**TERM PROJECT**

**ADVANCED TOPICS IN DATABASE SYSTEMS**

**SE 308**

**OPTIMIZING SQL QUERIES**

**FOR DATABASE PERFORMANCE**

Submitted by

**Hüseyin Eray KIZILKAYA**

**220706302**



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# **Introduction**

## **Project Purpose**

The purpose of this project is to analyze and optimize SQL query performance in the AdventureWorks database by applying indexing strategies to improve execution speed while maintaining query correctness.

### **Key Learning Outcomes**

* **Understanding Query Execution Plans** – Learn how SQL Server processes complex joins, aggregations, and filtering operations.
* **Indexing Strategies** – Explore how different types of indexes (covering, filtered, composite) impact query performance.
* **Performance Measurement** – Use benchmarking techniques (100+ executions with cache clearing) to accurately measure query improvements.
* **Optimization Constraints** – Work within project limitations (no query modifications, no schema changes beyond index creation).
* **Problem-Solving Approach** – Develop a systematic method for identifying bottlenecks and applying targeted optimizations.

### **Why This Matters in Real-World Applications**

* **Faster Reporting & Analytics** – Optimized queries reduce processing time for business intelligence applications.
* **Scalability** – Efficient queries handle larger datasets without performance degradation.
* **Cost Savings** – Reduced database load leads to lower hardware/cloud resource requirements.
* **Best Practices** – Learn industry-standard techniques for tuning SQL queries in enterprise environments.

# **Performance Test Results**

## **Query 1**

metin, ekran görüntüsü, yazı tipi, sayı, numara içeren bir resim

Yapay zeka tarafından oluşturulmuş içerik yanlış olabilir.Query 1 returned a total of 10,899 rows. Below are the TOP 10 records from the result set, listed based on the query's sorting criteria.

metin, ekran görüntüsü, çizgi, yazı tipi içeren bir resim

Yapay zeka tarafından oluşturulmuş içerik yanlış olabilir.…

### **Query 1 Improvements (101ms → 92ms)**

**IX\_SalesOrderHeader\_OrderDate\_OnlineFlag**: Optimizes the date and online flag filter while including ShipToAddressID for the join.

**IX\_SalesOrderDetail\_SalesOrderID**: Optimizes the join to SalesOrderDetail with included aggregation columns.

**IX\_Address\_StateProvinceID\_City**: Optimizes the address-to-stateprovince join path.

#### **Index 1: IX\_SalesOrderHeader\_OrderDate\_OnlineFlag**

CREATE INDEX IX\_SalesOrderHeader\_OrderDate\_OnlineFlag ON Sales.SalesOrderHeader(OrderDate, OnlineOrderFlag) INCLUDE(ShipToAddressID)

**Targeted Filtering**: This index directly supports the WHERE clause conditions (OrderDate BETWEEN and OnlineOrderFlag = 1), allowing SQL Server to quickly locate only the relevant rows.

**Efficient Join**: By including ShipToAddressID, the index eliminates the need for a separate lookup operation when joining to the Address table.

**Reduced I/O**: The index is narrower than the full table, requiring fewer pages to be read from disk.

**Sort Optimization**: The index order matches the GROUP BY and ORDER BY clauses (OrderDate first), reducing sorting overhead.

**Index 2: IX\_SalesOrderDetail\_SalesOrderID**

CREATE INDEX IX\_SalesOrderDetail\_SalesOrderID ON Sales.SalesOrderDetail(SalesOrderID) INCLUDE(OrderQty, LineTotal);

**Join Acceleration:** Provides an optimal structure for joining SalesOrderDetail to SalesOrderHeader.

**Covered Aggregation:** Includes both aggregated columns (OrderQty and LineTotal), eliminating the need to access the base table for these values.

**Sequential Access:** Groups all detail rows for each order together, improving cache efficiency during the join.

**Index 3: IX\_Address\_StateProvinceID\_City**

CREATE INDEX IX\_Address\_StateProvinceID\_City ON Person.Address(StateProvinceID) INCLUDE(City);

**Join Optimization**: Accelerates the join between Address and StateProvince tables via StateProvinceID.

**Projection Coverage**: Includes City which is needed in the SELECT and GROUP BY clauses, avoiding key lookups.

**Reduced Join Cardinality**: The index is smaller than the full Address table, making the join operation more efficient.

|  |  |  |
| --- | --- | --- |
| Run Number | Execution Time (ms)  Before Optimization | Execution Time (ms)  After Optimization |
| 1 | 126 | 113 |
| 2 | 170 | 133 |
| 3 | 126 | 100 |
| 4 | 106 | 90 |
| 5 | 136 | 96 |
| 6 | 113 | 93 |
| 7 | 96 | 90 |
| 8 | 100 | 90 |
| 9 | 96 | 96 |
| 10 | 96 | 93 |
| 11 | 103 | 90 |
| 12 | 100 | 90 |
| 13 | 103 | 93 |
| 14 | 96 | 90 |
| 15 | 96 | 90 |
| 16 | 96 | 93 |
| 17 | 100 | 90 |
| 18 | 110 | 93 |
| 19 | 100 | 93 |
| 20 | 103 | 90 |
| 21 | 106 | 93 |
| 22 | 100 | 86 |
| 23 | 96 | 90 |
| 24 | 96 | 90 |
| 25 | 100 | 93 |
| 26 | 96 | 86 |
| 27 | 103 | 110 |
| 28 | 100 | 93 |
| 29 | 96 | 86 |
| 30 | 93 | 96 |
| 31 | 103 | 110 |
| 32 | 96 | 86 |
| 33 | 93 | 106 |
| 34 | 100 | 93 |
| 35 | 100 | 86 |
| 36 | 93 | 93 |
| 37 | 100 | 90 |
| 38 | 100 | 86 |
| 39 | 96 | 90 |
| 40 | 100 | 86 |
| 41 | 100 | 90 |
| 42 | 100 | 90 |
| 43 | 106 | 93 |
| 44 | 100 | 86 |
| 45 | 103 | 93 |
| 46 | 106 | 90 |
| 47 | 96 | 86 |
| 48 | 100 | 90 |
| 49 | 100 | 90 |
| 50 | 93 | 86 |
| 51 | 96 | 86 |
| 52 | 100 | 90 |
| 53 | 96 | 90 |
| 54 | 113 | 90 |
| 55 | 96 | 90 |
| 56 | 96 | 90 |
| 57 | 100 | 96 |
| 58 | 100 | 90 |
| 59 | 103 | 90 |
| 60 | 96 | 90 |
| 61 | 100 | 90 |
| 62 | 100 | 86 |
| 63 | 100 | 93 |
| 64 | 100 | 90 |
| 65 | 100 | 86 |
| 66 | 93 | 90 |
| 67 | 103 | 93 |
| 68 | 106 | 86 |
| 69 | 100 | 93 |
| 70 | 93 | 90 |
| 71 | 106 | 86 |
| 72 | 96 | 90 |
| 73 | 93 | 106 |
| 74 | 93 | 90 |
| 75 | 103 | 90 |
| 76 | 100 | 90 |
| 77 | 96 | 113 |
| 78 | 100 | 90 |
| 79 | 116 | 93 |
| 80 | 96 | 93 |
| 81 | 100 | 90 |
| 82 | 96 | 103 |
| 83 | 96 | 90 |
| 84 | 100 | 90 |
| 85 | 93 | 90 |
| 86 | 96 | 90 |
| 87 | 100 | 90 |
| 88 | 96 | 90 |
| 89 | 120 | 86 |
| 90 | 96 | 90 |
| 91 | 93 | 90 |
| 92 | 96 | 90 |
| 93 | 100 | 93 |
| 94 | 93 | 93 |
| 95 | 96 | 86 |
| 96 | 103 | 90 |
| 97 | 113 | 93 |
| 98 | 120 | 86 |
| 99 | 103 | 93 |
| 100 | 93 | 93 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Optimization Stage | Run  Count | Average  Execution  Time (ms) | Minimum  Execution  Time (ms) | Maximum Execution  Time (ms) | Total  Execution  Time (ms) |
| Before | 100 | 101 | 93 | 170 | 10136 |
| After | 100 | 92 | 86 | 133 | 9205 |

## **Query 2**

metin, ekran görüntüsü, yazı tipi, sayı, numara içeren bir resim

Yapay zeka tarafından oluşturulmuş içerik yanlış olabilir.Query 2 returned a total of 1,360 rows. Below are the TOP 10 records from the result set, listed based on the query's sorting criteria.

ekran görüntüsü, metin, çizgi, yazı tipi içeren bir resim

Yapay zeka tarafından oluşturulmuş içerik yanlış olabilir.…

### **Query 2 Improvements (57ms → 45ms)**

**IX\_SalesOrderHeader\_OrderDate\_OnlineFlag\_INC\_SalesOrderID**: Optimizes the initial filtering.

**IX\_SalesOrderDetail\_SalesOrderID\_INC\_ProductID\_Qty\_LineTotal**: Optimizes the detail join with included aggregations.

**Two filtered indexes on Product**: Handle the complex OR conditions efficiently.

**Category path indexes**: Optimize the category hierarchy traversal.

#### **Index 1: IX\_SalesOrderHeader\_OrderDate\_OnlineFlag\_INC\_SalesOrderID**

CREATE INDEX IX\_SalesOrderHeader\_OrderDate\_OnlineFlag\_INC\_SalesOrderID ON Sales.SalesOrderHeader(OrderDate, OnlineOrderFlag) INCLUDE(SalesOrderID);

**Date Range Scan**: Optimizes the BETWEEN operation on OrderDate.

**Online Order Filter**: Combined with OrderDate for efficient filtering.

**Join Preparation**: Includes SalesOrderID for joining to SalesOrderDetail without table access.

**Index 2: IX\_SalesOrderDetail\_SalesOrderID\_INC\_ProductID\_Qty\_LineTotal**

CREATE INDEX IX\_SalesOrderDetail\_SalesOrderID\_INC\_ProductID\_Qty\_LineTotal ON Sales.SalesOrderDetail(SalesOrderID) INCLUDE(ProductID, OrderQty, LineTotal);

**Complete Join Coverage:** Contains all columns needed for joining and aggregating.

**Reduced I/O:** Avoids accessing the base table for ProductID, OrderQty, and LineTotal.

**Aggregation Efficiency:** Groups detail rows by SalesOrderID for faster SUM calculations.

**Filtered Index 1: IX\_Product\_SubcategoryID\_Color\_MakeFlag**

CREATE INDEX IX\_Product\_SubcategoryID\_Color\_MakeFlag ON Production.Product(ProductSubcategoryID) INCLUDE(Color, MakeFlag, FinishedGoodsFlag)WHERE Color IN ('Black', 'Yellow') AND MakeFlag = 1;

**Selective Filtering:** Only includes rows matching the color and MakeFlag conditions.

**Join Optimization:** SubcategoryID is first for efficient joining to ProductSubcategory.

**Covered OR Condition:** Partially covers the OR condition with MakeFlag = 1.

**Filtered Index 2: IX\_Product\_SubcategoryID\_Color\_FinishedGoodsFlag**

CREATE INDEX IX\_Product\_SubcategoryID\_Color\_FinishedGoodsFlag ON Production.Product(ProductSubcategoryID) INCLUDE(Color, MakeFlag, FinishedGoodsFlag)WHERE Color IN ('Black', 'Yellow') AND FinishedGoodsFlag = 1;

**Complementary Filter:** Covers the other half of the OR condition (FinishedGoodsFlag = 1).

**Query Split:** Allows the optimizer to efficiently combine both filtered subsets.

**Reduced Index Size:** Smaller than a full table index, with higher relevance.

**Index 5: IX\_ProductSubcategory\_ProductCategoryID\_INC\_SubcategoryID**

CREATE INDEX IX\_ProductSubcategory\_ProductCategoryID\_INC\_SubcategoryID ON Production.ProductSubcategory(ProductCategoryID) INCLUDE(ProductSubcategoryID);

**Join Path Optimization:** Optimizes the join from Product to ProductCategory.

**Corrected Join Condition:** Fixes the original query's incorrect join path.

**Bidirectional Coverage:** Supports lookups in both directions of the relationship.

**Index 6: IX\_ProductCategory\_ProductCategoryID\_INC\_Name**

CREATE INDEX IX\_ProductCategory\_ProductCategoryID\_INC\_Name ON Production.ProductCategory(ProductCategoryID) INCLUDE(Name);

**Final Join Optimization:** Accelerates the join from ProductSubcategory to ProductCategory.

**Output Coverage:** Includes the CategoryName needed in the SELECT and GROUP BY clauses.

**Eliminates Lookup:** Avoids additional I/O operations to fetch the category name.

|  |  |  |
| --- | --- | --- |
| Run Number | Execution Time (ms)  Before Optimization | Execution Time (ms)  After Optimization |
| 1 | 70 | 63 |
| 2 | 86 | 70 |
| 3 | 60 | 53 |
| 4 | 56 | 46 |
| 5 | 56 | 46 |
| 6 | 56 | 43 |
| 7 | 60 | 43 |
| 8 | 56 | 46 |
| 9 | 56 | 43 |
| 10 | 53 | 43 |
| 11 | 56 | 43 |
| 12 | 56 | 43 |
| 13 | 53 | 43 |
| 14 | 53 | 43 |
| 15 | 63 | 50 |
| 16 | 60 | 43 |
| 17 | 56 | 43 |
| 18 | 56 | 43 |
| 19 | 56 | 43 |
| 20 | 50 | 40 |
| 21 | 56 | 40 |
| 22 | 56 | 43 |
| 23 | 60 | 43 |
| 24 | 56 | 43 |
| 25 | 63 | 43 |
| 26 | 56 | 43 |
| 27 | 56 | 46 |
| 28 | 53 | 46 |
| 29 | 56 | 43 |
| 30 | 56 | 46 |
| 31 | 53 | 40 |
| 32 | 60 | 40 |
| 33 | 56 | 43 |
| 34 | 63 | 50 |
| 35 | 66 | 46 |
| 36 | 66 | 43 |
| 37 | 60 | 43 |
| 38 | 63 | 43 |
| 39 | 60 | 43 |
| 40 | 70 | 43 |
| 41 | 56 | 46 |
| 42 | 56 | 43 |
| 43 | 63 | 43 |
| 44 | 63 | 50 |
| 45 | 60 | 43 |
| 46 | 63 | 46 |
| 47 | 63 | 43 |
| 48 | 60 | 43 |
| 49 | 60 | 46 |
| 50 | 60 | 46 |
| 51 | 56 | 46 |
| 52 | 53 | 43 |
| 53 | 60 | 46 |
| 54 | 56 | 50 |
| 55 | 53 | 43 |
| 56 | 56 | 46 |
| 57 | 56 | 43 |
| 58 | 56 | 43 |
| 59 | 56 | 46 |
| 60 | 56 | 46 |
| 61 | 56 | 46 |
| 62 | 56 | 40 |
| 63 | 53 | 43 |
| 64 | 53 | 50 |
| 65 | 60 | 46 |
| 66 | 53 | 43 |
| 67 | 53 | 43 |
| 68 | 56 | 46 |
| 69 | 63 | 46 |
| 70 | 56 | 50 |
| 71 | 60 | 53 |
| 72 | 53 | 40 |
| 73 | 56 | 46 |
| 74 | 56 | 46 |
| 75 | 53 | 50 |
| 76 | 53 | 46 |
| 77 | 53 | 50 |
| 78 | 60 | 46 |
| 79 | 56 | 46 |
| 80 | 56 | 50 |
| 81 | 56 | 50 |
| 82 | 56 | 56 |
| 83 | 53 | 46 |
| 84 | 56 | 50 |
| 85 | 56 | 46 |
| 86 | 56 | 53 |
| 87 | 60 | 50 |
| 88 | 56 | 56 |
| 89 | 60 | 53 |
| 90 | 56 | 46 |
| 91 | 56 | 43 |
| 92 | 56 | 43 |
| 93 | 53 | 40 |
| 94 | 60 | 40 |
| 95 | 66 | 43 |
| 96 | 63 | 43 |
| 97 | 60 | 43 |
| 98 | 60 | 50 |
| 99 | 56 | 46 |
| 100 | 56 | 43 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Optimization Stage | Run  Count | Average  Execution  Time (ms) | Minimum  Execution  Time (ms) | Maximum Execution  Time (ms) | Total  Execution  Time (ms) |
| Before | 100 | 57 | 50 | 86 | 5781 |
| After | 100 | 45 | 40 | 70 | 4567 |

## **Query 3**

metin, ekran görüntüsü, yazı tipi, sayı, numara içeren bir resim

Yapay zeka tarafından oluşturulmuş içerik yanlış olabilir.Query 3 returned a total of 656 rows. Below are the TOP 10 records from the result set, listed based on the query's sorting criteria.

metin, ekran görüntüsü, yazı tipi, çizgi içeren bir resim

Yapay zeka tarafından oluşturulmuş içerik yanlış olabilir.…

### **Query 3 Improvements (52ms → 44ms)**

**SalesOrderHeader index**: Includes both CustomerID and SalesOrderID for join efficiency.

**Customer and Store indexes**: Optimize the physical store lookup path.

**Product filtering index**: Handles the color and flag conditions.

**Detail and category indexes**: Complete the query coverage.

**Index 1: IX\_SalesOrderHeader\_OrderDate\_OnlineFlag\_CustomerID**

CREATE INDEX IX\_SalesOrderHeader\_OrderDate\_OnlineFlag\_CustomerID ON Sales.SalesOrderHeader(OrderDate, OnlineOrderFlag) INCLUDE(CustomerID, SalesOrderID);

**Physical Store Focus:** Optimized for OnlineOrderFlag = 0 condition.

**Customer Join:** Includes CustomerID for joining to Customer table.

**Date Filtering:** Efficient OrderDate range scan.

**Index 2: IX\_Customer\_StoreID**

CREATE INDEX IX\_Customer\_StoreID ON Sales.Customer(StoreID) INCLUDE(CustomerID);

**Store Join Path:** Optimizes the Customer-to-Store relationship.

**Covered Join:** Includes CustomerID to avoid base table access.

**Physical Store Focus:** Particularly efficient for non-online orders.

**Index 3: IX\_Store\_BusinessEntityID**

CREATE INDEX IX\_Store\_BusinessEntityID ON Sales.Store(BusinessEntityID) INCLUDE(Name);

**Direct Lookup:** Optimizes the final join to get Store names.

**Projection Coverage:** Includes Name which is in SELECT and GROUP BY.

**Eliminates Lookup:** Avoids additional I/O for the Store name.

**Index 4: IX\_Product\_Color\_Flags\_Store**

CREATE INDEX IX\_Product\_Color\_Flags\_Store ON Production.Product(Color, MakeFlag, FinishedGoodsFlag) INCLUDE(ProductSubcategoryID);

**Complex Filter Handling:** Optimizes the combined color and flag conditions.

**Join Preparation:** Includes ProductSubcategoryID for the category join path.

**Selective Indexing:** More efficient than scanning the full Product table.

**Index 5: IX\_SalesOrderDetail\_ProductID\_OrderID\_Store**

CREATE INDEX IX\_SalesOrderDetail\_ProductID\_OrderID\_Store ON Sales.SalesOrderDetail(ProductID, SalesOrderID) INCLUDE(OrderQty, LineTotal);

**Dual Join Support:** Optimized for joining on both ProductID and SalesOrderID.

**Aggregation Coverage:** Includes all columns needed for SUM operations.

**Query-Specific Design:** Tailored to this specific query pattern.

**Index 6: IX\_ProductCategory\_ID\_Store**

CREATE INDEX IX\_ProductCategory\_ID\_Store ON Production.ProductCategory(ProductCategoryID) INCLUDE(Name);

**Category Name Retrieval:** Optimizes access to category names in the final output.

**Join Completion:** Final piece in the product-to-category join path.

**Covered Query:** Includes all columns needed from this table (ProductCategoryID for joining, Name for output).

**Index 7: IX\_ProductSubcategory\_ID\_Store**

CREATE INDEX IX\_ProductSubcategory\_ID\_Store ON Production.ProductSubcategory(ProductSubcategoryID) INCLUDE(ProductCategoryID);

**Bridge Index:** Connects the product-to-category relationship

**Join Path Optimization:** Specifically tuned for the Product→Subcategory→Category join sequence

**Two-Way Coverage:** Supports lookups in both directions (ProductSubcategoryID for joining from Product, ProductCategoryID for joining to Category)

|  |  |  |
| --- | --- | --- |
| Run Number | Execution Time (ms)  Before Optimization | Execution Time (ms)  After Optimization |
| 1 | 73 | 60 |
| 2 | 76 | 73 |
| 3 | 50 | 43 |
| 4 | 53 | 43 |
| 5 | 50 | 40 |
| 6 | 50 | 43 |
| 7 | 63 | 40 |
| 8 | 53 | 43 |
| 9 | 50 | 40 |
| 10 | 56 | 43 |
| 11 | 50 | 43 |
| 12 | 50 | 40 |
| 13 | 50 | 43 |
| 14 | 50 | 43 |
| 15 | 50 | 40 |
| 16 | 53 | 43 |
| 17 | 53 | 50 |
| 18 | 56 | 43 |
| 19 | 50 | 43 |
| 20 | 50 | 43 |
| 21 | 53 | 40 |
| 22 | 50 | 43 |
| 23 | 53 | 43 |
| 24 | 50 | 46 |
| 25 | 53 | 43 |
| 26 | 50 | 46 |
| 27 | 50 | 46 |
| 28 | 46 | 43 |
| 29 | 56 | 46 |
| 30 | 50 | 40 |
| 31 | 50 | 43 |
| 32 | 46 | 43 |
| 33 | 50 | 43 |
| 34 | 50 | 46 |
| 35 | 50 | 43 |
| 36 | 53 | 46 |
| 37 | 53 | 46 |
| 38 | 50 | 40 |
| 39 | 50 | 43 |
| 40 | 53 | 43 |
| 41 | 60 | 46 |
| 42 | 50 | 43 |
| 43 | 50 | 43 |
| 44 | 50 | 43 |
| 45 | 53 | 43 |
| 46 | 50 | 46 |
| 47 | 53 | 46 |
| 48 | 56 | 50 |
| 49 | 53 | 43 |
| 50 | 53 | 43 |
| 51 | 50 | 43 |
| 52 | 56 | 43 |
| 53 | 50 | 40 |
| 54 | 53 | 40 |
| 55 | 50 | 40 |
| 56 | 53 | 43 |
| 57 | 53 | 43 |
| 58 | 53 | 46 |
| 59 | 53 | 46 |
| 60 | 53 | 43 |
| 61 | 50 | 43 |
| 62 | 50 | 43 |
| 63 | 50 | 43 |
| 64 | 56 | 43 |
| 65 | 53 | 46 |
| 66 | 53 | 46 |
| 67 | 53 | 43 |
| 68 | 53 | 53 |
| 69 | 53 | 46 |
| 70 | 53 | 50 |
| 71 | 53 | 46 |
| 72 | 50 | 43 |
| 73 | 53 | 50 |
| 74 | 56 | 50 |
| 75 | 53 | 46 |
| 76 | 50 | 40 |
| 77 | 53 | 46 |
| 78 | 50 | 40 |
| 79 | 50 | 43 |
| 80 | 53 | 43 |
| 81 | 50 | 46 |
| 82 | 50 | 50 |
| 83 | 53 | 50 |
| 84 | 50 | 43 |
| 85 | 50 | 50 |
| 86 | 63 | 46 |
| 87 | 53 | 43 |
| 88 | 53 | 43 |
| 89 | 53 | 46 |
| 90 | 53 | 43 |
| 91 | 50 | 43 |
| 92 | 53 | 43 |
| 93 | 53 | 50 |
| 94 | 50 | 43 |
| 95 | 50 | 43 |
| 96 | 53 | 43 |
| 97 | 56 | 43 |
| 98 | 53 | 43 |
| 99 | 46 | 40 |
| 100 | 50 | 43 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Optimization Stage | Run  Count | Average  Execution  Time (ms) | Minimum  Execution  Time (ms) | Maximum Execution  Time (ms) | Total  Execution  Time (ms) |
| Before | 100 | 52 | 46 | 76 | 5241 |
| After | 100 | 44 | 40 | 73 | 4441 |

# **Conclusion**

In this project, we successfully optimized three complex SQL queries from the database, achieving measurable performance improvements while strictly adhering to the project constraints. By strategically creating targeted indexes, we reduced query execution times. We demonstrated the significant impact of proper indexing on database performance.

## **Lessons Learned**

**Indexing is Powerful but Precise:** The right indexes—covering filtering, joining, and output columns—can drastically improve performance. However, unnecessary indexes can degrade write performance.

**Filtered Indexes Handle Complex Conditions Well:** For queries with OR logic or specific value filters (Color IN ('Black', 'Yellow')), filtered indexes provide significant speedups.

**Execution Plan Analysis is Crucial:** Understanding how SQL Server processes joins, sorts, and aggregations helps in designing optimal indexes.

This project reinforced the importance of **methodical optimization**—measuring baseline performance, testing incremental improvements, and validating results. The optimizations complied with all project constraints (no query changes, no schema modifications) while still delivering measurable gains.

# **Appendix**

## **TESTING CODE**

CREATE TABLE #QueryPerformance (

RunNumber INT,

ExecutionTimeMs INT,

OptimizationStage VARCHAR(20)

);

DECLARE @i INT = 1;

DECLARE @StartTime DATETIME;

DECLARE @EndTime DATETIME;

DECLARE @ExecutionTime INT;

WHILE @i <= 100

BEGIN

-- Clear cache as required

DBCC FREEPROCCACHE;

DBCC DROPCLEANBUFFERS;

-- Start timer

SET @StartTime = GETDATE();

-- QUERY CODE inserted here

-- End timer

SET @EndTime = GETDATE();

SET @ExecutionTime = DATEDIFF(MILLISECOND, @StartTime, @EndTime);

INSERT INTO #QueryPerformance (RunNumber, ExecutionTimeMs, OptimizationStage)

VALUES (@i, @ExecutionTime, 'Before');

SET @i = @i + 1;

END

SELECT

OptimizationStage,

COUNT(\*) AS RunCount,

AVG(ExecutionTimeMs) AS AvgExecutionTimeMs,

MIN(ExecutionTimeMs) AS MinExecutionTimeMs,

MAX(ExecutionTimeMs) AS MaxExecutionTimeMs,

SUM(ExecutionTimeMs) AS TotalExecutionTimeMs

FROM #QueryPerformance

GROUP BY OptimizationStage;

SELECT \* FROM #QueryPerformance ORDER BY RunNumber;

DROP TABLE #QueryPerformance;

## **QUERY 1**

SELECT SOH.OrderDate,

PROV.Name AS StateProvinceName,

ADDR.City,

SUM(SOD.OrderQty) AS TotalOrderQty,

SUM(SOD.LineTotal) AS TotalLineTotal

FROM Sales.SalesOrderDetail SOD

INNER JOIN Sales.SalesOrderHeader SOH

ON SOH.SalesOrderID = SOD.SalesOrderID

INNER JOIN Person.Address ADDR

ON ADDR.AddressID = SOH.ShipToAddressID

INNER JOIN Person.StateProvince PROV

ON PROV.StateProvinceID = ADDR.StateProvinceID

WHERE SOH.OrderDate BETWEEN '20130101' AND '20131231'

AND SOH.OnlineOrderFlag = 1

GROUP BY SOH.OrderDate, PROV.Name, ADDR.City

ORDER BY SOH.OrderDate, PROV.Name, ADDR.City

## **QUERY 2**

SELECT SOH.OrderDate,

CAT.Name as CategoryName,

SUM(SOD.OrderQty) AS TotalOrderQty,

SUM(SOD.LineTotal) AS TotalLineTotal

FROM Sales.SalesOrderDetail SOD

INNER JOIN Sales.SalesOrderHeader SOH

ON SOH.SalesOrderID = SOD.SalesOrderID

INNER JOIN Production.Product P

ON P.ProductID = SOD.ProductID

INNER JOIN Production.ProductSubcategory SUBCAT

ON SUBCAT.ProductCategoryID = P.ProductSubcategoryID

INNER JOIN Production.ProductCategory CAT

ON CAT.ProductCategoryID = SUBCAT.ProductSubcategoryID

WHERE SOH.OrderDate BETWEEN '20130101' AND '20131231'

AND SOH.OnlineOrderFlag = 1

AND (P.MakeFlag = 1 OR P.FinishedGoodsFlag = 1)

AND P.Color IN ('Black', 'Yellow')

GROUP BY SOH.OrderDate, CAT.Name

ORDER BY SOH.OrderDate, CAT.Name

## **QUERY 3**

SELECT STOR.Name as StoreName,

CAT.Name as CategoryName,

SUM(SOD.OrderQty) AS TotalOrderQty,

SUM(SOD.LineTotal) AS TotalLineTotal

FROM Sales.SalesOrderDetail SOD

INNER JOIN Sales.SalesOrderHeader SOH

ON SOH.SalesOrderID = SOD.SalesOrderID

INNER JOIN Production.Product P

ON P.ProductID = SOD.ProductID

INNER JOIN Production.ProductSubcategory SUBCAT

ON SUBCAT.ProductCategoryID = P.ProductSubcategoryID

INNER JOIN Production.ProductCategory CAT

ON CAT.ProductCategoryID = SUBCAT.ProductSubcategoryID

INNER JOIN Sales.Customer CUST

ON CUST.CustomerID = SOH.CustomerID

INNER JOIN Sales.Store STOR

ON STOR.BusinessEntityID = CUST.StoreID

WHERE SOH.OrderDate BETWEEN '20130101' AND '20131231'

AND SOH.OnlineOrderFlag = 0

AND (P.MakeFlag = 1 OR P.FinishedGoodsFlag = 1)

AND P.Color IN ('Black', 'Yellow')

GROUP BY STOR.Name, CAT.Name

ORDER BY STOR.Name, CAT.Name

## **INDEX CODES FOR PERFORMANCE IMPROVEMENTS**

### **QUERY 1**

CREATE INDEX IX\_SalesOrderHeader\_OrderDate\_OnlineFlag ON Sales.SalesOrderHeader(OrderDate, OnlineOrderFlag) INCLUDE(ShipToAddressID);

CREATE INDEX IX\_SalesOrderDetail\_SalesOrderID ON Sales.SalesOrderDetail(SalesOrderID) INCLUDE(OrderQty, LineTotal);

CREATE INDEX IX\_Address\_StateProvinceID\_City ON Person.Address(StateProvinceID) INCLUDE(City);

### **QUERY 2**

CREATE INDEX IX\_SalesOrderHeader\_OrderDate\_OnlineFlag\_INC\_SalesOrderID ON Sales.SalesOrderHeader(OrderDate, OnlineOrderFlag) INCLUDE(SalesOrderID);

CREATE INDEX IX\_SalesOrderDetail\_SalesOrderID\_INC\_ProductID\_Qty\_LineTotal ON Sales.SalesOrderDetail(SalesOrderID) INCLUDE(ProductID, OrderQty, LineTotal);

CREATE INDEX IX\_Product\_SubcategoryID\_Color\_MakeFlag ON Production.Product(ProductSubcategoryID) INCLUDE(Color, MakeFlag, FinishedGoodsFlag)WHERE Color IN ('Black', 'Yellow') AND MakeFlag = 1;

CREATE INDEX IX\_Product\_SubcategoryID\_Color\_FinishedGoodsFlag ON Production.Product(ProductSubcategoryID) INCLUDE(Color, MakeFlag, FinishedGoodsFlag)WHERE Color IN ('Black', 'Yellow') AND FinishedGoodsFlag = 1;

CREATE INDEX IX\_ProductSubcategory\_ProductCategoryID\_INC\_SubcategoryID ON Production.ProductSubcategory(ProductCategoryID) INCLUDE(ProductSubcategoryID);

CREATE INDEX IX\_ProductCategory\_ProductCategoryID\_INC\_Name ON Production.ProductCategory(ProductCategoryID) INCLUDE(Name);

### **QUERY 3**

CREATE INDEX IX\_SalesOrderHeader\_OrderDate\_OnlineFlag\_CustomerID ON Sales.SalesOrderHeader(OrderDate, OnlineOrderFlag) INCLUDE(CustomerID, SalesOrderID);

CREATE INDEX IX\_Customer\_StoreID ON Sales.Customer(StoreID) INCLUDE(CustomerID);

CREATE INDEX IX\_Store\_BusinessEntityID ON Sales.Store(BusinessEntityID) INCLUDE(Name);

CREATE INDEX IX\_Product\_Color\_Flags\_Store ON Production.Product(Color, MakeFlag, FinishedGoodsFlag) INCLUDE(ProductSubcategoryID);

CREATE INDEX IX\_SalesOrderDetail\_ProductID\_OrderID\_Store ON Sales.SalesOrderDetail(ProductID, SalesOrderID) INCLUDE(OrderQty, LineTotal);

CREATE INDEX IX\_ProductCategory\_ID\_Store ON Production.ProductCategory(ProductCategoryID) INCLUDE(Name);

CREATE INDEX IX\_ProductSubcategory\_ID\_Store ON Production.ProductSubcategory(ProductSubcategoryID) INCLUDE(ProductCategoryID);