
    Find cheaper alternatives for a given product.

    Args:
        product_code: Code of the product to find alternatives for
        max_alternatives: Maximum number of alternatives to return

    Returns:
        List of alternative products with their details and savings
    """
    if self.clusters is None:

```

```

        raise ValueError("Model must be fitted first")

    # Find the target product
    target_mask = self.df['product_code'] == product_code
    if not target_mask.any():
        raise ValueError(f"Product code {product_code} not found")

    target_product = self.df[target_mask].iloc[0]
    target_cluster = target_product['cluster']

    # If product is in noise cluster (HDBSCAN), return empty list
    if target_cluster == -1:
        return []

    # Find products in the same cluster + same category + same subcategory
    cluster_products = self.df[
        (self.df['cluster'] == target_cluster) &
        (self.df['product_code'] != product_code) &
        (self.df['category'] == target_product['category']) &
        (self.df['subcategory'] == target_product['subcategory'])
    ].copy()

    # If none found, relax to same category only
    if cluster_products.empty:
        cluster_products = self.df[
            (self.df['cluster'] == target_cluster) &
            (self.df['product_code'] != product_code) &
            (self.df['category'] == target_product['category'])
        ].copy()

    if cluster_products.empty:
        return []

    # Filter to only cheaper alternatives
    cheaper_alternatives = cluster_products[
        cluster_products['sale_price'] < target_product['sale_price']
    ].copy()

    if cheaper_alternatives.empty:
        return []

    # Calculate savings and sort by price
    cheaper_alternatives['savings'] = target_product['sale_price'] - ↵
    ↪ cheaper_alternatives['sale_price']
    cheaper_alternatives['savings_pct'] = (cheaper_alternatives['savings'] /
    ↪ target_product['sale_price']) * 100

```



```

# Sort by sale price (cheapest first)
cheaper_alternatives = cheaper_alternatives.sort_values('sale_price')

# Prepare results
alternatives = []
for _, alt in cheaper_alternatives.head(max_alternatives).iterrows():
    alternatives.append({
        'product_code': alt['product_code'],
        'name': alt['name'],
        'brand': alt['brand'],
        'brand_tier': alt['brand_tier'],
        'original_price': alt['sale_price'],
        'savings': alt['savings'],
        'savings_pct': alt['savings_pct'],
        'price_per_unit': alt['price_per_unit'],
        'cluster_id': alt['cluster']
    })

return alternatives

def optimize_cart(self, cart_product_codes: List[str]) -> Dict:
    """
    Optimize an entire cart by finding alternatives for all items.

    Args:
        cart_product_codes: List of product codes in the cart

    Returns:
        Dictionary with optimization results
    """
    if self.clusters is None:
        raise ValueError("Model must be fitted first")

    original_total = 0
    optimized_total = 0
    recommendations = {}
    items_with_alternatives = 0

    for product_code in cart_product_codes:
        try:
            # Get original product details
            original_product = self.df[self.df['product_code'] ==
product_code].iloc[0]
            original_price = original_product['sale_price']
            original_total += original_price

            # Find alternatives

```

```

        alternatives = self.find_alternatives(product_code,
↪max_alternatives=3)

        if alternatives:
            best_alternative = alternatives[0] # Cheapest option
            optimized_total += best_alternative['original_price']
            items_with_alternatives += 1

            recommendations[product_code] = {
                'original_name': original_product['name'],
                'original_price': original_price,
                'alternatives': alternatives,
                'best_alternative': best_alternative
            }
        else:
            optimized_total += original_price
            recommendations[product_code] = {
                'original_name': original_product['name'],
                'original_price': original_price,
                'alternatives': [],
                'best_alternative': None
            }

    except (IndexError, ValueError) as e:
        print(f"Warning: Could not process product {product_code}: {e}")
        continue

    total_savings = original_total - optimized_total
    savings_pct = (total_savings / original_total * 100) if original_total
↪ 0 else 0

    return {
        'original_total': original_total,
        'optimized_total': optimized_total,
        'total_savings': total_savings,
        'savings_percentage': savings_pct,
        'items_with_alternatives': items_with_alternatives,
        'total_items': len(cart_product_codes),
        'recommendations': recommendations
    }

def substitution_summary(self, cart_results:Dict) -> pd.DataFrame:
    """
    Create a summary table comparing original products and their
↪substitutions.
    """

```

```

records = []
for product_code, rec in cart_results['recommendations'].items():
    original_name = rec['original_name']
    original_price = rec['original_price']

    if rec['best_alternative']:
        alt = rec['best_alternative']
        records.append({
            "original_code": product_code,
            "original_name": original_name,
            "original_price": original_price,
            "alt_code": alt["product_code"],
            "alt_name": alt["name"],
            "alt_price": alt["original_price"],
            "savings": alt["savings"],
            "savings_pct": alt["savings_pct"]
        })
    else:
        records.append({
            "original_code": product_code,
            "original_name": original_name,
            "original_price": original_price,
            "alt_code": None,
            "alt_name": "No substitute found",
            "alt_price": None,
            "savings": 0,
            "savings_pct": 0
        })

return pd.DataFrame(records)

def analyze_cluster(self, cluster_id: int) -> Dict:
    """Analyze a specific cluster's characteristics."""
    if self.clusters is None:
        raise ValueError("Model must be fitted first")

    cluster_products = self.df[self.df['cluster'] == cluster_id]

    if cluster_products.empty:
        return {'error': f'No products found in cluster {cluster_id}'}

    analysis = {
        'cluster_id': cluster_id,
        'size': len(cluster_products),
        'subcategories': cluster_products['subcategory'].value_counts().
        to_dict(),

```

```

        'brands': cluster_products['brand'].value_counts().to_dict(),
        'brand_tiers': cluster_products['brand_tier'].value_counts().
↳to_dict(),
        'price_range': {
            'min': cluster_products['sale_price'].min(),
            'max': cluster_products['sale_price'].max(),
            'mean': cluster_products['sale_price'].mean(),
            'std': cluster_products['sale_price'].std()
        },
        'sample_products': cluster_products[['name', 'brand', '
↳sale_price']].head().to_dict('records')
    }

    return analysis

```

1.2.1 Implement KMeans Clustering with K=20 for demonstration:

```

[ ]: def demo_with_sample_data():

    # Initialize and fit the optimizer
    optimizer = ProductClusteringOptimizer(
        clustering_method='kmeans',
        n_clusters=20 # Small number for demo
    )

    print("Fitting clustering model...")
    optimizer.prepare_features(data)
    optimizer.plot_elbow_method(max_k=40)
    print(data.columns)
    print(data.head())

    # Show cluster quality metrics
    metrics = optimizer.get_cluster_quality_metrics()
    print(f"Clustering Quality Metrics:")
    print(f"- Silhouette Score: {metrics['silhouette_score']:.3f}")
    print(f"- Number of Clusters: {metrics['n_clusters']}")
    print(f"- Average Cluster Size: {metrics['avg_cluster_size']:.1f}")
    print("\n" + "="*80 + "\n")

    # Analyze clusters
    print("Cluster Analysis:")
    for cluster_id in sorted(optimizer.df['cluster'].unique()):
        if cluster_id >= 0: # Skip noise points
            analysis = optimizer.analyze_cluster(cluster_id)
            print(f"\nCluster {cluster_id}:")
            print(f"    Size: {analysis['size']} products")

```

```

        print(f" Subcategories: {analysis['subcategories']}")
        print(f" Brands: {analysis['brands']}")
        print(f" Price range: ${analysis['price_range']['min']:.2f} -
↪ ${analysis['price_range']['max']:.2f}")

    print("\n" + "="*80 + "\n")

    optimizer.visualize_clusters()
    # Demo individual product alternatives
    print("Finding Alternatives for Individual Products:")
    for product_code in [8371390, 5726070]: # Test a few products
        try:
            product_name = data[data['product_code'] == product_code]['name'].
↪ iloc[0]
            alternatives = optimizer.find_alternatives(product_code)

            print(f"\nProduct: {product_name} (Code: {product_code})")
            if alternatives:
                print(f"Found {len(alternatives)} cheaper alternatives:")
                for i, alt in enumerate(alternatives, 1):
                    print(f" {i}. {alt['name']}")
                    print(f" Price: ${alt['original_price']:.2f} (Save
↪ ${alt['savings']:.2f}, {alt['savings_pct']:.1f}%)")
                    print(f" Brand: {alt['brand']} ({alt['brand_tier']})")
            else:
                print(" No cheaper alternatives found in cluster")
        except Exception as e:
            print(f" Error finding alternatives: {e}")

    print("\n" + "="*80 + "\n")

    # Demo cart optimization
    print("Cart Optimization Demo:")
    sample_cart = [8371390, 7107738, 4885191] # Sample cart
    cart_results = optimizer.optimize_cart(sample_cart)

    print(f"Original cart total: ${cart_results['original_total']:.2f}")
    print(f"Optimized cart total: ${cart_results['optimized_total']:.2f}")
    print(f"Total savings: ${cart_results['total_savings']:.2f}
↪ ({cart_results['savings_percentage']:.1f}%)")
    print(f"Items with alternatives: {cart_results['items_with_alternatives']}/
↪ {cart_results['total_items']}")

    print("\nDetailed Recommendations:")
    for product_code, rec in cart_results['recommendations'].items():
        print(f"\n{rec['original_name']} (${rec['original_price']:.2f}")
        if rec['best_alternative']:

```

```

        alt = rec['best_alternative']
        print(f" → Recommended: {alt['name']}")
        print(f"      Price: ${alt['original_price']:.2f} (Save_
↪ ${alt['savings']:.2f})")
    else:
        print(f" → No cheaper alternatives found")

    return optimizer

```

```
[ ]: optimizer_basic = demo_with_sample_data()
```

Fitting clustering model...

<__main__.ProductClusteringOptimizer object at 0x7af1424528d0>

```

Index(['product_code', 'name', 'brand', 'brand_tier', 'category',
      'subcategory', 'original_price', 'sale_price', 'std_item_size',
      'std_item_size_unit', 'item_size', 'price_per_unit', 'unit_type'],
      dtype='object')

```

	product_code		name	brand	\
0	8371390	coles hot cross buns traditional fruit	coles		
1	7473849	coles hot cross buns choc chip	coles		
2	5726070	coles hot cross buns traditional fruit mini	coles		
3	7107738	cadbury dairy milk chocolate easter egg hunt c...	cadbury		
4	4885191	cadbury dairy milk easter chocolate eggs bag	cadbury		

	brand_tier	category	subcategory	original_price	sale_price	std_item_size	\
0	store	easter	easter	4.4	3.0	6.0	
1	store	easter	easter	4.4	3.0	6.0	
2	store	easter	easter	4.4	3.0	9.0	
3	branded	easter	easter	8.0	8.0	306.0	
4	branded	easter	easter	6.7	6.7	114.0	

	std_item_size_unit	item_size	price_per_unit	unit_type
0	pack	6.02740	0.7300	each
1	pack	6.02740	0.7300	each
2	pack	8.97959	0.4900	each
3	g	306.51341	0.0261	g
4	g	113.94558	0.0588	g

Clustering Quality Metrics:

- Silhouette Score: 0.621
- Number of Clusters: 20
- Average Cluster Size: 1186.8

=====

Cluster Analysis:

Cluster 0:

Size: 263 products

Subcategories: {'whisky': 46, 'beer': 45, 'liquor rtd': 43, 'mixed': 26, 'gin': 20, 'liquorland': 18, 'tequila': 14, 'liqueurs': 10, 'rum': 8, 'serum': 8, 'vodka': 7, 'moisturiser': 5, 'makeup': 3, 'cold & flu': 2, 'supplements': 2, 'red wine': 2, 'sparkling wine': 2, 'household': 1, 'white wine': 1}

Brands: {'revitalift': 11, '12yo': 6, 'double': 6, 'bourbon': 6, 'paris': 5, 'gin': 5, 'white': 5, 'zero': 5, 'tequila': 5, 'dry': 4, 'kentucky': 4, 'cola': 4, '10yo': 4, 'great': 4, 'up': 3, 'hard': 3, 'true': 3, 'age': 3, 'vodka': 3, 'blue': 3, 'blanco': 3, 'spiced': 3, 'premium': 3, 'mid': 3, 'pale': 3, 'the': 3, 'draught': 2, 'rare': 2, 'anejo': 2, 'wild': 2, 'australian': 2, 'brewed': 2, 'vs': 2, 'triple': 2, 'pink': 2, 'ginger': 2, 'extra': 2, 'victoria': 2, 'cruiser': 2, 'black': 2, 'hahn': 2, '18yo': 2, 'irish': 2, 'nastro': 2, 'red': 2, 'mini': 2, 'silver': 2, 'especial': 2, 'liqueur': 2, 'omo': 1, 'hazelnut': 1, 'bitter': 1, 'longbranch': 1, 'japanese': 1, 'arboralis': 1, 'half': 1, 'sloe': 1, 'coastal': 1, 'distillery': 1, 'aperitif': 1, 'glucosamine': 1, 'bio': 1, 'gold': 1, 'fish': 1, '101': 1, 'harmony': 1, 'tennessee': 1, 'ultra': 1, 'xpa': 1, 'pacific': 1, 'gentleman': 1, 'cerveza': 1, 'lager': 1, 'ichiban': 1, 'original': 1, 'no': 1, 'south': 1, 'refreshing': 1, 'london': 1, 'brut': 1, 'coffee': 1, 'whisky': 1, 'carlton': 1, 'gage': 1, 'xxxx': 1, 'heineken': 1, 'smirnoff': 1, 'makers': 1, 'corona': 1, 'st': 1, 'johnnie': 1, 'asahi': 1, 'vintage': 1, 'export': 1, 'pear': 1, 'newtowner': 1, '16yo': 1, 'ice': 1, 'two': 1, 'summer': 1, 'apple': 1, 'cabernet': 1, 'midori': 1, 'ipa': 1, 'xv': 1, 'sour': 1, 'vsop': 1, 'xo': 1, 'honeycomb': 1, 'scotch': 1, 'cinnamon': 1, 'special': 1, 'lime': 1, 'watermelon': 1, 'straight': 1, 'odyssey': 1, 'hinterland': 1, 'can': 1, 'american': 1, 'superior': 1, 'jungle': 1, 'blended': 1, 'coconut': 1, 'pure': 1, 'limoncello': 1, 'rosa': 1, 'captain': 1, 'small': 1, 'herbal': 1, 'bonded': 1, 'blackberry': 1, 'grape': 1, 'byron': 1, 'altos': 1, 'melbourne': 1, 'bottles': 1, 'lemon': 1, 'citron': 1, 'peanut': 1, 'soda': 1, 'imported': 1, 'amaretto': 1, 'vanilla': 1, 'old': 1, 'mdc': 1, 'crushed': 1, 'reserve': 1, 'campfire': 1, 'mixed': 1, 'cold': 1, 'gsm': 1, 'marlborough': 1, 'riesling': 1, 'caribbean': 1, 'whispering': 1, 'green': 1}

Price range: \$24.50 - \$332.00

Cluster 1:

Size: 108 products

Subcategories: {'infant nappies': 81, 'dry dog food': 13, 'rice': 5, 'dog food': 3, 'mixed': 2, 'melons': 1, 'seafood deli': 1, 'flour': 1, 'rice & grains': 1}

Brands: {'ultra': 37, 'premium': 25, 'adult': 11, 'nappy': 6, 'ultimate': 6, 'cosifit': 5, 'australian': 2, 'little': 2, 'frozen': 1, 'watermelon': 1, 'classic': 1, 'white': 1, 'puppy': 1, 'calico': 1, 'dry': 1, 'large': 1, 'complete': 1, 'cat': 1, 'lucky': 1, 'simply': 1, 'sella': 1, 'infant': 1}

Price range: \$8.00 - \$85.00

Cluster 2:

Size: 639 products

Subcategories: {'mixed': 308, 'energy/sport/icedtea': 29, 'water': 26, 'wet cat food': 25, 'electrical': 18, 'wet dog food': 18, 'surface cleaners': 16, 'lemonades': 12, 'better for you': 11, 'infant nappies': 11, 'detergents': 10,

'cat food': 9, 'entertainment': 9, 'fruit drinks': 9, 'gum': 9, 'cat treats': 8, 'noodles': 7, 'infant formula': 7, 'rice': 7, 'energy drinks': 6, 'whisky': 5, 'instant noodles': 5, 'fruit-shelf stable': 5, 'protein bars': 5, 'fresh pet food dy': 4, 'colas': 4, 'mousse': 4, 'soap bars': 4, 'toothbrush': 4, 'tuna': 4, 'grocery milk': 4, 'dried fruit/nuts': 4, 'makeup': 3, 'pain relief': 2, 'drinks': 2, 'biscuits': 2, 'processed cheese': 2, 'lamb': 2, 'facial tissues': 2, 'desserts (gr)': 2, 'picnic pool bbq acc': 2, 'canned veg': 2, 'household': 1, 'chips/crisps': 1, 'toothpaste': 1, 'pasta': 1, 'chilled healthfoods': 1, 'pudding': 1, 'canned meals': 1, 'pest control': 1, 'supplements': 1, 'hair treatments': 1, 'dog food': 1}

Brands: {'adult': 21, 'classic': 18, 'protein': 17, 'zero': 16, 'energy': 14, 'liquid': 13, 'cat': 13, 'led': 13, 'brewed': 12, 'sparkling': 12, 'vanilla': 9, 'creamy': 9, 'low': 9, 'lightly': 9, 'bom': 8, 'microwave': 7, 'orange': 7, 'strawberry': 7, 'grain': 7, 'coconut': 6, 'lemon': 6, 'night': 6, 'no': 6, 'wet': 6, 'beauty': 6, 'ultimate': 5, 'fresh': 5, 'premium': 5, 'grilled': 5, 'laundry': 5, 'scented': 5, 'lemonade': 5, 'snacks': 5, 'diet': 5, 'soft': 5, 'sugar': 5, 'gravy': 5, 'activia': 4, 'rice': 4, 'natural': 4, 'blue': 4, 'tempters': 4, 'original': 4, 'the': 4, 'dairy': 4, 'petite': 4, 'tin': 4, 'power': 4, 'dog': 3, 'luxé': 3, 'taste': 3, 'slow': 3, 'chunks': 3, 'complete': 3, 'fragrance': 3, 'pure': 3, 'better': 3, 'by': 3, 'sodaly': 3, 'globe': 3, 'favourites': 3, 'singles': 3, 'potato': 3, 'apple': 3, 'fried': 3, 'mango': 3, 'chocolate': 3, 'iced': 3, 'kombucha': 3, 'age': 3, 'black': 3, 'beef': 3, 'mini': 3, 'agail': 2, 'tropical': 2, 'yoghurt': 2, 'pea': 2, 'peppermint': 2, 'australian': 2, 'chicken': 2, 'disney': 2, 'upgo': 2, 'jin': 2, 'raspberry': 2, 'golden': 2, 'white': 2, 'wafers': 2, 'healthy': 2, 'one': 2, 'tasty': 2, '1': 2, 'stir': 2, 'daily': 2, 'puppy': 2, 'pulled': 2, 'nights': 2, 'multipack': 2, 'big': 2, 'milk': 2, 'profutura': 2, 'high': 2, 'inspirations': 2, 'spearmint': 2, 'dip': 2, 'facial': 2, 'sensitive': 2, 'transparent': 2, 'gold': 2, 'sleepynights': 2, 'bar': 2, 'deluxe': 2, 'brilliant': 2, 'ultra': 2, 'lime': 2, 'ginger': 2, 'water': 2, 'extra': 2, 'bbq': 2, 'biscoff': 1, 'cola': 1, 'le': 1, 'crunchy': 1, 'kindy': 1, 'sea': 1, 'sultanas': 1, 'juicy': 1, 'pk': 1, 'peanut': 1, 'holy': 1, 'aussie': 1, 'caramel': 1, 'buldak': 1, 'diced': 1, 'drink': 1, 'organic': 1, 'berry': 1, 'childrens': 1, 'cocacola': 1, 'surf': 1, 'hommus': 1, 'veggie': 1, 'organics': 1, 'milky': 1, 'summer': 1, 'cheesey': 1, 'chive': 1, 'fetta': 1, 'pine': 1, 'bready': 1, 'tetra': 1, 'coles': 1, 'endulge': 1, 'sweet': 1, 'strong': 1, 'light': 1, 'sensations': 1, 'grape': 1, 'kids': 1, 'fava': 1, 'garland': 1, 'seed': 1, 'celebrating': 1, 'asia': 1, 'multi': 1, 'charlottes': 1, 'fairy': 1, 'baked': 1, 'pasito': 1, '4': 1, 'sleepy': 1, 'baby': 1, 'blister': 1, 'shots': 1, 'pro': 1, 'children': 1, 'spa': 1, 'touch': 1, 'tubular': 1, 'duo': 1, 'pilot': 1, 'stain': 1, 'kill': 1, 'kole': 1, 'ionic': 1, 'passionfruit': 1, 'refreshers': 1, 'alkaline': 1, 'long': 1, 'latte': 1, 'double': 1, 'pink': 1, 'creaming': 1, 'spring': 1, 'tonic': 1, 'sunshine': 1, 'finger': 1, 'non': 1, 'traditional': 1, 'glowwhite': 1, 'fruit': 1, 'seafood': 1, 'desire': 1, 'royale': 1, 'so': 1, 'shredded': 1, 'meat': 1, 'essential': 1, 'lamb': 1, 'seaweed': 1, 'graze': 1, 'reduced': 1, 'probiotics': 1, 'jasmine': 1, 'watermelon': 1, 'toddler': 1, 'soy': 1, 'kitchen': 1, 'fruche': 1, 'chef': 1, 'krackjack': 1, 'chilsung': 1, 'japanese': 1, 'milkis': 1, 'essenza': 1, 'all': 1, 'washing': 1, 'nice': 1, 'senior': 1,

'regal': 1, 'hanwood': 1, 'kitten': 1}

Price range: \$1.50 - \$82.00

Cluster 3:

Size: 3028 products

Subcategories: {'mixed': 1133, 'instore bread': 95, 'kitchen needs/bags': 83, 'party goods': 77, 'toothbrush': 75, 'pods & capsules': 70, 'minerals': 70, 'instore cake': 63, 'disposable tableware': 61, 'electrical': 61, 'tea bags': 53, 'dishwashing': 52, 'multivitamins': 52, 'picnic pool bbq acc': 50, 'brushware': 47, 'seasonal events': 45, 'supplements': 44, 'hair removal': 43, 'specific vitamins': 40, 'infant nappies': 39, 'dog treats': 38, 'cold & flu': 35, 'shaving': 35, 'black tea': 31, 'kitchenware': 31, 'surface cleaners': 31, 'household gloves': 31, 'beauty/travel travel': 30, 'pet accessories': 30, 'facial tissues': 29, 'tampons': 28, 'soft vegetables': 28, 'baby wipes': 27, 'pain relief': 27, 'toilet paper': 25, 'auto': 21, 'pest control': 21, 'bunch lines': 20, 'hardware': 19, 'paper towels': 18, 'sugar/sweeteners': 17, 'melons & tropical': 16, 'herbal tea': 16, 'organic fruit & veg': 13, 'continence products': 10, 'green tea': 10, 'hair treatments': 10, 'dental floss': 9, 'poultry (dl)': 8, 'bakery packaged cake': 7, 'herbs & chillies': 6, 'shoe care': 6, 'hair accessories': 5, 'vine vegetables': 5, 'household': 5, 'allergy': 4, 'bakery easter': 4, 'desserts (gr)': 4, 'melons': 4, 'kiwi fruit': 4, 'international foods': 3, 'milk additives': 3, 'beans': 3, 'first aid': 3, 'bread rolls & fbread': 3, 'linen': 3, 'diapers': 3, 'infant formula': 3, 'smallgoods': 3, 'fruit & vegetables': 2, 'bird food': 2, 'avocado & mango': 2, 'apples & pears': 2, 'continental': 2, 'citrus': 2, 'flour': 2, 'health & beauty': 1, 'ground coffee': 1, 'bbq': 1, 'dl prepared foods': 1, 'seafood deli': 1, 'antip/olive/dip/pate': 1, 'makeup': 1, 'moisturiser': 1, 'dental accessories': 1, 'nail care': 1, 'cleansers': 1, 'hard vegetables': 1, 'sunscreens': 1, 'air fresheners': 1, 'easter': 1, 'rice & grains': 1}

Brands: {'ultra': 45, 'kids': 40, 'ultiboost': 34, 'extra': 30, 'effervescent': 29, 'super': 28, 'pads': 27, 'organic': 26, 'venus': 23, 'stone': 22, 'adult': 21, 'to': 21, 'kitchen': 19, 'gummies': 19, 'high': 18, 'blue': 18, 'laundry': 18, 'liners': 17, 'ultimate': 17, 'happy': 17, 'pure': 16, 'espresso': 16, '3': 16, 'magnesium': 15, 'bbq': 15, 'by': 15, 'green': 15, 'double': 15, 'disinfectant': 15, 'cotton': 14, 'energy': 14, 'paper': 14, 'incontinence': 14, 'original': 14, 'ultivite': 13, 'live': 13, 'simply': 13, 'mini': 13, 'english': 13, 'magic': 13, 'heavy': 13, 'thick': 13, 'beauty': 13, '360': 13, 'candle': 13, 'large': 13, 'multi': 12, 'plus': 12, 'platinum': 12, 'vanilla': 12, 'rapid': 11, 'white': 11, 'regular': 10, 'sensitive': 10, 'baby': 10, 'black': 10, 'advanced': 10, 'total': 10, 'electrolyte': 10, 'ansell': 10, 'premium': 10, 'coffee': 10, 'citronella': 9, 'cold': 9, 'soft': 9, 'bake': 9, 'probiotic': 9, 'multivitamin': 9, 'sweetener': 9, '3ply': 9, 'command': 9, 'real': 9, 'nappy': 9, 'gold': 9, 'all': 8, 'tea': 8, 'natural': 8, 'lithium': 8, 'coppertop': 8, 'cappuccino': 8, 'pro': 8, 'hot': 8, 'cafe': 8, 'iced': 8, 'rspca': 8, 'interdental': 8, 'chewable': 8, 'no': 8, 'tampons': 7, 'ice': 7, 'mens': 7, 'mega': 7, 'nappies': 7, 'skin': 7, 'timber': 7, 'duracell': 7, 'quantum': 7, 'lemon': 7, 'dentastix': 7, 'colour': 7, 'discreet': 7, 'hydrate': 7, 'alkaline': 7, 'patterned': 7, 'specialty': 7, 'sleep': 7, 'sugar': 7,

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Price range: \$0.50 - \$76.50

Cluster 4:

Size: 65 products

Subcategories: {'mixed': 26, 'electrical': 10, 'hair treatments': 8, 'shampoo': 5, 'canned veg': 4, 'baby wipes': 3, 'moisturiser': 2, 'infant formula': 2, 'tuna': 1, 'continence products': 1, 'infant nappies': 1, 'whisky': 1, 'red wine': 1}

Brands: {'got2b': 10, 'nice': 5, 'coppertop': 4, 'beans': 3, 'high': 3, '2': 3, 'fragrance': 3, 'colorstay': 3, 'bodyscience': 2, 'alkaline': 2, 'gold': 2, 'hearing': 2, 'nutrisse': 2, 'lithium': 1, 'best': 1, 'perform': 1, 'organic': 1, 'chun': 1, 'paris': 1, 'revitalift': 1, 'excellence': 1, 'regenerist': 1, 'specialty': 1, 'lemon': 1, 'fruit': 1, '3': 1, 'for': 1, 'good': 1, 'promo': 1, 'brow': 1, 'preference': 1, 'pouch': 1, 'symphony': 1, '1859': 1}

Price range: \$1.10 - \$150.00

Cluster 5:

Size: 1172 products

Subcategories: {'mixed': 427, 'ice cream tubs': 73, 'bread rolls & fbread': 57, 'bakery packaged cake': 53, 'eggs': 52, 'chocolate': 25, 'tea bags': 24, 'bakery snacks': 23, 'desserts (gr)': 21, 'instant noodles': 21, 'frozen desserts': 18, 'instore cake': 18, 'mexican foods': 17, 'biscuits': 17, 'protein snacks': 17, 'chips/crisps': 16, 'canned meals': 16, 'black tea': 15, 'hair treatments': 11, 'bakery bought in': 11, 'noodles': 10, 'green tea': 10, 'fruit-shelf stable': 9, 'frozen world foods': 9, 'easter': 8, 'boxed chocolates': 8, 'chilled healthfoods': 7, 'international foods': 7, 'gum': 6, 'frozen finger foods': 6, 'health & beauty': 6, 'bakery': 6, 'cookies': 6, 'hot cereal': 6, 'processed cheese': 6, 'pods & capsules': 6, 'herbal tea': 5, 'dried fruit/nuts': 5, 'protein bars': 5, 'dietary & world foods': 5, 'lamb': 5, 'dairy, eggs & fridge': 4, 'popcorn': 4, 'pantry': 4, 'milk additives': 4, 'makeup': 4, 'frozen vegetables': 4, 'bbq meat': 4, 'frozen': 4, 'breakfast cereal': 4, 'bought in seasonal': 3, 'canned veg': 3, 'prepackaged seafood': 3, 'infant nappies': 3, 'bonus credit products': 2, 'chips, chocolates & snacks': 2, 'smallgoods dy': 2, 'footy's back': 2, 'beef': 2, 'entertainment': 2, 'surface cleaners': 2, 'pet accessories': 2, 'sausages': 2, 'cat treats': 2, 'grocery milk': 2, 'mints': 2, 'rice': 2, 'trail mix': 1, 'gluten free': 1, 'chocolate spreads': 1, 'antip/olive/dip/pate': 1, 'cream cheese': 1, 'gourmet

cheese': 1, 'citrus': 1, 'picnic pool bbq acc': 1, 'frozen appetizers': 1, 'soap bars': 1, 'serum': 1, 'moisturiser': 1, 'facial tissues': 1, 'air fresheners': 1, 'kitchenware': 1, 'cleansers': 1, 'shampoo': 1, 'dog treats': 1, 'household': 1, 'bh bought in easter': 1, 'sardines': 1, 'seasonal events': 1, 'cheesecake': 1, 'beauty/travel': 1, 'diapers': 1}

Brands: {'frozen': 58, 'mini': 27, 'free': 26, 'ice': 21, 'chocolate': 20, 'dairy': 19, 'protein': 15, 'low': 14, 'fruit': 13, 'nut': 12, 'drumstick': 12, 'lcms': 11, 'pure': 11, 'premium': 11, '2': 11, 'gluten': 10, 'original': 10, 'milk': 10, 'creamy': 10, 'coles': 9, 'lite': 9, 'choc': 8, 'white': 8, 'maxibon': 8, 'organic': 7, 'cage': 7, 'natural': 7, 'simply': 7, 'lemon': 7, 'multipack': 7, 'nice': 7, 'blueberry': 6, 'french': 6, 'im': 6, 'plant': 6, 'ktime': 6, 'classic': 6, 'english': 6, 'cheese': 5, 'all': 5, 'barn': 5, 'regular': 5, 'spaghetti': 5, 'peanut': 5, 'canned': 5, 'earl': 5, 'irresistible': 5, 'multigrain': 5, 'roasted': 5, 'chicken': 5, 'dark': 5, 'salted': 5, 'oat': 5, 'minis': 5, 'baked': 5, 'shapes': 5, 'happy': 5, 'brioche': 5, 'natures': 5, 'tasty': 4, 'fit': 4, 'diced': 4, 'caramel': 4, 'potato': 4, 'variety': 4, 'paddle': 4, 'porridge': 4, 'apple': 4, 'pita': 4, 'sticks': 4, 'rocher': 4, 'golden': 4, 'kitchen': 4, 'high': 4, 'splits': 4, 'dolce': 4, 'ramen': 4, 'night': 4, 'mixed': 4, 'frosty': 4, 'vanilla': 4, 'crunch': 4, 'joyful': 4, 'sweet': 4, 'no': 4, 'licks': 4, 'steam': 4, 'lamb': 4, 'bake': 4, 'breakfast': 4, 'soft': 4, 'greek': 3, 'tropical': 3, 'snack': 3, 'regenerist': 3, 'easter': 3, 'baby': 3, 'slow': 3, 'indian': 3, 'buldak': 3, 'tomato': 3, 'organics': 3, 'christmas': 3, 'vegan': 3, 'noodle': 3, 'thins': 3, 'angus': 3, 'healthier': 3, 'green': 3, 'cookies': 3, 'party': 3, 'pizza': 3, 'mango': 3, 'wholemeal': 3, 'creme': 3, 'crumpet': 3, 'pie': 2, 'orange': 2, 'double': 2, 'banana': 2, 'meal': 2, 'cafe': 2, 'fusian': 2, 'gourmet': 2, 'polyblands': 2, 'popcorn': 2, 'smoothie': 2, 'lil': 2, 'plain': 2, 'snacks': 2, 'bueno': 2, 'skinny': 2, 'preference': 2, 'muesli': 2, 'fresh': 2, 'tiny': 2, 'eco': 2, 'ultralight': 2, 'instant': 2, 'libra': 2, 'swisspers': 2, 'beef': 2, 'active': 2, 'fermented': 2, 'caramilk': 2, 'twirl': 2, 'minecraft': 2, 'stackers': 2, 'snacking': 2, 'chips': 2, 'hot': 2, 'hoys': 2, 'calippo': 2, 'laneway': 2, 'microwave': 2, 'graze': 2, 'jumbo': 2, 'tasmanian': 2, 'collection': 2, 'thick': 2, 'raffaello': 2, 'assorted': 2, 'tandoori': 2, 'lemonade': 2, 'vintage': 2, 'gingin': 2, 'cupcakes': 2, 'spinach': 2, 'sticky': 2, 'preservative': 2, 'garlic': 2, 'sesame': 2, 'vegetable': 2, 'strawberry': 2, 'bodyscience': 2, 'gooey': 2, 'cherry': 2, 'mix': 2, 'matcha': 2, 'microwavable': 2, 'raspberry': 2, 'shin': 2, 'mandarin': 2, 'sponge': 2, 'quelch': 2, 'australian': 2, 'stand': 2, 'cup': 2, 'extra': 2, 'espressotoria': 2, 'jelly': 2, 'decaffeinated': 2, 'mr': 2, 'sensodyne': 2, 'ferrero': 1, 'fourn': 1, 'the': 1, 'danone': 1, 'pauls': 1, 'bega': 1, 'tip': 1, 'illy': 1, 'abes': 1, 'smiths': 1, 'arnotts': 1, 'gym': 1, 'solid': 1, '2minute': 1, 'risone': 1, 'dandy': 1, 'rooibos': 1, 'phulka': 1, 'animal': 1, 'triple': 1, 'melona': 1, 'ham': 1, 'bulk': 1, 'nipple': 1, 'emery': 1, 'polish': 1, 'nappy': 1, 'tortillas': 1, 'corn': 1, 'pho': 1, 'rainbow': 1, 'cocktail': 1, 'yorkshire': 1, 'mi': 1, 'caffeine': 1, 'writing': 1, 'pears': 1, 'pot': 1, 'plum': 1, 'sourdough': 1, 'pain': 1, 'i': 1, 'irish': 1, 'assam': 1, 'spice': 1, 'chamomile': 1, 'hazelnut': 1, 'tea': 1, 'italian': 1, 'bengal': 1, 'quick': 1, 'taco': 1, 'berry': 1, 'melbourne': 1, 'lemongrass': 1, 'three': 1, 'street': 1}

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Price range: \$1.10 - \$60.00

Cluster 6:

Size: 55 products

Subcategories: {'mixed': 20, 'specific vitamins': 10, 'pasta': 6, 'ground coffee': 4, 'infant formula': 3, 'makeup': 2, 'toothbrush': 2, 'wet dog food': 2, 'shoe care': 2, 'sunscreen': 1, 'liquorland': 1, 'sparkling wine': 1, 'infant nappies': 1}

Brands: {'vitamin': 6, 'blend': 5, '3': 5, '4': 4, 'bone': 3, '5': 2, 'fit': 2, 'pro': 2, '4in1': 2, 'step': 2, 'penne': 1, 'farfalle': 1, 'fusilli': 1, 'rigatoni': 1, 'orecchiette': 1, 'spaghetti': 1, 'olia': 1, '5in1': 1, 'vita': 1, 'colorstay': 1, 'lip': 1, 'gold': 1, 'loaf': 1, 'adult': 1, 'james': 1, 'prosecco': 1, 'super': 1, 'party': 1, '462': 1, 'vit': 1, 'nordic': 1, 'eco': 1}

Price range: \$2.80 - \$90.00

Cluster 7:

Size: 70 products

Subcategories: {'mixed': 21, 'pods & capsules': 19, 'sunscreen': 6, 'shaving': 4, 'hair treatments': 4, 'supplements': 3, 'conditioner': 2, 'makeup': 2, 'cleansers': 2, 'hardware': 2, 'hair removal': 1, 'dog treats': 1, 'moisturiser': 1, 'infant nappies': 1, 'white wine': 1}

Brands: {'espresso': 17, 'spf': 6, 'brilliance': 4, 'hydro': 3, 'regenerist': 3, 'by': 3, '3': 2, 'just': 2, 'fit': 2, 'odourless': 2, 'blend': 2, 'cheese': 1, 'prov': 1, 'fat': 1, 'fructis': 1, 'hot': 1, 'barbie': 1, 'sensation': 1, 'colours': 1, 'nutrisse': 1, 'scandaleyes': 1, 'preference': 1, 'sensor': 1, '4': 1, 'womens': 1, '365': 1, 'turmeric': 1, 'good': 1, 'echinacea': 1, '2': 1, 'hook': 1, '17026clr': 1, 'nice': 1, 'eco': 1, 'bin': 1}

Price range: \$3.50 - \$70.00

Cluster 8:

Size: 53 products

Subcategories: {'mixed': 16, 'sunscreen': 6, 'beef': 5, 'hair treatments': 3, 'specific vitamins': 3, 'supplements': 2, 'mexican foods': 2, 'pain relief': 2, 'infant formula': 2, 'pork': 2, 'beans': 1, 'chips/crisps': 1, 'minerals': 1, 'chocolate': 1, 'ground coffee': 1, 'moisturiser': 1, 'makeup': 1, 'shaving': 1, 'infant nappies': 1, 'liquorland': 1}

Brands: {'no': 5, 'ultiboost': 5, 'pop': 3, 'sun': 3, 'chocolate': 3, 'spf': 2, 'beauty': 2, 'pork': 2, 'original': 1, 'potato': 1, 'no3': 1, 'white': 1, 'no8': 1, 'organic': 1, 'total': 1, 'high': 1, 'olia': 1, 'preference': 1, 'nordic': 1, 'blend': 1, 'revitalift': 1, 'nutrisse': 1, 'calcium': 1, 'fit': 1, 'tattoo': 1, 'brilliance': 1, 'quattro': 1, '247': 1, 'pain': 1, 'extra': 1, 'gold': 1, 'eco': 1, 'grant': 1, '3': 1, 'fashion': 1, 'face': 1}

Price range: \$1.40 - \$59.50

Cluster 9:

Size: 234 products

Subcategories: {'mixed': 93, 'deodorants': 67, 'shampoo': 17, 'makeup': 11, 'hair treatments': 8, 'surface cleaners': 7, 'pet accessories': 4, 'beauty/trial travel': 4, 'household': 4, 'pest control': 4, 'liquid soap': 2, 'bread rolls & fbread': 2, 'sunscreen': 2, 'health & beauty': 1, 'pain relief': 1, 'toothbrush': 1, 'electrical': 1, 'skincare cosmetics': 1, 'cold & flu': 1, 'cleansers': 1, 'continence products': 1, 'detergents': 1}

Brands: {'women': 31, 'men': 29, 'superstay': 11, 'deodorant': 9, 'colorsilk': 8, 'professional': 8, 'lasting': 6, 'sensitive': 5, 'ultra': 4, 'paris': 4, 'kids': 4, 'infallible': 4, 'laundry': 4, 'ultimate': 3, '3': 3, 'technocolor': 3, 'clinical': 3, 'ultramen': 3, 'clean': 3, 'gold': 3, 'for': 2, 'biodegradable': 2, 'xtreme': 2, 'pure': 2, 'coffee': 2, 'dog': 2, 'screen': 2, 'power': 2, '2': 2, 'preen': 2, 'thin': 2, 'spray': 2, 'omo': 2, 'tide': 2, 'apple': 2, 'itchy': 2, 'smooth': 2, 'instant': 2, 'touch': 2, 'antibacterial': 2, 'repellent': 2, 'earth': 2, 'quick': 1, 'sprinkles': 1, 'deluxe': 1, 'blue': 1, 'cef14': 1, 'expert': 1, 'cake': 1, 'double': 1, 'spa': 1, 'pro': 1, 'lyher': 1}

1, 'olia': 1, 'advanced': 1, 'pain': 1, 'preference': 1, 'complete': 1, 'cool': 1, 'forest': 1, 'monoi': 1, 'duo': 1, 'stone': 1, 'active': 1, 'washing': 1, 'daily': 1, 'insta': 1, 'naturals': 1, 'flick': 1, 'kid': 1, 'aspire': 1, 'bluey': 1, 'play': 1, 'soothing': 1, 'manipro': 1, '3in1': 1, 'ice': 1, 'baby': 1, 'g7': 1, 'mens': 1, 'uber': 1, 'nutrisse': 1, 'australia': 1, 'manuka': 1}
Price range: \$1.80 - \$45.00

Cluster 10:

Size: 101 products

Subcategories: {'electrical': 70, 'mixed': 19, 'hair treatments': 4, 'sauces': 3, 'shaving': 2, 'chips/crisps': 1, 'beans': 1, 'infant nappies': 1}

Brands: {'led': 22, 'light': 12, 'gls': 7, 'genio': 5, 'coppertop': 4, 'crunchy': 3, 'pasta': 3, 'globe': 3, 'brilliance': 3, 'excellence': 2, 'ultra': 2, 'olia': 2, 'mach3': 2, 'lithium': 2, 'warm': 2, 'round': 2, 'a23': 2, 'canned': 1, '2': 1, 'tuscan': 1, 'top': 1, 'no4': 1, 'soup': 1, 'specialty': 1, 'alkaline': 1, 'ed': 1, 'pilot': 1, 'globes': 1, 'watch': 1, 'medical': 1, 'march': 1, 'men': 1, 'good': 1, 'activated': 1, 'energy': 1, 'fusion': 1, 'nutrisse': 1, 'nice': 1, '101': 1, 'eco': 1}

Price range: \$2.00 - \$39.90

Cluster 11:

Size: 76 products

Subcategories: {'mixed': 23, 'supplements': 9, 'hair removal': 9, 'shaving': 6, 'hair treatments': 5, 'beer': 5, 'red wine': 3, 'liquor rtd': 3, 'infant nappies': 3, 'infant formula': 3, 'makeup': 2, 'drinks': 1, 'hardware': 1, 'specific vitamins': 1, 'cleansers': 1, 'serum': 1}

Brands: {'venus': 8, 'brilliance': 5, 'excellence': 4, 'cola': 3, 'preference': 3, 'sn2': 3, 'bin': 3, 'hydro': 3, 'super': 3, 'nappy': 3, 'effervescent': 2, 'live': 2, 'olia': 2, 'draught': 2, 'belly': 2, 'for': 2, 'magic': 2, 'fusion': 2, 'restore': 1, 'surprise': 1, 'powerade': 1, 'way': 1, '2010': 1, 'true': 1, 'caldk2': 1, 'colorstay': 1, 'nutrisse': 1, 'powder': 1, 'skinguuard': 1, 'labs': 1, 'proglide': 1, 'regenerist': 1, '2': 1, 'skinloving': 1, 'probiotic': 1, 'good': 1, '3in1': 1, 'kids': 1, 'nice': 1, 'natural': 1}

Price range: \$2.40 - \$172.00

Cluster 12:

Size: 115 products

Subcategories: {'kitchen needs/bags': 39, 'mixed': 33, 'dental floss': 10, 'electrical': 5, 'hair treatments': 5, 'first aid': 3, 'pain relief': 2, 'gum': 2, 'specific vitamins': 2, 'sunscreen': 2, 'dishwashing': 2, 'picnic pool bbq acc': 2, 'shaving': 1, 'hardware': 1, 'toothpaste': 1, 'energy/sport/icedtea': 1, 'serum': 1, 'conditioner': 1, 'makeup': 1, 'moisturiser': 1}

Brands: {'excellence': 7, 'extra': 6, 'cling': 6, 'light': 4, 'simply': 4, 'aluminium': 3, 'non': 3, 'greener': 3, '2': 2, 'clickzip': 2, 'alfoil': 2, 'square': 2, 'regenerist': 2, 'nonstick': 2, 'dental': 2, 'waxed': 2, 'nutrisse': 2, 'bbq': 2, 'vitamin': 2, 'round': 1, 'tartar': 1, 'twinzip': 1, '1st': 1, 'wrap': 1, 'veggie': 1, 'groovy': 1, 'seriously': 1, '3v': 1, 'large': 1}

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Price range: \$1.50 - \$70.00

Cluster 13:

Size: 5604 products

Subcategories: {'mixed': 2178, 'shampoo': 253, 'conditioner': 204, 'red wine': 184, 'beer': 140, 'liquor rtd': 130, 'white wine': 110, 'surface cleaners': 109, 'makeup': 109, 'body wash': 102, 'oils': 101, 'ice cream tubs': 99, 'grocery milk': 97, 'liquid soap': 84, 'deodorants': 76, 'sunscreen': 74, 'kitchenware': 70, 'cordials': 69, 'energy/sport/icedtea': 69, 'water': 68, 'dishwashing': 66, 'cleansers': 56, 'salad dressings': 55, 'moisturiser': 48, 'gravy/stock': 47, 'cold drink': 42, 'serum': 42, 'fruit juices': 42, 'mouthwash': 39, 'vinegar': 39, 'beauty/travel': 36, 'sparkling wine': 35, 'body lotion': 35, 'sauces': 34, 'better for you': 32, 'air fresheners': 30, 'whisky': 26, 'international foods': 23, 'gin': 23, 'lemonades': 21, 'nail care': 21, 'colas': 20, 'fruit drinks': 20, 'pest control': 20, 'hair treatments': 19, 'juices': 19, 'specific vitamins': 18, 'diffusers': 17, 'pain relief': 17, 'infant formula': 17, 'milk alternatives': 16, 'supplements': 15, 'desserts (gr)': 14, 'cold & flu': 14, 'dairy world foods': 13, 'hot sauces': 12, 'vodka': 11, 'shoe care': 11, 'value added fp': 11, 'auto': 10, 'tequila': 9, 'condiments': 9, 'pet accessories': 9, 'disposable tableware': 8, 'energy drinks': 8, 'marinades': 8, 'liquorland': 8, 'minerals': 8, 'shaving': 8, 'liqueurs': 7, 'picnic pool bbq acc': 6, 'spec/fresh cheese': 6, 'bleach & stain removers': 6, 'allergy': 6, 'first aid': 6, 'soft drinks': 5, 'baby lotions': 5, 'frozen': 4, 'rum': 4, 'seasonal events': 4, 'skincare cosmetics': 4, 'frozen world foods': 4, 'drinks': 4, 'brushware': 4, 'bonus credit products': 3, 'household': 3, 'frozen desserts': 3, 'milk additives': 3, 'seafood deli': 3, 'vegetable juices': 3, 'baby cereals': 2, 'masks': 2, 'kitchen needs/bags': 2, 'dairy, eggs & fridge': 2, 'gourmet cheese': 1, 'health & beauty': 1, 'chips, chocolates & snacks': 1, 'ground coffee': 1, 'sugar/sweeteners': 1, 'mexican foods': 1, 'noodles': 1, 'ironing': 1, 'multivitamins': 1, 'wet cat food': 1, 'hair styling': 1, 'toothbrush': 1, 'cat treats': 1, 'bird food': 1, 'soap bars': 1, 'spices': 1}

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Price range: \$0.85 - \$125.00

Cluster 14:

Size: 11665 products

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Price range: \$0.28 - \$135.00

Cluster 15:

Size: 61 products

Subcategories: {'mixed': 21, 'instore bread': 5, 'frozen desserts': 4, 'vinegar': 4, 'shaving': 4, 'bakery bought in': 3, 'white wine': 2, 'red wine': 2, 'serum': 2, 'makeup': 2, 'hair removal': 2, 'toothbrush': 2, 'bakery packaged cake': 1, 'sunscreen': 1, 'breakfast cereal': 1, 'nut butters': 1, 'electrical': 1, 'hair treatments': 1, 'easter': 1, 'toilet paper': 1}

Brands: {'fresh': 4, 'high': 3, 'bin': 3, 'im': 2, 'balsamic': 2, 'sweets': 2, 'xtreme': 2, 'hydro': 2, 'frozen': 2, 'silk': 2, 'aged': 2, 'chocolate': 1, 'by': 1, 'sun': 1, 'smunchy': 1, 'topping': 1, 'fun': 1, 'asia': 1, 'sensations': 1, 'io': 1, 'appliance': 1, 'regenerist': 1, 'sensor': 1, 'preference': 1, 'pro': 1, 'sense': 1, 'nordic': 1, '599': 1, 'fit': 1, 'pastry': 1, '3': 1, '2': 1, 'skincare': 1, '50': 1, 'lasting': 1, '100s': 1, 'excellence': 1, 'cold': 1, 'lasagne': 1, 'filled': 1, 'low': 1, 'act': 1, 'frz': 1, '1000': 1, 'brilliance': 1, 'olia': 1}

Price range: \$1.75 - \$99.50

Cluster 16:

Size: 88 products

Subcategories: {'mixed': 33, 'shaving': 20, 'instore cake': 7, 'hair removal': 4, 'infant formula': 3, 'toothbrush': 3, 'hair treatments': 3, 'frozen desserts': 3, 'toilet paper': 2, 'bakery snacks': 1, 'shampoo': 1, 'facial tissues': 1, 'electrical': 1, 'popcorn': 1, 'disposable tableware': 1, 'ice cream tubs': 1, 'cold & flu': 1, 'white wine': 1, 'beer': 1}

Brands: {'rapid': 5, 'silk': 4, 'fusion': 3, 'hydration': 3, 'apple': 3, 'original': 3, 'nice': 3, 'gold': 2, 'hydro': 2, 'pro': 2, 'assorted': 2, 'quattro': 2, '150mg': 2, 'hybrid': 2, 'mixed': 1, 'detection': 1, 'pops': 1, 'mini': 1, 'surprise': 1, 'popcorn': 1, 'creamy': 1, 'alkaline': 1, 'white': 1, 'king': 1, 'custard': 1, 'mango': 1, 'frozen': 1, 'lemon': 1, 'prov': 1, 'croissant': 1, 'ready': 1, 'creme': 1, 'dermo': 1, 'smooth': 1, 'blue': 1, 'mach3': 1, 'energy': 1, 'gummies': 1, '500mg': 1, 'cranberry': 1, 'good': 1, 'vitality': 1, 'orange': 1, 'eliminate': 1, 'sensitive': 1, '2': 1, 'brilliance': 1, '5': 1, 'follow': 1, 'for': 1, '6': 1, 'toddler': 1, 'mosquito': 1, 'beef': 1, 'jumbo': 1, 'infant': 1, 'bites': 1, 'sharer': 1, 'tasty': 1, 'pains': 1, 'baguette': 1, 'intimate': 1, 'bin': 1, 'dry': 1}

Price range: \$2.20 - \$90.00

Cluster 17:

Size: 1 products

Subcategories: {'mixed': 1}

Brands: {'grape': 1}

Price range: \$2.00 - \$2.00

Cluster 18:

Size: 3 products

Subcategories: {'red wine': 2, 'mixed': 1}

Brands: {'grange': 2, 'flying': 1}

Price range: \$508.00 - \$990.00

Cluster 19:

Size: 334 products

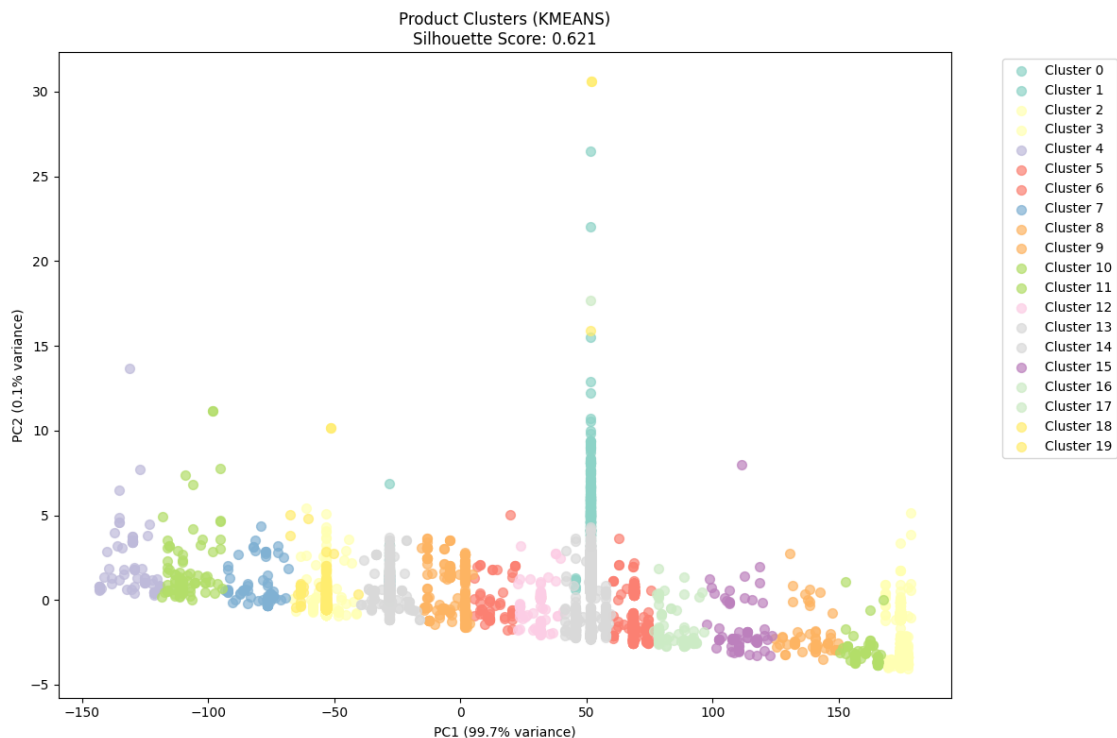
Subcategories: {'mixed': 205, 'brushware': 20, 'hair treatments': 17, 'seasonal events': 13, 'toothbrush': 13, 'pet accessories': 12, 'antip/olive/dip/pate': 9, 'pest control': 8, 'candles': 5, 'hardware': 5, 'beauty/travel': 3, 'health & beauty': 3, 'seafood deli': 2, 'hair removal': 2, 'bbq': 2, 'kitchenware': 2, 'air fresheners': 2, 'best buys': 2, 'auto': 2, 'shaving': 2, 'desserts (gr)': 1, 'electrical': 1, 'diffusers': 1, 'infant nappies': 1, 'shoe care': 1}

Brands: {'period': 14, 'bloody': 11, 'live': 10, 'total': 8, 'preference': 8, 'water': 7, 'by': 7, 'excellence': 6, 'brilliance': 6, 'casting': 5, 'mid': 5, 'the': 5, 'overnight': 4, 'easy': 4, 'vitality': 4, 'digital': 4, 'comfort': 4, 'blonde': 4, 'double': 4, 'womens': 4, 'peaceful': 3, 'thinx': 3, 'super': 3, 'for': 3, 'pro': 3, 'origins': 3, 'washable': 3, 'electric': 3, 'ezy': 2, 'venus': 2, 'root': 2, 'decolour': 2, 'colorstay': 2, 'face': 2, 'fusion': 2, 'skin': 2, 'precision': 2, 'magic': 2, 'olia': 2, 'quick': 2, 'aerosol': 2, 'classic': 2, 'blue': 2, 'wraps': 2, 'ultra': 2, 'command': 2, 'superswish': 2, 'scented': 2, 'oral': 2, 'soy': 2, 'teen': 2, 'expert': 2, 'intuition': 2,

'lash': 2, 'underwear': 2, 'salon': 2, 'permanent': 2, 'full': 2, 'large': 2, 'disney': 2, 'men': 2, 'powergard': 1, 'sense': 1, 'day': 1, 'gas': 1, 'grill': 1, 'pan': 1, 'pot': 1, 'umbrella': 1, 'signature': 1, 'mediterranean': 1, 'sweet': 1, 'artisan': 1, 'no': 1, 'black': 1, 'xl': 1, 'hydrate': 1, 'westloop': 1, 'food': 1, 'optic': 1, 'flip': 1, 'deli': 1, 'lobster': 1, 'pork': 1, 'snackers': 1, 'tritan': 1, 'snackbox': 1, 'to': 1, 'reusable': 1, 'hard': 1, 'travel': 1, 'saucer': 1, 'roll': 1, 'apron': 1, 'maker': 1, 'fruity': 1, 'container': 1, 'lightning': 1, 'micro': 1, 'mixed': 1, 'grab': 1, 'pro100': 1, 'anti': 1, 'labs': 1, 'naturgard': 1, 'xxl': 1, 'bear': 1, 'squishies': 1, 'with': 1, 'bento': 1, 'domed': 1, 'moroccan': 1, 'battery': 1, 'jumbo': 1, 'indoor': 1, 'antibacterial': 1, 'caribbean': 1, 'pillar': 1, 'silicone': 1, 'nordic': 1, 'tools': 1, 'beard': 1, 'silver': 1, 'hydro': 1, 'heat': 1, 'all': 1, 'plus': 1, 'mach3': 1, 'mini': 1, 'gel': 1, 'gemtip': 1, 'hair': 1, 'vanilla': 1, 'hooks': 1, 'automatic': 1, 'sippy': 1, 'munch': 1, 'lunch': 1, 'silicon': 1, 'flexipen': 1, 'baby': 1, 'extra': 1, 'nice': 1, 'white': 1, 'paddle': 1, 'freeze': 1, 'good': 1, 'grooming': 1, 'organix': 1, '5': 1, 'chamois': 1, 'socks': 1, 'uptown': 1, 'elements': 1, 'espresso': 1, 'jasmine': 1, 'vet': 1, '454': 1, 'castings': 1, 'dustpan': 1, 'fresh': 1, 'toilet': 1, 'compact': 1, 'whoopsies': 1, 'flight': 1, 'french': 1, 'clean': 1, 'sneaker': 1, 'premium': 1, 'pedi': 1, 'cushion': 1, 'gold': 1, 'auto': 1, 'clipper': 1, 'set': 1, 'chocolate': 1, 'crystal': 1, 'body': 1, 'gua': 1, 'liver': 1, 'dogwood': 1}

Price range: \$11.00 - \$160.00

=====



Finding Alternatives for Individual Products:

Product: coles hot cross buns traditional fruit (Code: 8371390)

Found 5 cheaper alternatives:

1. swisspers cotton tips paperstems
Price: \$1.10 (Save \$1.90, 63.3%)
Brand: swisspers (branded)
2. peanut butter cups milk chocolate
Price: \$1.25 (Save \$1.75, 58.3%)
Brand: peanut (branded)
3. peanut butter cup white
Price: \$1.25 (Save \$1.75, 58.3%)
Brand: peanut (branded)
4. cup a soup creamy mushroom with croutons
Price: \$1.40 (Save \$1.60, 53.3%)
Brand: cup (branded)
5. sesame snaps
Price: \$1.50 (Save \$1.50, 50.0%)
Brand: sesame (branded)

Product: coles hot cross buns traditional fruit mini (Code: 5726070)

Found 5 cheaper alternatives:

1. swisspers cotton tips paperstems
Price: \$1.10 (Save \$1.90, 63.3%)
Brand: swisspers (branded)
2. peanut butter cups milk chocolate
Price: \$1.25 (Save \$1.75, 58.3%)
Brand: peanut (branded)
3. peanut butter cup white
Price: \$1.25 (Save \$1.75, 58.3%)
Brand: peanut (branded)
4. cup a soup creamy mushroom with croutons
Price: \$1.40 (Save \$1.60, 53.3%)
Brand: cup (branded)
5. sesame snaps
Price: \$1.50 (Save \$1.50, 50.0%)
Brand: sesame (branded)

=====

Cart Optimization Demo:

Original cart total: \$17.70

Optimized cart total: \$1.66

Total savings: \$16.04 (90.6%)

Items with alternatives: 3/3

Detailed Recommendations:

coles hot cross buns traditional fruit (\$3.00)

→ Recommended: swisspers cotton tips paperstems

Price: \$1.10 (Save \$1.90)

cadbury dairy milk chocolate easter egg hunt carton (\$8.00)

→ Recommended: okra loose

Price: \$0.28 (Save \$7.72)

cadbury dairy milk easter chocolate eggs bag (\$6.70)

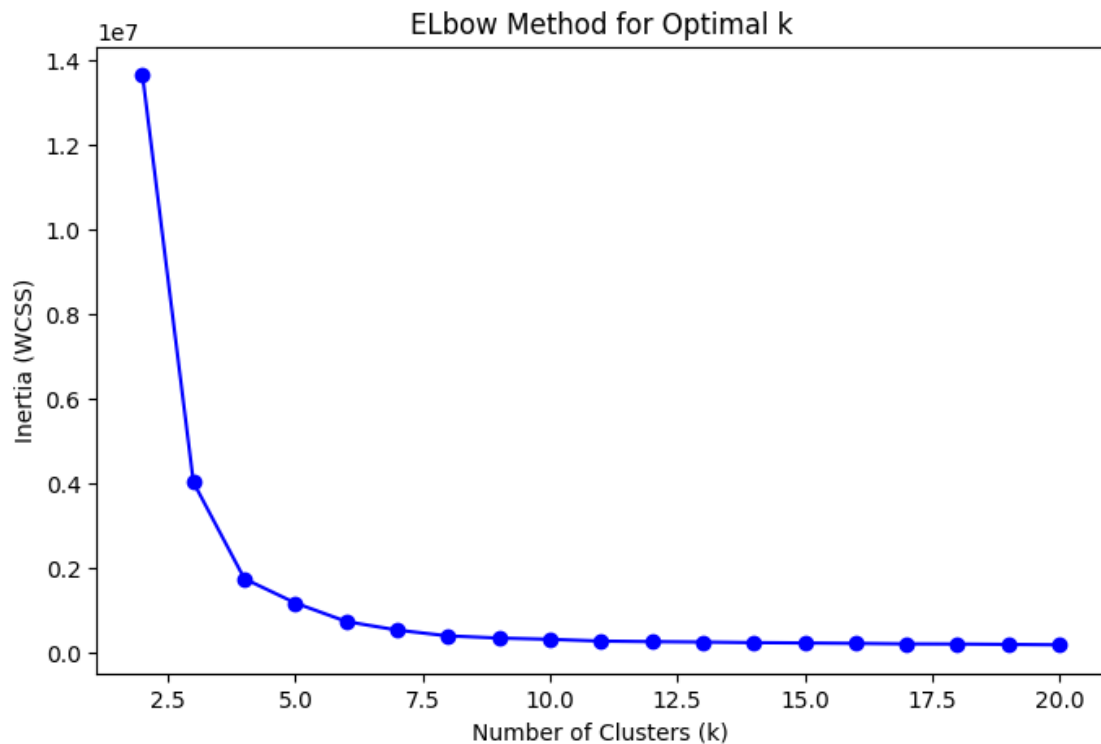
→ Recommended: okra loose

Price: \$0.28 (Save \$6.42)

- The Silhouette Score is approximately 0.621 an average value.
- Product alternative suggestions are not great.

1.2.2 Find Optimal K

```
[ ]: optimizer = ProductClusteringOptimizer(  
    clustering_method='kmeans',  
    n_clusters=20 # Small number for demo  
)  
optimizer.prepare_features(data)  
optimizer.plot_elbow_method(max_k=20)
```



It is clear that the optimal number of clusters is observed at $k = 4$.

```
[ ]: # fit kmeans with optimal clusters
optimizer = ProductClusteringOptimizer(
    clustering_method='kmeans',
    n_clusters=4
)
optimizer.prepare_features(data)
optimizer.fit()

# Show cluster quality metrics
metrics = optimizer.get_cluster_quality_metrics()
print(f"Clustering Quality Metrics:")
print(f"- Silhouette Score: {metrics['silhouette_score']:.3f}")
print(f"- Number of Clusters: {metrics['n_clusters']}")
print(f"- Average Cluster Size: {metrics['avg_cluster_size']:.1f}")
print("\n" + "="*80 + "\n")

# Analyze clusters
print("Cluster Analysis:")
for cluster_id in sorted(optimizer.df['cluster'].unique()):
    if cluster_id >= 0: # Skip noise points
        analysis = optimizer.analyze_cluster(cluster_id)
        print(f"\nCluster {cluster_id}:")
        print(f"  Size: {analysis['size']} products")
        print(f"  Subcategories: {analysis['subcategories']}")
        print(f"  Brands: {analysis['brands']}")
        print(f"  Price range: ${analysis['price_range']['min']:.2f} -
↳ ${analysis['price_range']['max']:.2f}")

print("\n" + "="*80 + "\n")

optimizer.visualize_clusters()

print("Cart Optimization Demo:")
sample_cart = [8371390, 7107738, 4885191, 7107738, 229828, 1167759, 3959190,
↳ 8086371] # Sample cart
cart_results = optimizer.optimize_cart(sample_cart)

print(f"Original cart total: ${cart_results['original_total']:.2f}")
print(f"Optimized cart total: ${cart_results['optimized_total']:.2f}")
print(f"Total savings: ${cart_results['total_savings']:.2f}
↳ ({cart_results['savings_percentage']:.1f}%)")
print(f"Items with alternatives: {cart_results['items_with_alternatives']}/
↳ {cart_results['total_items']}")
```

```

print("\nDetailed Recommendations:")
for product_code, rec in cart_results['recommendations'].items():
    print(f"\n{rec['original_name']} (${rec['original_price']:.2f})")
    if rec['best_alternative']:
        alt = rec['best_alternative']
        print(f"    → Recommended: {alt['name']}")
        print(f"    Price: ${alt['original_price']:.2f} (Save ${alt['savings']:.2f})")
    else:
        print(f"    → No cheaper alternatives found")

substitution_df = optimizer.substitution_summary(cart_results)
print(substitution_df)

```

Clustering Quality Metrics:

- Silhouette Score: 0.857
- Number of Clusters: 4
- Average Cluster Size: 5933.8

=====

Cluster Analysis:

Cluster 0:

Size: 7301 products

Subcategories: {'mixed': 2718, 'shampoo': 255, 'conditioner': 205, 'red wine': 188, 'beer': 186, 'ice cream tubs': 173, 'liquor rtd': 173, 'makeup': 119, 'white wine': 114, 'surface cleaners': 111, 'body wash': 102, 'oils': 101, 'grocery milk': 99, 'liquid soap': 84, 'sunscreen': 77, 'deodorants': 76, 'whisky': 72, 'kitchenware': 71, 'energy/sport/icedtea': 70, 'cordials': 69, 'dishwashing': 68, 'water': 68, 'cleansers': 57, 'bread rolls & fbread': 57, 'salad dressings': 55, 'moisturiser': 55, 'bakery packaged cake': 53, 'eggs': 52, 'serum': 52, 'gravy/stock': 47, 'vinegar': 43, 'gin': 43, 'cold drink': 42, 'fruit juices': 42, 'kitchen needs/bags': 41, 'mouthwash': 39, 'hair treatments': 39, 'sparkling wine': 38, 'beauty/travel': 37, 'desserts (gr)': 35, 'body lotion': 35, 'sauces': 34, 'shaving': 33, 'better for you': 32, 'air fresheners': 31, 'international foods': 30, 'liquorland': 27, 'chocolate': 25, 'instore cake': 25, 'tea bags': 24, 'frozen desserts': 24, 'bakery snacks': 24, 'tequila': 23, 'lemonades': 21, 'instant noodles': 21, 'infant formula': 21, 'nail care': 21, 'pest control': 20, 'specific vitamins': 20, 'fruit drinks': 20, 'colas': 20, 'pain relief': 19, 'juices': 19, 'mexican foods': 18, 'vodka': 18, 'cold & flu': 17, 'liqueurs': 17, 'diffusers': 17, 'biscuits': 17, 'protein snacks': 17, 'supplements': 17, 'milk alternatives': 16, 'canned meals': 16, 'chips/crisps': 16, 'black tea': 15, 'bakery bought in': 14, 'shoe care': 13, 'frozen world foods': 13, 'dairy world foods': 13, 'hot sauces': 12, 'rum': 12, 'value added fp': 11, 'noodles': 11, 'pet accessories': 11, 'green tea': 10, 'dental floss': 10, 'auto': 10, 'disposable tableware': 9, 'picnic pool bbq

acc': 9, 'first aid': 9, 'easter': 9, 'fruit-shelf stable': 9, 'condiments': 9, 'frozen': 8, 'boxed chocolates': 8, 'minerals': 8, 'energy drinks': 8, 'marinades': 8, 'gum': 8, 'chilled healthfoods': 7, 'health & beauty': 7, 'milk additives': 7, 'bakery': 6, 'bleach & stain removers': 6, 'electrical': 6, 'processed cheese': 6, 'pods & capsules': 6, 'hair removal': 6, 'allergy': 6, 'toothbrush': 6, 'frozen finger foods': 6, 'spec/fresh cheese': 6, 'dairy, eggs & fridge': 6, 'cookies': 6, 'hot cereal': 6, 'protein bars': 5, 'herbal tea': 5, 'household': 5, 'bonus credit products': 5, 'baby lotions': 5, 'breakfast cereal': 5, 'popcorn': 5, 'dried fruit/nuts': 5, 'instore bread': 5, 'soft drinks': 5, 'dietary & world foods': 5, 'seasonal events': 5, 'lamb': 5, 'drinks': 4, 'bbq meat': 4, 'pantry': 4, 'skincare cosmetics': 4, 'brushware': 4, 'frozen vegetables': 4, 'chips, chocolates & snacks': 3, 'vegetable juices': 3, 'cat treats': 3, 'canned veg': 3, 'prepackaged seafood': 3, 'bought in seasonal': 3, 'seafood deli': 3, 'infant nappies': 3, "footy's back": 2, 'wet dog food': 2, 'rice': 2, 'entertainment': 2, 'beef': 2, 'smallgoods dy': 2, 'baby cereals': 2, 'sausages': 2, 'masks': 2, 'toilet paper': 2, 'facial tissues': 2, 'mints': 2, 'soap bars': 2, 'gourmet cheese': 2, 'trail mix': 1, 'toothpaste': 1, 'gluten free': 1, 'cream cheese': 1, 'antip/olive/dip/pate': 1, 'chocolate spreads': 1, 'citrus': 1, 'ground coffee': 1, 'sugar/sweeteners': 1, 'nut butters': 1, 'frozen appetizers': 1, 'multivitamins': 1, 'hardware': 1, 'ironing': 1, 'hair styling': 1, 'bird food': 1, 'dog treats': 1, 'wet cat food': 1, 'bh bought in easter': 1, 'sardines': 1, 'cheesecake': 1, 'spices': 1, 'diapers': 1}

Brands: {'ultra': 89, 'extra': 86, 'organic': 75, 'zero': 73, 'frozen': 66, 'men': 59, 'pinot': 55, 'body': 54, 'ice': 54, 'original': 51, 'apple': 50, 'lemon': 50, 'naturals': 48, 'premium': 45, 'chocolate': 44, 'paris': 43, 'mini': 42, 'energy': 41, 'orange': 41, 'shampoo': 40, 'classic': 40, 'pure': 40, 'elvive': 39, 'conditioner': 35, 'fructis': 34, 'dairy': 34, 'natural': 34, 'white': 33, 'light': 33, 'simply': 33, 'sparkling': 32, 'no': 31, 'deo': 31, 'dry': 30, 'antibacterial': 29, 'double': 29, 'blue': 28, 'free': 27, 'laundry': 27, 'daily': 27, 'cordial': 27, 'gold': 27, 'lactose': 26, 'vanilla': 26, 'hand': 26, 'soft': 25, 'spf': 25, 'luminous': 25, 'coconut': 25, 'protein': 25, 'super': 25, 'rose': 25, 'iced': 25, 'baby': 24, '100': 23, 'fruit': 23, 'full': 23, 'fresh': 23, 'shiraz': 23, 'low': 22, 'vitamin': 21, 'creamy': 21, 'estate': 21, 'colorstay': 21, 'skin': 21, 'kombucha': 21, 'mango': 20, 'bio': 20, 'so': 20, 'black': 20, 'revitalift': 19, 'the': 19, 'tropical': 19, 'miracles': 19, 'prosecco': 18, 'japanese': 18, 'ginger': 18, 'fit': 18, 'cabernet': 18, 'advanced': 18, 'all': 17, 'chardonnay': 17, 'gluten': 17, 'liquid': 17, 'watermelon': 17, 'strawberry': 16, 'soy': 16, 'sweet': 16, 'instant': 16, 'food': 16, 'high': 16, 'v8': 15, 'asia': 15, 'cola': 15, '2': 15, 'milk': 15, 'real': 15, 'oat': 15, 'australian': 15, 'sauvignon': 15, 'sports': 14, 'red': 14, 'professional': 14, 'dishwashing': 14, 'moisturising': 14, 'juice': 14, 'tomato': 13, 'lime': 13, 'grape': 13, 'max': 13, 'frizz': 13, 'skincare': 13, 'sun': 13, 'multipurpose': 13, 'foaming': 13, 'klip': 13, 'cold': 13, 'women': 13, 'lightly': 13, 'shower': 13, 'eucalyptus': 13, 'signature': 13, 'non': 13, 'green': 13, 'unsweetened': 12, 'drumstick': 12, 'nut': 12, 'brut': 12, 'hydrating': 12, 'smooth': 12, 'vodka': 12, 'regular': 12, 'chill': 12, 'lite': 12, 'kids': 12, 'plus': 12, 'fragrance': 12, 'concentrate': 12, 'aloe': 12,

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'disinfectant': 5, 'cookies': 5, 'superstay': 5, 'vent': 5, 'zavance': 5,
'thickened': 5, 'barn': 5, 'preference': 5, 'mouthwash': 5, 'purple': 5,
'freshburst': 5, 'lamellar': 5, 'canned': 5, 'sunscreen': 5, 'easy': 5,
'carrot': 5, 'ultimate': 5, 'thirst': 5, 'peach': 5, 'squeeze': 5, 'salt': 5,
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Price range: \$0.85 - \$990.00

Cluster 1:

Size: 12044 products

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Price range: \$0.28 - \$135.00

Cluster 2:

Size: 820 products

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Price range: \$1.40 - \$99.50

Cluster 3:

Size: 3570 products

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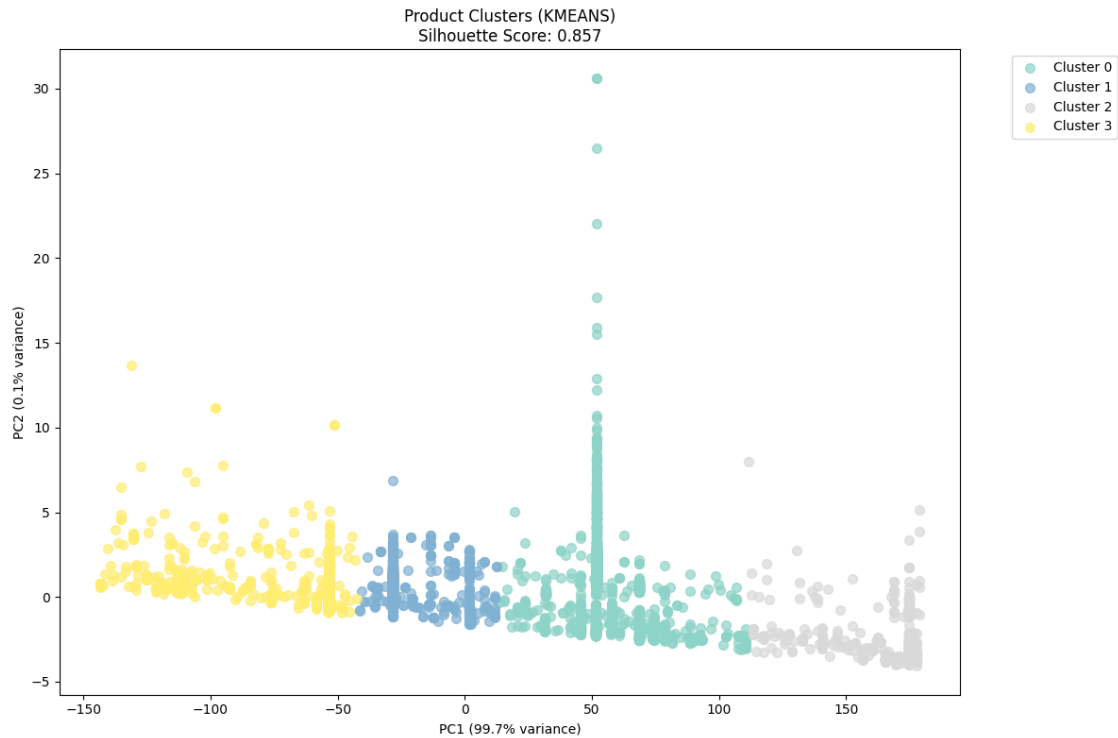
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 'tile': 1, 'mommy': 1, 'drawtight': 1, 'intimate': 1, 'artificial': 1, 'ibs': 1,
 '454': 1, 'klip': 1, 'damper': 1, 'pancakes': 1, 'vegemite': 1, 'britecrawlers':
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 'spiderman': 1, 'whoopsies': 1, 'blue3': 1, '3in1': 1, 'neck': 1, 'cream': 1,
 'banh': 1, 'fairy': 1, 'kit': 1, 'beetroot': 1, 'pineapple': 1, 'snake': 1,
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 'papaya': 1, 'castings': 1, 'brow': 1, '1859': 1, 'powerade': 1, 'cadbury': 1,
 'elastomer': 1, 'c3': 1, 'steel': 1, 'red': 1, 'mount': 1, 'toilet': 1,
 'dustpan': 1, 'pouch': 1, 'mint': 1, 'piccadilly': 1, 'sandalwood': 1,
 'chamomile': 1, 'banoffee': 1, 'felt': 1, 'champagne': 1, 'peg': 1,
 'entertaining': 1, 'fluffy': 1, 'slogan': 1, 'gliitter': 1, '7inch': 1,
 'restful': 1, 'gua': 1, 'sapphire': 1, 'sponge': 1, 'body': 1, 'crystal': 1,
 'sectioning': 1, 'scissor': 1, 'sourdough': 1, 'click': 1, 'clear': 1,

```
'17026clr': 1, 'hook': 1, 'salt': 1, 'best': 1, 'joint': 1, 'turbo': 1,
'quality': 1, 'lengthening': 1, 'pedi': 1, 'flexiglide': 1, 'napkins': 1,
'storage': 1, 'balloon': 1}
Price range: $0.50 - $172.00
```

=====



Cart Optimization Demo:

Original cart total: \$61.50

Optimized cart total: \$23.45

Total savings: \$38.05 (61.9%)

Items with alternatives: 7/8

Detailed Recommendations:

coles hot cross buns traditional fruit (\$3.00)

→ Recommended: chocolate easter bunnies

Price: \$2.45 (Save \$0.55)

cadbury dairy milk chocolate easter egg hunt carton (\$8.00)

→ Recommended: easter fried eggs and bunnies gummies

Price: \$2.50 (Save \$5.50)

cadbury dairy milk easter chocolate eggs bag (\$6.70)
 → Recommended: easter fried eggs and bunnies gummies
 Price: \$2.50 (Save \$4.20)

ferrero rocher chocolate gift box (\$9.00)
 → Recommended: founr twenty frozen meat pies
 Price: \$4.50 (Save \$4.50)

sensodyne repair protect toothbrush (\$3.00)
 → No cheaper alternatives found

maybelline lash sensational sky high washable mascara blackest black (\$17.50)
 → Recommended: sensodyne repair protect toothbrush
 Price: \$3.00 (Save \$14.50)

sensodyne soft daily care toothbrush (\$6.30)
 → Recommended: sensodyne repair protect toothbrush
 Price: \$3.00 (Save \$3.30)

	original_code	original_name	original_price	\
0	8371390	coles hot cross buns traditional fruit	3.0	

	alt_code	alt_name	alt_price	savings	savings_pct
0	8805864	chocolate easter bunnies	2.45	0.55	18.333333

- The clustering quality (Silhouette Score) has improved: 0.85
- Product alternative suggestion are much better than the previous model.
- However, products that have categories and subcategories such as seasonal events, ‘Easter’, ‘Footy’s back’ etc. appears to have incorrect product alternatives.

Improvement suggestions:

- Define subcategories more

```
[ ]: import json

with open("subcategories_map.json", "r", encoding="utf-8") as f:
    category_dict = json.load(f)
```

```
[ ]: category_dict = {k.lower(): v for k, v in category_dict.items()}
```

```
[ ]: def get_subcategory(product_name, category, current_subcat):
    keywords_dict = category_dict.get(category, {})
    if keywords_dict:
        pname = product_name.lower()
        for keyword, subcat in keywords_dict.items():
            if keyword in pname:
                return subcat.lower()
    # return the current subcategory if no match
```

```
return current_subcat
```

```
[ ]: data["new_subcategory"] = data.apply(
    lambda row: get_subcategory(row["name"], row["category"],
    row["subcategory"]), axis=1
)
```

```
[ ]: data[data['category'] == 'hair care']
```

```
[ ]:
    product_code      name      brand \
175      1256826      medium brunette dry shampoo      medium
176      1256860  summer fruits berries cherry dry shampoo      summer
177      1331342      floral flirty blush dry shampoo      floral
178      1331353      coconut exotic tropical dry shampoo      coconut
205      2319273      divine dark brown dry shampoo plus      divine
...
24156      5259600      olia b max bleach      olia
24157      5500601      olia hair colour 80 blonde      olia
24158      5272074      semi permanent rose hair colour      semi
24159      5272100      semi permanent turquoise hair colour      semi
24168      3593656      elastomer ponytailer      elastomer

    brand_tier  category      subcategory  original_price  sale_price \
175      branded  hair care      shampoo      14.0      10.0
176      branded  hair care      shampoo      14.0      10.0
177      branded  hair care      shampoo      14.0      10.0
178      branded  hair care      shampoo      14.0      10.0
205      branded  hair care      shampoo      17.0      10.0
...
24156      branded  hair care      mixed      22.0      11.0
24157      branded  hair care  hair treatments      22.0      11.0
24158      branded  hair care  hair treatments      0.0      10.0
24159      branded  hair care  hair treatments      0.0      10.0
24168      branded  hair care      mixed      0.0      4.5

    std_item_size  std_item_size_unit  item_size  price_per_unit  unit_type \
175      280.0      ml      280.0      0.05      ml
176      280.0      ml      280.0      0.05      ml
177      280.0      ml      280.0      0.05      ml
178      280.0      ml      280.0      0.05      ml
205      340.0      ml      340.0      0.05      ml
...
24156      2.0      each      2.0      11.00      each
24157      8.0      blonde      2.0      11.00      each
24158      1.0      each      1.0      10.00      each
24159      1.0      each      1.0      10.00      each
24168      1.0      each      1.0      0.09      each
```

	new_subcategory
175	shampoo
176	shampoo
177	shampoo
178	shampoo
205	shampoo
...	...
24156	hair colour
24157	hair colour
24158	hair colour
24159	hair colour
24168	mixed

[1055 rows x 14 columns]

```
[ ]: data['category'].unique()
```

```
[ ]: array(['easter', 'footy's back', 'bonus credit products',
'meat & seafood', 'fruit & vegetables', 'dairy, eggs & fridge',
'bakery', 'deli', 'pantry', 'dietary & world foods',
'chips, chocolates & snacks', 'drinks', 'frozen', 'household',
'health & beauty', 'cheese dairy', 'medicinal products',
'sanitary protection', 'spreads', 'infant food', 'meals',
'bakery packaged cake', 'protein & meals', 'picnic pool bbq acc',
'continental', 'aircare', 'frozen desserts', 'hair care',
'spices/herbs', 'chilled desserts', 'international foods',
'cleaning goods', 'chilled spreads', 'softdrinks',
'instant noodles', 'meal bases', 'poultry (mt)', 'snacks',
'seafood deli', 'bread rolls & fbread', 'infant personal',
'sauces/relish', 'apples & pears', 'value added fp',
'smallgoods dy', 'desserts (gr)', 'juices/drinks',
'pickled vegetables', 'gourmet cheese', 'kitchen needs/bags',
'pork', 'paper towels', 'rice', 'biscuits & cookies', 'water',
'instore bread', 'nutritional snacks', 'facial tissues',
'health foods', 'spec/fresh cheese', 'frozen world foods',
'chilled healthfoods', 'canned fish', 'mens deos & grooming',
'lamb', 'grocery milk', 'ready to eat protein', 'soup',
'dishwashing', 'bbq meat', 'cereal', 'homewares',
'beauty/trial travel', 'coffee', 'frozen seafood', 'tea', 'beef',
'bars gum pocket pack', 'instore cake', 'womens deos & groom',
'ice cream', 'toilet paper', 'frozen snacks', 'convenience meals',
'vitamins', 'dog food', 'juices & cordials', 'shoe care', 'pasta',
'laundry accessories', 'infant nappies', 'frozen vegetables',
'entertainment', 'dried fruit/nuts', 'canned veg',
'soaps & body wash', 'dental health', 'bakery snacks',
'kitchenware', 'kiwi fruit', 'indian foods', 'skin care',
```



```
'value added', 'asian foods', 'avocado & mango', 'citrus',
'bunch lines', 'mexican foods', 'canned meals', 'sliced meats',
'confectionery', 'fruit-shelf stable', 'nuts/dried',
'salad dressings', 'smoked & cured fish', 'bakery bought in',
'disposable tableware', 'pest control', 'poultry (dl)',
'smallgoods', 'vine vegetables', 'soft vegetables', 'tomatoes',
'eggs', 'laundry', 'cold drink', 'dy milk', 'boxed chocolates',
'cat food', 'flour', 'prepackaged seafood', 'oils', 'game',
'herbs & chillies', 'cherries', 'hard vegetables', 'potatoes',
'organic fruit & veg', 'mushrooms', 'melons & tropical', 'melons',
'berries & cherries', 'bananas', 'grapes', 'antip/olive/dip/pate',
'grab & go', 'pies and quiches', 'milk additives',
'bought in seasonal', 'bbq', 'dl prepared foods', 'gravy/stock',
'sugar/sweeteners', 'baking mixes', 'vinegar', 'better for you',
'beer', 'spirits', 'infant formula', 'wine',
'energy/sport/icedtea', 'fresh pet food dy', 'liquor rtd',
'christmas gr food', 'electrical', 'brushware', 'household gloves',
'hardware', 'auto', 'seasonal events', 'best buys', 'party goods',
'cosmetics/toiletries', 'pet accessories', 'bird food',
'liquorland', 'bh bought in easter', 'pet food', 'stone fruit',
'bakery easter', 'sausages', 'organic meat', 'hams',
'dairy world foods'], dtype=object)
```

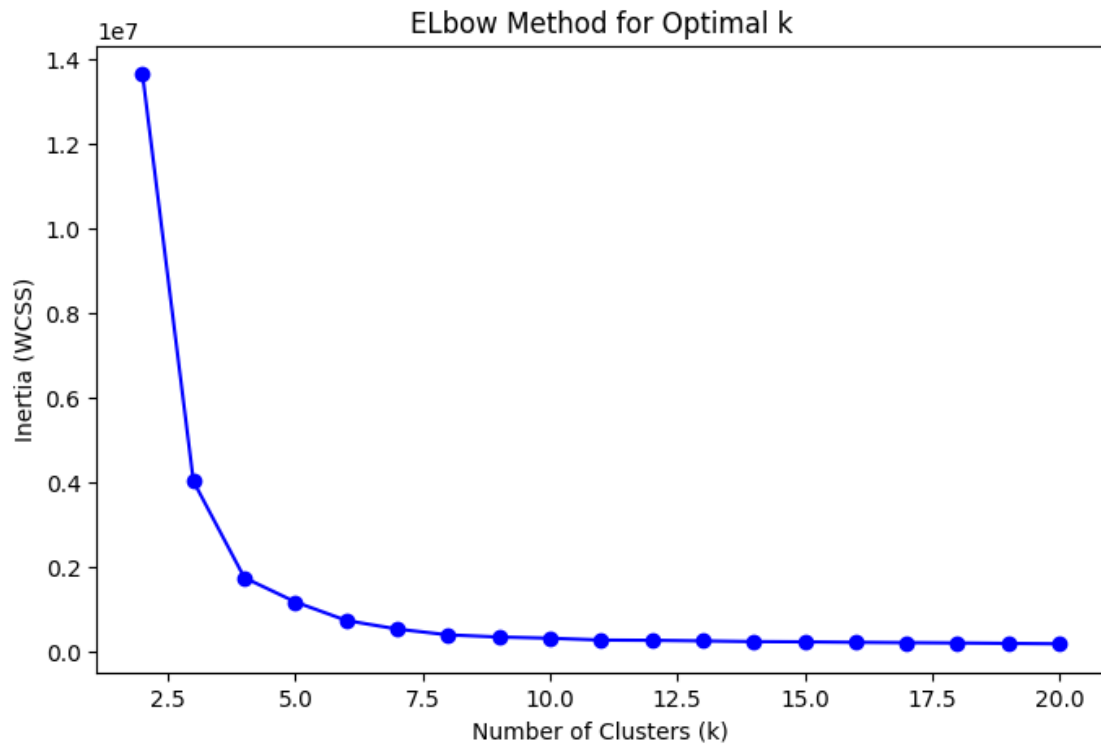
```
[ ]: category_dict.get('seasonal events', {})
```

```
[ ]: {'afl ball': 'Card Game',
      'afl game': 'Card Game',
      'lazy susan pantry tray': 'Food Storage',
      'portion freezer pods': 'Food Storage',
      'prep storage box with 6 dividers and lid': 'Food Storage',
      'freezer pod': 'Food Storage',
      'asparagus keeper': 'FoodStorage',
      'saver container': 'Food Storage',
      'saver': 'Food Storage',
      'notebook': 'Stationery',
      'dish': 'Kitchenware',
      'jug': 'Kitchenware',
      'crew sports socks': 'Apparel',
      'carlton': 'Team Merchandise',
      'eels': 'Team Merchandise'}
```

```
[ ]: category_dict.keys()
```

```
[ ]: dict_keys(['hair care', 'kitchenware', 'stationery', 'hosiery', 'easter',
               'household appliances', 'meat & seafood', 'seasonal events', 'shoe care',
               'family socks', 'hardware'])
```

```
[ ]: optimizer = ProductClusteringOptimizer(
    clustering_method='kmeans',
    n_clusters=20 # Small number for demo
)
optimizer.prepare_features(data)
optimizer.plot_elbow_method(max_k=20)
```



```
[ ]: # fit kmeans with optimal clusters
optimizer = ProductClusteringOptimizer(
    clustering_method='kmeans',
    n_clusters=4
)
optimizer.prepare_features(data)
optimizer.fit()

# Show cluster quality metrics
metrics = optimizer.get_cluster_quality_metrics()
print(f"Clustering Quality Metrics:")
print(f"- Silhouette Score: {metrics['silhouette_score']:.3f}")
print(f"- Number of Clusters: {metrics['n_clusters']}")
print(f"- Average Cluster Size: {metrics['avg_cluster_size']:.1f}")
print("\n" + "="*80 + "\n")
```

```

# Analyze clusters
print("Cluster Analysis:")
for cluster_id in sorted(optimizer.df['cluster'].unique()):
    if cluster_id >= 0: # Skip noise points
        analysis = optimizer.analyze_cluster(cluster_id)
        print(f"\nCluster {cluster_id}:")
        print(f"  Size: {analysis['size']} products")
        print(f"  Subcategories: {analysis['subcategories']}")
        print(f"  Brands: {analysis['brands']}")
        print(f"  Price range: ${analysis['price_range']['min']:.2f} -
↳ ${analysis['price_range']['max']:.2f}")

print("\n" + "="*80 + "\n")

optimizer.visualize_clusters()

# Demo cart optimization
print("Cart Optimization Demo:")
sample_cart = [8371390, 7107738, 4885191, 7107738, 229828, 1167759, 3959190,
↳ 8086371] # Sample cart
cart_results = optimizer.optimize_cart(sample_cart)

print(f"Original cart total: ${cart_results['original_total']:.2f}")
print(f"Optimized cart total: ${cart_results['optimized_total']:.2f}")
print(f"Total savings: ${cart_results['total_savings']:.2f}
↳ ({cart_results['savings_percentage']:.1f}%)")
print(f"Items with alternatives: {cart_results['items_with_alternatives']}/
↳ {cart_results['total_items']}")

print("\nDetailed Recommendations:")
for product_code, rec in cart_results['recommendations'].items():
    print(f"\n{rec['original_name']} (${rec['original_price']:.2f})")
    if rec['best_alternative']:
        alt = rec['best_alternative']
        print(f"  → Recommended: {alt['name']}")
        print(f"    Price: ${alt['original_price']:.2f} (Save ${alt['savings']:.
↳ 2f})")
    else:
        print(f"  → No cheaper alternatives found")

substitution_df = optimizer.substitution_summary(cart_results)
print(substitution_df)

```

Clustering Quality Metrics:

- Silhouette Score: 0.857
- Number of Clusters: 4

- Average Cluster Size: 5933.8

=====
Cluster Analysis:

Cluster 0:

Size: 7301 products

Subcategories: {'mixed': 2605, 'shampoo': 255, 'conditioner': 206, 'red wine': 188, 'beer': 186, 'liquor rtd': 173, 'ice cream tubs': 173, 'makeup': 119, 'white wine': 114, 'surface cleaners': 111, 'body wash': 102, 'oils': 101, 'grocery milk': 99, 'liquid soap': 84, 'sunscreen': 77, 'deodorants': 76, 'whisky': 72, 'energy/sport/icedtea': 70, 'cordials': 69, 'dishwashing': 68, 'water': 68, 'food storage': 67, 'bread rolls & fbread': 57, 'cleansers': 57, 'moisturiser': 55, 'salad dressings': 55, 'bakery packaged cake': 53, 'eggs': 52, 'serum': 52, 'hair treatments': 52, 'gravy/stock': 47, 'styling products': 43, 'vinegar': 43, 'hair colour': 43, 'gin': 43, 'cold drink': 42, 'fruit juices': 42, 'kitchen needs/bags': 41, 'mouthwash': 39, 'sparkling wine': 38, 'beauty/travel': 37, 'desserts (gr)': 35, 'body lotion': 35, 'sauces': 34, 'shaving': 33, 'better for you': 32, 'air fresheners': 31, 'international foods': 30, 'liquorland': 27, 'chocolate': 27, 'instore cake': 25, 'tea bags': 24, 'frozen desserts': 24, 'bakery snacks': 24, 'tequila': 23, 'infant formula': 21, 'instant noodles': 21, 'lemonades': 21, 'nail care': 21, 'pest control': 20, 'colas': 20, 'fruit drinks': 20, 'specific vitamins': 20, 'pain relief': 19, 'juices': 19, 'mexican foods': 18, 'vodka': 18, 'liqueurs': 17, 'cold & flu': 17, 'diffusers': 17, 'protein snacks': 17, 'biscuits': 17, 'supplements': 17, 'milk alternatives': 16, 'canned meals': 16, 'chips/crisps': 16, 'black tea': 15, 'bakery bought in': 14, 'frozen world foods': 13, 'dairy world foods': 13, 'rum': 12, 'hot sauces': 12, 'value added fp': 11, 'noodles': 11, 'pet accessories': 11, 'green tea': 10, 'auto': 10, 'shoe care': 10, 'dental floss': 10, 'picnic pool bbq acc': 9, 'condiments': 9, 'disposable tableware': 9, 'fruit-shelf stable': 9, 'first aid': 9, 'gum': 8, 'frozen': 8, 'boxed chocolates': 8, 'marinades': 8, 'minerals': 8, 'energy drinks': 8, 'health & beauty': 7, 'milk additives': 7, 'chilled healthfoods': 7, 'hot cereal': 6, 'allergy': 6, 'beauty & nail care': 6, 'toothbrush': 6, 'electrical': 6, 'pods & capsules': 6, 'hair removal': 6, 'processed cheese': 6, 'cookies': 6, 'spec/fresh cheese': 6, 'dairy, eggs & fridge': 6, 'bakery': 6, 'frozen finger foods': 6, 'bleach & stain removers': 6, 'herbal tea': 5, 'protein bars': 5, 'seasonal events': 5, 'instore bread': 5, 'household': 5, 'soft drinks': 5, 'breakfast cereal': 5, 'dried fruit/nuts': 5, 'bonus credit products': 5, 'lamb': 5, 'popcorn': 5, 'hair accessories': 5, 'baby lotions': 5, 'dietary & world foods': 5, 'frozen vegetables': 4, 'drinks': 4, 'easter': 4, 'pantry': 4, 'bbq meat': 4, 'skincare cosmetics': 4, 'brushware': 4, 'seafood deli': 3, 'chips, chocolates & snacks': 3, 'bought in seasonal': 3, 'prepackaged seafood': 3, 'cat treats': 3, 'infant nappies': 3, 'canned veg': 3, 'vegetable juices': 3, 'footy's back': 2, 'kitchenware': 2, 'sprays': 2, 'baby cereals': 2, 'sausages': 2, 'wet dog food': 2, 'toilet paper': 2, 'beef': 2, 'entertainment': 2, 'smallgoods dy': 2, 'gourmet cheese': 2, 'rice': 2, 'hair tools': 2, 'soap

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Price range: \$0.85 - \$990.00

Cluster 1:

Size: 12044 products

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Price range: \$0.28 - \$135.00

Cluster 2:

Size: 820 products

Subcategories: {'mixed': 345, 'electrical': 89, 'energy/sport/icedtea': 29, 'water': 26, 'wet cat food': 25, 'hair colour': 19, 'wet dog food': 18, 'surface cleaners': 16, 'infant nappies': 13, 'lemonades': 12, 'better for you': 11, 'detergents': 10, 'gum': 9, 'infant formula': 9, 'entertainment': 9, 'fruit drinks': 9, 'cat food': 9, 'cat treats': 8, 'noodles': 7, 'rice': 7, 'toothbrush': 6, 'sunscreen': 6, 'energy drinks': 6, 'protein bars': 5, 'whisky': 5, 'beef': 5, 'instant noodles': 5, 'fruit-shelf stable': 5, 'frozen desserts': 4, 'pain relief': 4, 'makeup': 4, 'soap bars': 4, 'mousse': 4, 'colas': 4, 'fresh pet food dy': 4, 'dried fruit/nuts': 4, 'tuna': 4, 'grocery milk': 4, 'chips/crisps': 3, 'sauces': 3, 'specific vitamins': 3, 'supplements': 3, 'shaving': 3, 'beans': 2, 'lamb': 2, 'mexican foods': 2, 'drinks': 2, 'facial tissues': 2, 'desserts (gr)': 2, 'biscuits': 2, 'pork': 2, 'processed cheese': 2, 'canned veg': 2, 'picnic pool bbq acc': 2, 'red wine': 2, 'serum': 2, 'household': 1, 'pasta': 1, 'ground coffee': 1, 'canned meals': 1, 'toothpaste': 1}

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Price range: \$1.40 - \$99.50

Cluster 3:

Size: 3570 products

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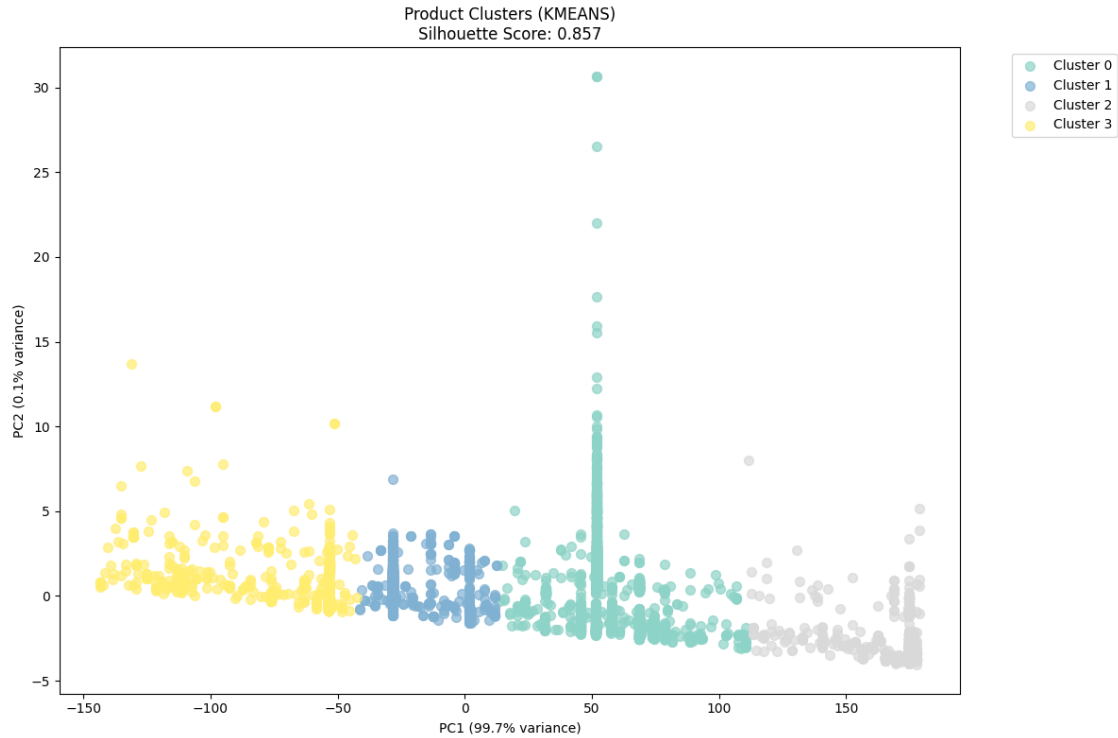
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Price range: \$0.50 - \$172.00

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Cart Optimization Demo:

Original cart total: \$61.50

Optimized cart total: \$24.00

Total savings: \$37.50 (61.0%)

Items with alternatives: 6/8

Detailed Recommendations:

coles hot cross buns traditional fruit (\$3.00)

→ No cheaper alternatives found

cadbury dairy milk chocolate easter egg hunt carton (\$8.00)

→ Recommended: dairy milk hollow chocolate easter egg

Price: \$2.50 (Save \$5.50)

cadbury dairy milk easter chocolate eggs bag (\$6.70)

→ Recommended: easter fried eggs and bunnies gummies

Price: \$2.50 (Save \$4.20)

ferrero rocher chocolate gift box (\$9.00)

→ Recommended: founr twenty frozen meat pies

Price: \$4.50 (Save \$4.50)

sensodyne repair protect toothbrush (\$3.00)

→ No cheaper alternatives found

maybelline lash sensational sky high washable mascara blackest black (\$17.50)

→ Recommended: sensodyne repair protect toothbrush

Price: \$3.00 (Save \$14.50)

sensodyne soft daily care toothbrush (\$6.30)

→ Recommended: sensodyne repair protect toothbrush

Price: \$3.00 (Save \$3.30)

	original_code	original_name	original_price	\
0	8371390	coles hot cross buns traditional fruit	3.0	

	alt_code	alt_name	alt_price	savings	savings_pct
0	None	No substitute found	None	0	0

```
[ ]: sample_cart = [3801470, 8183899, 1331353]
cart_results = optimizer.optimize_cart(sample_cart)

print(f"Original cart total: ${cart_results['original_total']:.2f}")
print(f"Optimized cart total: ${cart_results['optimized_total']:.2f}")
print(f"Total savings: ${cart_results['total_savings']:.2f}␣
↪({cart_results['savings_percentage']:.1f}%)")
print(f"Items with alternatives: {cart_results['items_with_alternatives']}/
↪{cart_results['total_items']}")

print("\nDetailed Recommendations:")
for product_code, rec in cart_results['recommendations'].items():
    print(f"\n{rec['original_name']} (${rec['original_price']:.2f}")
    if rec['best_alternative']:
        alt = rec['best_alternative']
        print(f"    → Recommended: {alt['name']}")
        print(f"    Price: ${alt['original_price']:.2f} (Save ${alt['savings']:.
↪2f})")
    else:
        print(f"    → No cheaper alternatives found")
```

Original cart total: \$19.85

Optimized cart total: \$9.60

Total savings: \$10.25 (51.6%)

Items with alternatives: 3/3

Detailed Recommendations:

944 pvc duct tape silver (\$6.85)

→ Recommended: 2010 beige masking tape 24mm

Price: \$5.35 (Save \$1.50)

container (\$3.00)

→ Recommended: container

Price: \$2.25 (Save \$0.75)

coconut exotic tropical dry shampoo (\$10.00)

→ Recommended: fruits apple fresh shampoo

Price: \$2.00 (Save \$8.00)

The algorithm has improved significantly in terms of suggesting product alternatives for a given product when the subcategories are more well defined.