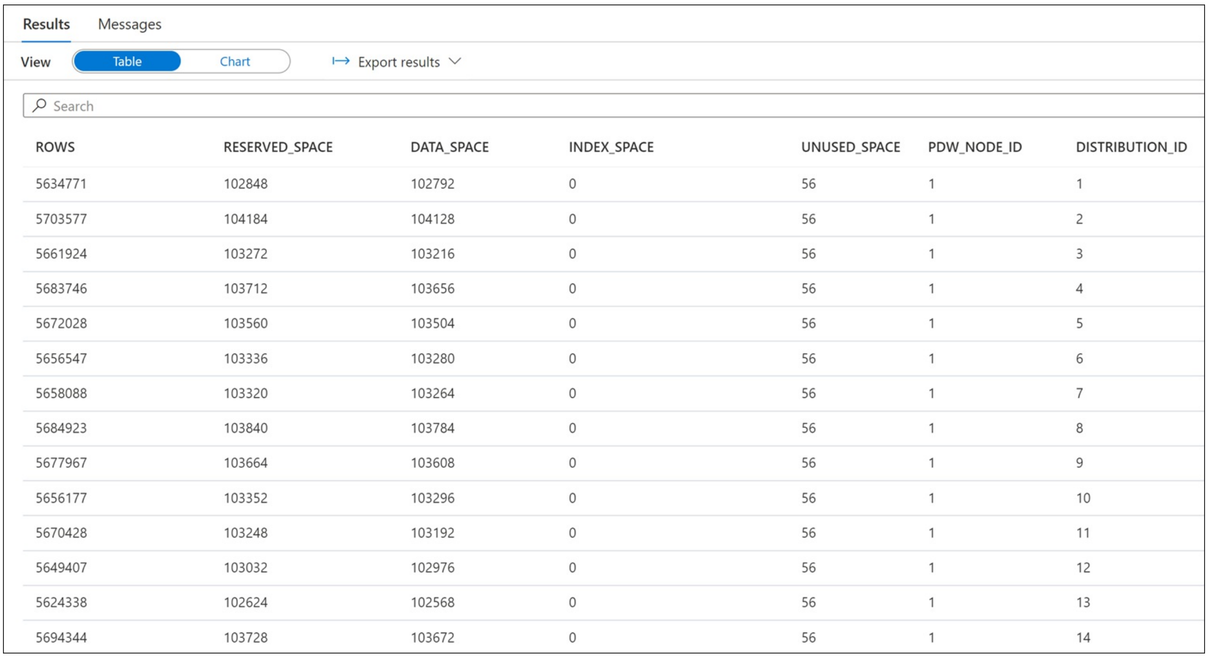
DW Optimization Part 2

Exercise 1 - Check for skewed data and space usage

Task 1 - Analyze the space used by tables

1. Run the following DBCC command:

```
DBCC PDW_SHOWSPACEUSED('wwi_perf.Sale_Hash');
```



Results Messages

View Table Chart Export results

Search

ROWS	RESERVED_SPACE	DATA_SPACE	INDEX_SPACE	UNUSED_SPACE	PDW_NODE_ID	DISTRIBUTION_ID
5634771	102848	102792	0	56	1	1
5703577	104184	104128	0	56	1	2
5661924	103272	103216	0	56	1	3
5683746	103712	103656	0	56	1	4
5672028	103560	103504	0	56	1	5
5656547	103336	103280	0	56	1	6
5658088	103320	103264	0	56	1	7
5684923	103840	103784	0	56	1	8
5677967	103664	103608	0	56	1	9
5656177	103352	103296	0	56	1	10
5670428	103248	103192	0	56	1	11
5649407	103032	102976	0	56	1	12
5624338	102624	102568	0	56	1	13
5694344	103728	103672	0	56	1	14

2. Analyze the number of rows in each distribution. Those numbers should be as even as possible. You can see from the results that rows are equally distributed across distributions. Let's dive a bit more into this analysis. Use the following query to get customers with the most sale transaction items:

```
SELECT TOP 1000
    CustomerId,
    count(*) as TransactionItemsCount
FROM
    [wwi_perf].[Sale_Hash]
GROUP BY
    CustomerId
ORDER BY
    count(*) DESC
```

Results Messages

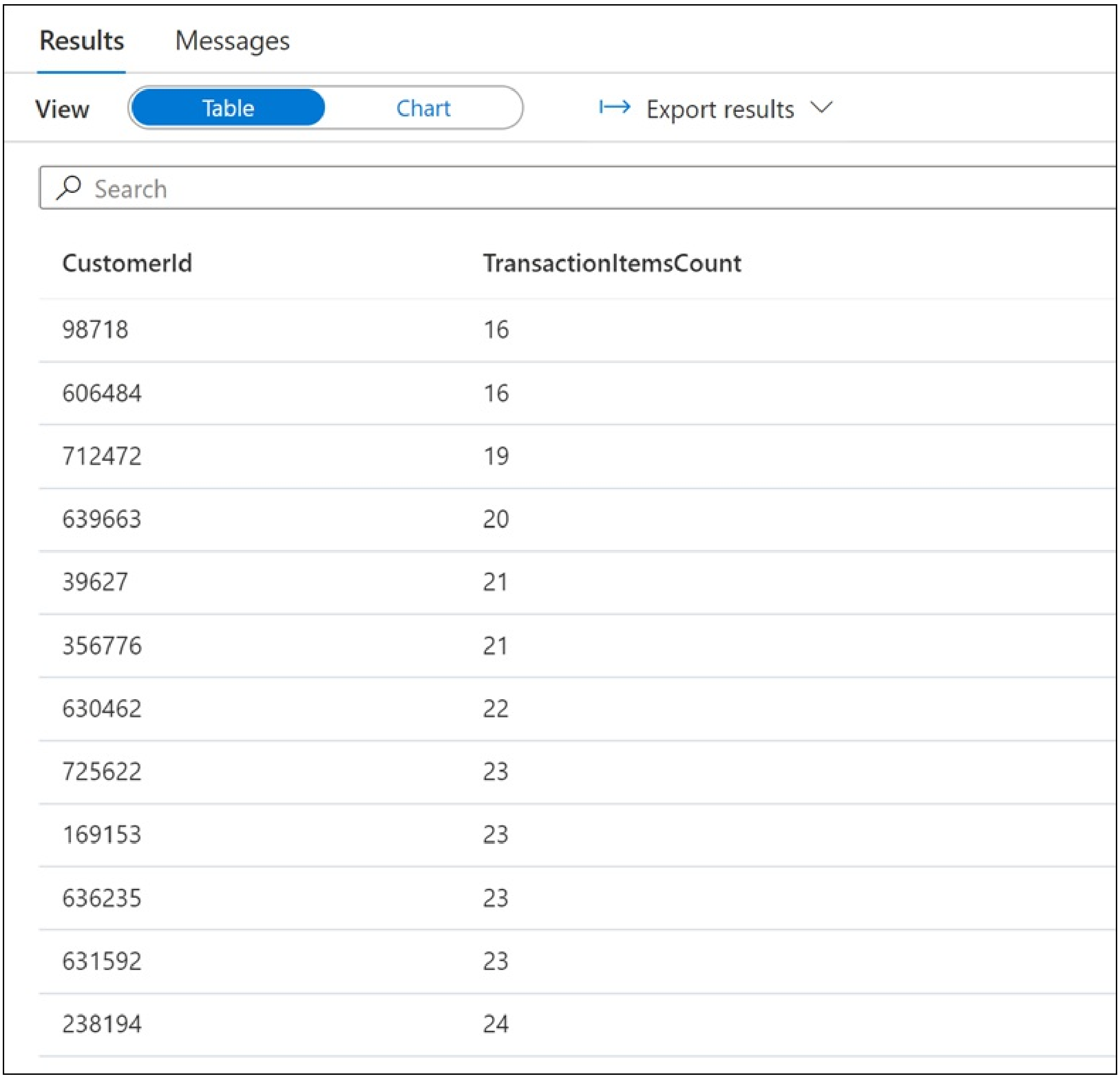
View Table Chart Export results

Search

CustomerId	TransactionItemsCount
325395	1715
549076	1687
185880	1637
405722	1633
705332	1614
420390	1601
268885	1596
554824	1593
648466	1553
519689	1550
887331	1524
382373	1520
636502	1471
587325	1467

Now find the customers with the least sale transaction items:

```
SELECT TOP 1000
    CustomerId,
    count(*) as TransactionItemsCount
FROM
    [wwi_perf].[Sale_Hash]
GROUP BY
    CustomerId
ORDER BY
    count(*) ASC
```



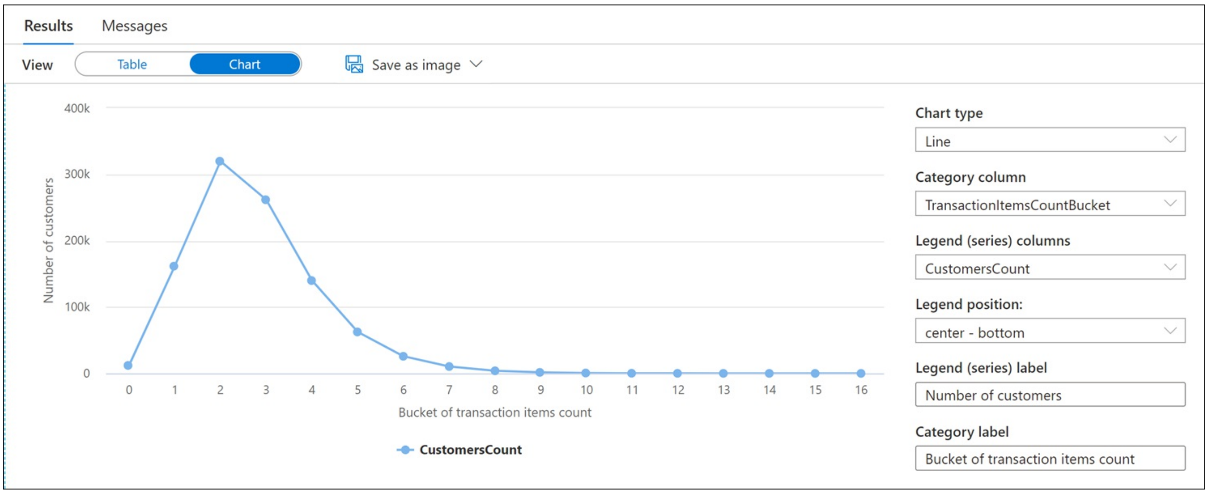
CustomerId	TransactionItemsCount
98718	16
606484	16
712472	19
639663	20
39627	21
356776	21
630462	22
725622	23
169153	23
636235	23
631592	23
238194	24

Notice the largest number of transaction items is 69 and the smallest is 16.

Let's find now the distribution of per-customer transaction item counts. Run the following query:

```
SELECT
    T.TransactionItemsCountBucket
    ,count(*) as CustomersCount
FROM
    (
        SELECT
            CustomerId,
            (count(*) - 16) / 100 as TransactionItemsCountBucket
        FROM
            [wwi_perf].[Sale_Hash]
        GROUP BY
            CustomerId
    ) T
GROUP BY
    T.TransactionItemsCountBucket
ORDER BY
    T.TransactionItemsCountBucket
```

In the `Results` pane, switch to the `Chart` view and configure it as follows (see the options set on the right side):



Without diving too much into the mathematical and statistical aspects of it, this histogram displays the reason why there is virtually no skew in the data distribution of the `Sale_Hash` table. If you haven't figured it out yet, the reason we are talking about is the quasi-normal distribution of the per-customer transaction items counts.

Task 2 - Use a more advanced approach to understand table space usage

1. Run the following script to create the `vTableSizes` view:

```
CREATE VIEW [wwi_perf].[vTableSizes]
AS
WITH base
AS
(
SELECT
    GETDATE()                                                            AS  [execution_time]
    , DB_NAME()                                                          AS  [database_name]
    , s.name                                                             AS  [schema_name]
    , t.name                                                             AS  [table_name]
    , QUOTENAME(s.name)+'.'+QUOTENAME(t.name)                            AS  [two_part_name]
    , nt.[name]                                                          AS  [node_table_name]
    , ROW_NUMBER() OVER(PARTITION BY nt.[name] ORDER BY (SELECT NULL))   AS
[node_table_name_seq]
    , tp.[distribution_policy_desc]                                      AS
[distribution_policy_name]
    , c.[name]                                                           AS
[distribution_column]
    , nt.[distribution_id]                                               AS  [distribution_id]
    , i.[type]                                                           AS  [index_type]
    , i.[type_desc]                                                      AS  [index_type_desc]
    , nt.[pdw_node_id]                                                   AS  [pdw_node_id]
    , pn.[type]                                                          AS  [pdw_node_type]
    , pn.[name]                                                          AS  [pdw_node_name]
    , di.name                                                            AS  [dist_name]
    , di.position                                                        AS  [dist_position]
    , nps.[partition_number]                                             AS  [partition_nmbr]
    , nps.[reserved_page_count]                                          AS
[reserved_space_page_count]
    , nps.[reserved_page_count] - nps.[used_page_count]                  AS
[unused_space_page_count]
    , nps.[in_row_data_page_count]
        + nps.[row_overflow_used_page_count]
        + nps.[lob_used_page_count]                                      AS
[data_space_page_count]
    , nps.[reserved_page_count]
    - (nps.[reserved_page_count] - nps.[used_page_count])
    - ([in_row_data_page_count]
            + [row_overflow_used_page_count]+[lob_used_page_count])      AS
[index_space_page_count]
    , nps.[row_count]                                                    AS  [row_count]
FROM
    sys.schemas s
```

```sql
INNER JOIN sys.tables t
    ON s.[schema_id] = t.[schema_id]
INNER JOIN sys.indexes i
    ON  t.[object_id] = i.[object_id]
    AND i.[index_id] <= 1
INNER JOIN sys.pdw_table_distribution_properties tp
    ON t.[object_id] = tp.[object_id]
INNER JOIN sys.pdw_table_mappings tm
    ON t.[object_id] = tm.[object_id]
INNER JOIN sys.pdw_nodes_tables nt
    ON tm.[physical_name] = nt.[name]
INNER JOIN sys.dm_pdw_nodes pn
    ON  nt.[pdw_node_id] = pn.[pdw_node_id]
INNER JOIN sys.pdw_distributions di
    ON  nt.[distribution_id] = di.[distribution_id]
INNER JOIN sys.dm_pdw_nodes_db_partition_stats nps
    ON nt.[object_id] = nps.[object_id]
    AND nt.[pdw_node_id] = nps.[pdw_node_id]
    AND nt.[distribution_id] = nps.[distribution_id]
LEFT OUTER JOIN (select * from sys.pdw_column_distribution_properties where distribution_ordinal =
1) cdp
    ON t.[object_id] = cdp.[object_id]
LEFT OUTER JOIN sys.columns c
    ON cdp.[object_id] = c.[object_id]
    AND cdp.[column_id] = c.[column_id]
WHERE pn.[type] = 'COMPUTE'
)
, size
AS
(
SELECT
[execution_time]
,  [database_name]
,  [schema_name]
,  [table_name]
,  [two_part_name]
,  [node_table_name]
,  [node_table_name_seq]
,  [distribution_policy_name]
,  [distribution_column]
,  [distribution_id]
,  [index_type]
,  [index_type_desc]
,  [pdw_node_id]
,  [pdw_node_type]
,  [pdw_node_name]
,  [dist_name]
,  [dist_position]
,  [partition_nmbr]
,  [reserved_space_page_count]
,  [unused_space_page_count]
,  [data_space_page_count]
,  [index_space_page_count]
,  [row_count]
,  ([reserved_space_page_count] * 8.0)                                  AS [reserved_space_KB]
,  ([reserved_space_page_count] * 8.0)/1000                             AS [reserved_space_MB]
,  ([reserved_space_page_count] * 8.0)/1000000                          AS [reserved_space_GB]
,  ([reserved_space_page_count] * 8.0)/1000000000                       AS [reserved_space_TB]
,  ([unused_space_page_count]   * 8.0)                                  AS [unused_space_KB]
,  ([unused_space_page_count]   * 8.0)/1000                             AS [unused_space_MB]
,  ([unused_space_page_count]   * 8.0)/1000000                          AS [unused_space_GB]
,  ([unused_space_page_count]   * 8.0)/1000000000                       AS [unused_space_TB]
,  ([data_space_page_count]     * 8.0)                                  AS [data_space_KB]
,  ([data_space_page_count]     * 8.0)/1000                             AS [data_space_MB]
,  ([data_space_page_count]     * 8.0)/1000000                          AS [data_space_GB]
,  ([data_space_page_count]     * 8.0)/1000000000                       AS [data_space_TB]
,  ([index_space_page_count]  * 8.0)                                    AS [index_space_KB]
,  ([index_space_page_count]  * 8.0)/1000                               AS [index_space_MB]
,  ([index_space_page_count]  * 8.0)/1000000                            AS [index_space_GB]
```

```
,   ([index_space_page_count]  * 8.0)/1000000000                    AS [index_space_TB]
FROM base
)
SELECT *
FROM size
```

Take a moment to analyze the script above. You have encountered already some of the tables in the previous lab. Here is a short description of the tables and DMVs involved in the query:

Table Name	Description
sys.schemas	All schemas in the database.
sys.tables	All tables in the database.
sys.indexes	All indexes in the database.
sys.columns	All columns in the database.
sys.pdw_table_mappings	Maps each table to local tables on physical nodes and distributions.
sys.pdw_nodes_tables	Contains information on each local table in each distribution.
sys.pdw_table_distribution_properties	Holds distribution information for tables (the type of distribution tables have).
sys.pdw_column_distribution_properties	Holds distribution information for columns. Filtered to include only columns used to distribute their parent tables (`distribution_ordinal` = 1).
sys.pdw_distributions	Holds information about the distributions from the SQL pool.
sys.dm_pdw_nodes	Holds information about the nodes from the SQL pool. Filtered to include only compute nodes (`type` = `COMPUTE`).
sys.dm_pdw_nodes_db_partition_stats	Returns page and row-count information for every partition in the current database.

2. Run the following script to view the details about the structure of the tables in the `wwi_perf` schema:

```
SELECT
    database_name
,    schema_name
,    table_name
,    distribution_policy_name
,      distribution_column
,    index_type_desc
,    COUNT(distinct partition_nmbr) as nbr_partitions
,    SUM(row_count)                 as table_row_count
,    SUM(reserved_space_GB)         as table_reserved_space_GB
,    SUM(data_space_GB)             as table_data_space_GB
,    SUM(index_space_GB)            as table_index_space_GB
,    SUM(unused_space_GB)           as table_unused_space_GB
FROM
    [wwi_perf].[vTableSizes]
WHERE
    schema_name = 'wwi_perf'
GROUP BY
    database_name
,    schema_name
,    table_name
,    distribution_policy_name
,      distribution_column
,    index_type_desc
ORDER BY
    table_reserved_space_GB desc
```

Analyze the results:

Results Messages

View Table Chart Export results

Search

Table_name	Distribution_policy_name	Distribution_column	Index_type_desc	Nbr_partitions	Table_row_count	Table_reserved_space_GB	Table_data_space_GB	Table_index_space_GB	Table_unused_...
Sale_Heap	ROUND_ROBIN	NULL	HEAP	1	339507246	16.953792000	16.945032000	0.001920000	0.006840000
Sale_Index	HASH	CustomerId	CLUSTERED	1	339507246	16.328832000	16.290816000	0.036024000	0.001992000
Sale_Hash_Projection	HASH	CustomerId	HEAP	1	339507246	8.966160000	8.419872000	0.001920000	0.544368000
Sale_Hash_Projection_Big	HASH	CustomerId	HEAP	1	339507246	8.286528000	8.278008000	0.001920000	0.006600000
Sale_Partition01	HASH	CustomerId	CLUSTERED COLUMNSTORE	13	340573898	7.109392000	7.048424000	0.002752000	0.058216000
Sale_Partition02	HASH	CustomerId	CLUSTERED COLUMNSTORE	5	339507246	6.392968000	6.376168000	0.000000000	0.016800000
Sale_Hash	HASH	CustomerId	CLUSTERED COLUMNSTORE	1	339507246	6.198184000	6.194824000	0.000000000	0.003360000
Sale_Hash_Ordered	HASH	CustomerId	CLUSTERED COLUMNSTORE	1	339507246	6.038936000	6.035576000	0.000000000	0.003360000

Notice the significant difference between the space used by `CLUSTERED COLUMNSTORE` and `HEAP` or `CLUSTERED` tables. This provides a clear indication on the significant advantages columnstore indexes have.

Also notice the slight increase of storage space for ordered CCI table (`Sale_Hash_Ordered`).

Exercise 2 - Understand column store storage details

Task 1 - Create view for column store row group stats

1. Run the following query to create the `vColumnStoreRowGroupStats`:

```
create view [wwi_perf].[vColumnStoreRowGroupStats]
as
with cte
as
(
select   tb.[name]                    AS [logical_table_name]
,        rg.[row_group_id]            AS [row_group_id]
,        rg.[state]                   AS [state]
,        rg.[state_desc]              AS [state_desc]
,        rg.[total_rows]              AS [total_rows]
,        rg.[trim_reason_desc]        AS trim_reason_desc
,        mp.[physical_name]           AS physical_name
FROM    sys.[schemas] sm
JOIN    sys.[tables] tb               ON  sm.[schema_id]          = tb.[schema_id]
JOIN    sys.[pdw_table_mappings] mp   ON  tb.[object_id]          = mp.[object_id]
JOIN    sys.[pdw_nodes_tables] nt     ON  nt.[name]               = mp.[physical_name]
JOIN    sys.[dm_pdw_nodes_db_column_store_row_group_physical_stats] rg      ON  rg.[object_id]
= nt.[object_id]
                                                                            AND rg.[pdw_node_id]
= nt.[pdw_node_id]
                                       AND rg.[distribution_id]    = nt.[distribution_id]
)
select *
from cte;
```

In this query we are using the `sys.dm_pdw_nodes_db_column_store_row_group_physical_stats` DMV which provides current rowgroup-level information about all of the columnstore indexes in the current database.

The `state_desc` column provides useful information on the state of a row group:

Name	Description
`INVISIBLE`	A rowgroup which is being compressed.
`OPEN`	A deltastore rowgroup that is accepting new rows. It is important to remember that an open rowgroup is still in rowstore format and has not been compressed to columnstore format.
`CLOSED`	A deltastore rowgroup that contains the maximum number of rows, and is waiting for the tuple mover process to compress it to the columnstore.
`COMPRESSED`	A row group that is compressed with columnstore compression and stored in the columnstore.
`TOMBSTONE`	A row group that was formerly in the deltastore and is no longer used.

The `trim_reason_desc` column describes the reason that triggered the `COMPRESSED` rowgroup to have less than the maximum number of rows:

Name	Description
`UNKNOWN_UPGRADED_FROM_PREVIOUS_VERSION`	Occurred when upgrading from the previous version of SQL Server.
`NO_TRIM`	The row group was not trimmed. The row group was compressed with the maximum of 1,048,476 rows. The number of rows could be less if a subset of rows was deleted after delta rowgroup was closed.
`BULKLOAD`	The bulk-load batch size limited the number of rows. This is what you should be looking for when optimizing data loading, as it is an indicator of resource starvation during the loading process.
`REORG`	Forced compression as part of REORG command.
`DICTIONARY_SIZE`	Dictionary size grew too large to compress all of the rows together.
`MEMORY_LIMITATION`	Not enough available memory to compress all the rows together.
`RESIDUAL_ROW_GROUP`	Closed as part of last row group with rows < 1 million during index build operation.

Task 2 - Explore column store storage details

1. Explore the statistics of the columnstore for the `Sale_Partition01` table using the following query:

```sql
SELECT
    *
FROM
    [wwi_perf].[vColumnStoreRowGroupStats]
WHERE
    Logical_Table_Name = 'Sale_Partition01'
```

2. Explore the results of the query:

Results Messages

View Table Chart Export results

Search

Logical_table_name	Row_group_id	State	State_desc	Total_rows	Trim_reason_desc	Physical_name
Sale_Partition01	0	3	COMPRESSED	149822	BULKLOAD	Table_5a8866f1e9624ff49526ebf0251a91e7_23
Sale_Partition01	1	3	COMPRESSED	113318	BULKLOAD	Table_5a8866f1e9624ff49526ebf0251a91e7_25
Sale_Partition01	5	3	COMPRESSED	184746	AUTO_MERGE	Table_5a8866f1e9624ff49526ebf0251a91e7_26
Sale_Partition01	3	3	COMPRESSED	112351	BULKLOAD	Table_5a8866f1e9624ff49526ebf0251a91e7_27
Sale_Partition01	4	3	COMPRESSED	78682	REORG	Table_5a8866f1e9624ff49526ebf0251a91e7_28
Sale_Partition01	4	3	COMPRESSED	82663	REORG	Table_5a8866f1e9624ff49526ebf0251a91e7_30
Sale_Partition01	3	3	COMPRESSED	149717	BULKLOAD	Table_5a8866f1e9624ff49526ebf0251a91e7_31
Sale_Partition01	1	3	COMPRESSED	110873	BULKLOAD	Table_5a8866f1e9624ff49526ebf0251a91e7_33
Sale_Partition01	0	3	COMPRESSED	125922	BULKLOAD	Table_5a8866f1e9624ff49526ebf0251a91e7_34
Sale_Partition01	2	3	COMPRESSED	105846	BULKLOAD	Table_5a8866f1e9624ff49526ebf0251a91e7_35
Sale_Partition01	2	3	COMPRESSED	139054	BULKLOAD	Table_5a8866f1e9624ff49526ebf0251a91e7_36
Sale_Partition01	1	1	OPEN	78635	NULL	Table_5a8866f1e9624ff49526ebf0251a91e7_37
Sale_Partition01	0	3	COMPRESSED	119465	BULKLOAD	Table_5a8866f1e9624ff49526ebf0251a91e7_38
Sale_Partition01	4	3	COMPRESSED	94810	REORG	Table_5a8866f1e9624ff49526ebf0251a91e7_39

Browse through the results and get an overview of the rowgroup states. Notice the `COMPRESSED` and `OPEN` states of some of the row groups.

3. Explore the statistics of the columnstore for the `Sale_Hash_Ordered` table using the same query:

```sql
SELECT
    *
FROM
    [wwi_perf].[vColumnStoreRowGroupStats]
WHERE
    Logical_Table_Name = 'Sale_Hash_Ordered'
```

4. Explore the results of the query:

Logical_table_name	Row_group_id	State	State_desc	Total_rows	Trim_reason_desc	Physical_name
Sale_Hash_Ordered	5	3	COMPRESSED	397731	BULKLOAD	Table_426afa17d3444d18b5173cbec7ae54a5_58
Sale_Hash_Ordered	5	3	COMPRESSED	454797	BULKLOAD	Table_426afa17d3444d18b5173cbec7ae54a5_59
Sale_Hash_Ordered	5	3	COMPRESSED	402974	BULKLOAD	Table_426afa17d3444d18b5173cbec7ae54a5_60
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_426afa17d3444d18b5173cbec7ae54a5_1
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_426afa17d3444d18b5173cbec7ae54a5_2
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_426afa17d3444d18b5173cbec7ae54a5_3
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_426afa17d3444d18b5173cbec7ae54a5_4
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_426afa17d3444d18b5173cbec7ae54a5_5
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_426afa17d3444d18b5173cbec7ae54a5_6
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_426afa17d3444d18b5173cbec7ae54a5_7
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_426afa17d3444d18b5173cbec7ae54a5_8
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_426afa17d3444d18b5173cbec7ae54a5_9
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_426afa17d3444d18b5173cbec7ae54a5_10

There is a significant difference in the rowgroup states from the previous one. This highlights one of the potential advantages of ordered CCIs.

Exercise 3 - Study the impact of wrong choices for column data types

Task 1 - Create and populate tables with optimal column data types

Use the following query to create two tables (`Sale_Hash_Projection` and `Sale_Hash_Projection2`) which contain a subset of the columns from `Sale_Heap`:

```sql
CREATE TABLE [wwi_perf].[Sale_Hash_Projection]
WITH
(
    DISTRIBUTION = HASH ( [CustomerId] ),
    HEAP
)
AS
SELECT
    [CustomerId]
    ,[ProductId]
    ,[Quantity]
FROM
    [wwi_perf].[Sale_Heap]

CREATE TABLE [wwi_perf].[Sale_Hash_Projection2]
WITH
(
    DISTRIBUTION = HASH ( [CustomerId] ),
    CLUSTERED COLUMNSTORE INDEX
)
AS
SELECT
    [CustomerId]
    ,[ProductId]
    ,[Quantity]
FROM
    [wwi_perf].[Sale_Heap]
```

The query should finish execution in a few minutes.

Task 2 - Create and populate tables with sub-optimal column data types

Use the following query to create two additional tables (`Sale_Hash_Projection_Big` and `Sale_Hash_Projection_Big2`) that have the same columns, but with different (sub_optimal) data types:

```sql
CREATE TABLE [wwi_perf].[Sale_Hash_Projection_Big]
WITH
(
    DISTRIBUTION = HASH ( [CustomerId] ),
    HEAP
)
AS
SELECT
    [CustomerId]
    ,CAST([ProductId] as bigint) as [ProductId]
    ,CAST([Quantity] as bigint) as [Quantity]
FROM
    [wwi_perf].[Sale_Heap]

CREATE TABLE [wwi_perf].[Sale_Hash_Projection_Big2]
WITH
(
    DISTRIBUTION = HASH ( [CustomerId] ),
    CLUSTERED COLUMNSTORE INDEX
)
AS
SELECT
    [CustomerId]
    ,CAST([ProductId] as bigint) as [ProductId]
    ,CAST([Quantity] as bigint) as [Quantity]
FROM
    [wwi_perf].[Sale_Heap]
```

Task 3 - Compare storage requirements

1. Verify that the four tables have the same number of rows (there should be 339,507,246 rows in each):

```
SELECT 'Sale_Hash_Projection', COUNT_BIG(*) FROM [wwi_perf].[Sale_Hash_Projection]
UNION
SELECT 'Sale_Hash_Projection2', COUNT_BIG(*) FROM [wwi_perf].[Sale_Hash_Projection2]
UNION
SELECT 'Sale_Hash_Projection_Big', COUNT_BIG(*) FROM [wwi_perf].[Sale_Hash_Projection_Big]
UNION
SELECT 'Sale_Hash_Projection_Big2', COUNT_BIG(*) FROM [wwi_perf].[Sale_Hash_Projection_Big2]
```

2. Run the following query to compare the storage requirements for the three tables:

```
SELECT
    database_name
,    schema_name
,    table_name
,    distribution_policy_name
,      distribution_column
,    index_type_desc
,    COUNT(distinct partition_nmbr) as nbr_partitions
,    SUM(row_count)                 as table_row_count
,    SUM(reserved_space_GB)         as table_reserved_space_GB
,    SUM(data_space_GB)             as table_data_space_GB
,    SUM(index_space_GB)            as table_index_space_GB
,    SUM(unused_space_GB)           as table_unused_space_GB
FROM
    [wwi_perf].[vTableSizes]
WHERE
    schema_name = 'wwi_perf'
    and table_name in ('Sale_Hash_Projection', 'Sale_Hash_Projection2',
        'Sale_Hash_Projection_Big', 'Sale_Hash_Projection_Big2')
GROUP BY
    database_name
,    schema_name
,    table_name
,    distribution_policy_name
,      distribution_column
,    index_type_desc
ORDER BY
    table_reserved_space_GB desc
```

3. Analyze the results:

Results Messages

View Table Chart Export results

Search

Table_name	Distribution_policy...	Distribution_column	Index_type_desc	Nbr_partitions	Table_row_count	Table_reserved_space_GB	Table_data_space_GB
Sale_Hash_Projection	HASH	CustomerId	HEAP	1	339507246	8.966160000	8.419872000
Sale_Hash_Projection_Big	HASH	CustomerId	HEAP	1	339507246	8.286528000	8.278008000
Sale_Hash_Projection_Big2	HASH	CustomerId	CLUSTERED COLUMNSTORE	1	339507246	1.099120000	1.095760000
Sale_Hash_Projection2	HASH	CustomerId	CLUSTERED COLUMNSTORE	1	339507246	1.099120000	1.095760000

There are two important conclusions to draw here:

- In the case of `HEAP` tables, the storage impact of using `BIGINT` instead of `SMALLINT`(for `ProductId`) and `TINYINT` (for `QUANTITY`) is almost 1 GB (0.8941 GB). We're talking here about only two columns and a moderate number of rows (2.9 billion).
- Even in the case of `CLUSTERED COLUMNSTORE` tables, where compression will offset some of the differences, there is still a difference of 12.7 MB.

Minimizing the size of data types shortens the row length, which leads to better query performance. Use the smallest data type that works for your data:

- Avoid defining character columns with a large default length. For example, if the longest value is 25 characters, then define your column as VARCHAR(25).
- Avoid using [NVARCHAR][NVARCHAR] when you only need VARCHAR.
- When possible, use NVARCHAR(4000) or VARCHAR(8000) instead of NVARCHAR(MAX) or VARCHAR(MAX).

> **Note**
>
> If you are using PolyBase external tables to load your SQL pool tables, the defined length of the table row cannot exceed 1 MB. When a row with variable-length data exceeds 1 MB, you can load the row with BCP, but not with PolyBase.

Exercise 4 - Study the impact of materialized views

Task 1 - Analyze the execution plan of a query

1. Run again the query to find the number of customers in each bucket of per-customer transaction items counts:

```
SELECT
    T.TransactionItemsCountBucket
    ,count(*) as CustomersCount
FROM
    (
        SELECT
            CustomerId,
            (count(*) - 184) / 100 as TransactionItemsCountBucket
        FROM
            [wwi_perf].[Sale_Hash]
        GROUP BY
            CustomerId
    ) T
GROUP BY
    T.TransactionItemsCountBucket
ORDER BY
    T.TransactionItemsCountBucket
```

2. Improve the query by adding support to calculate the lower margin of the first per-customer transactions items count bucket:

```
SELECT
    T.TransactionItemsCountBucket
    ,count(*) as CustomersCount
FROM
    (
        SELECT
            CustomerId,
            (
                COUNT(*) -
                (
                    SELECT
                        MIN(TransactionItemsCount)
                    FROM
                    (
                        SELECT
                            COUNT(*) as TransactionItemsCount
                        FROM
                            [wwi_perf].[Sale_Hash]
                        GROUP BY
                            CustomerId
                    ) X
                )
            ) / 100 as TransactionItemsCountBucket
        FROM
            [wwi_perf].[Sale_Hash]
        GROUP BY
            CustomerId
    ) T
GROUP BY
    T.TransactionItemsCountBucket
ORDER BY
    T.TransactionItemsCountBucket
```

Task 2 - Improve the execution plan of the query with a materialized view

1. Run the query with the `EXPLAIN` directive (note the `WITH_RECOMMENDATIONS` option as well):

```sql
EXPLAIN WITH_RECOMMENDATIONS
SELECT
    T.TransactionItemsCountBucket
    ,count(*) as CustomersCount
FROM
    (
        SELECT
            CustomerId,
            (
                COUNT(*) -
                (
                    SELECT
                        MIN(TransactionItemsCount)
                    FROM
                    (
                        SELECT
                            COUNT(*) as TransactionItemsCount
                        FROM
                            [wwi_perf].[Sale_Hash]
                        GROUP BY
                            CustomerId
                    ) X
                )
            ) / 100 as TransactionItemsCountBucket
        FROM
            [wwi_perf].[Sale_Hash]
        GROUP BY
            CustomerId
    ) T
GROUP BY
    T.TransactionItemsCountBucket
ORDER BY
    T.TransactionItemsCountBucket
```

2. Analyze the resulting execution plan. Take a close look to the `<materialized_view_candidates>` section which suggests possible materialized views you can create to improve the performance of the query.

```xml
<?xml version="1.0" encoding="utf-8"?>
<dsql_query number_nodes="5" number_distributions="60" number_distributions_per_node="12">
<sql>SELECT
    T.TransactionItemsCountBucket
    ,count(*) as CustomersCount
FROM
    (
        SELECT
            CustomerId,
            (
                COUNT(*) -
                (
                    SELECT
                        MIN(TransactionItemsCount)
                    FROM
                    (
                        SELECT
                            COUNT(*) as TransactionItemsCount
                        FROM
                            [wwi_perf].[Sale_Hash]
                        GROUP BY
                            CustomerId
                    ) X
                )
            ) / 100 as TransactionItemsCountBucket
        FROM
            [wwi_perf].[Sale_Hash]
        GROUP BY
            CustomerId
    ) T
GROUP BY
    T.TransactionItemsCountBucket
```

```
ORDER BY
    T.TransactionItemsCountBucket</sql>
<materialized_view_candidates>
    <materialized_view_candidates with_constants="False">CREATE MATERIALIZED VIEW View1 WITH
(DISTRIBUTION = HASH([Expr0])) AS
SELECT [SQLPool01].[wwi_perf].[Sale_Hash].[CustomerId] AS [Expr0],
    COUNT(*) AS [Expr1]
FROM [wwi_perf].[Sale_Hash]
GROUP BY [SQLPool01].[wwi_perf].[Sale_Hash].[CustomerId]</materialized_view_candidates>
</materialized_view_candidates>
<dsql_operations total_cost="0.0242811172881356" total_number_operations="9">
    <dsql_operation operation_type="RND_ID">
    <identifier>TEMP_ID_99</identifier>
    </dsql_operation>
    <dsql_operation operation_type="ON">
    <location permanent="false" distribution="AllComputeNodes" />
    <sql_operations>
        <sql_operation type="statement">CREATE TABLE [qtabledb].[dbo].[TEMP_ID_99] ([col] INT )
WITH(DISTRIBUTED_MOVE_FILE='');</sql_operation>
    </sql_operations>
    </dsql_operation>
    <dsql_operation operation_type="BROADCAST_MOVE">
    <operation_cost cost="0.00096" accumulative_cost="0.00096" average_rowsize="4" output_rows="1"
GroupNumber="69" />
    <source_statement>SELECT [T1_1].[col] AS [col] FROM (SELECT MIN([T2_1].[col]) AS [col] FROM
(SELECT COUNT(CAST ((0) AS INT)) AS [col], 0 AS [col1] FROM [SQLPool01].[wwi_perf].[Sale_Hash] AS
T3_1 GROUP BY [T3_1].[CustomerId]) AS T2_1 GROUP BY [T2_1].[col1]) AS T1_1
OPTION (MAXDOP 6, MIN_GRANT_PERCENT = [MIN_GRANT], DISTRIBUTED_MOVE(N''))</source_statement>
    <destination_table>[TEMP_ID_99]</destination_table>
    </dsql_operation>
    <dsql_operation operation_type="RND_ID">
    <identifier>TEMP_ID_100</identifier>
    </dsql_operation>
    <dsql_operation operation_type="ON">
    <location permanent="false" distribution="AllDistributions" />
    <sql_operations>
        <sql_operation type="statement">CREATE TABLE [qtabledb].[dbo].[TEMP_ID_100] ([col] INT,
[col1] BIGINT ) WITH(DISTRIBUTED_MOVE_FILE='');</sql_operation>
    </sql_operations>
    </dsql_operation>
    <dsql_operation operation_type="SHUFFLE_MOVE">
    <operation_cost cost="0.0233211172881356" accumulative_cost="0.0242811172881356"
average_rowsize="12" output_rows="95.5518" GroupNumber="75" />
    <source_statement>SELECT [T1_1].[col1] AS [col], [T1_1].[col] AS [col1] FROM (SELECT
COUNT_BIG(CAST ((0) AS INT)) AS [col], [T2_1].[col] AS [col1] FROM (SELECT (([T3_2].[col] - [T3_1].
[col]) / CAST ((100) AS INT)) AS [col] FROM (SELECT MIN([T4_1].[col]) AS [col] FROM [qtabledb].
[dbo].[TEMP_ID_99] AS T4_1) AS T3_1 INNER JOIN
(SELECT COUNT(CAST ((0) AS INT)) AS [col] FROM [SQLPool01].[wwi_perf].[Sale_Hash] AS T4_1 GROUP BY
[T4_1].[CustomerId]) AS T3_2
ON (0 = 0)) AS T2_1 GROUP BY [T2_1].[col]) AS T1_1
OPTION (MAXDOP 6, MIN_GRANT_PERCENT = [MIN_GRANT], DISTRIBUTED_MOVE(N''))</source_statement>
    <destination_table>[TEMP_ID_100]</destination_table>
    <shuffle_columns>col;</shuffle_columns>
    </dsql_operation>
    <dsql_operation operation_type="RETURN">
    <location distribution="AllDistributions" />
    <select>SELECT [T1_1].[col1] AS [col], [T1_1].[col] AS [col1] FROM (SELECT CONVERT (INT,
[T2_1].[col], 0) AS [col], [T2_1].[col1] AS [col1] FROM (SELECT ISNULL([T3_1].[col], CONVERT
(BIGINT, 0, 0)) AS [col], [T3_1].[col1] AS [col1] FROM (SELECT SUM([T4_1].[col1]) AS [col], [T4_1].
[col] AS [col1] FROM [qtabledb].[dbo].[TEMP_ID_100] AS T4_1 GROUP BY [T4_1].[col]) AS T3_1) AS
T2_1) AS T1_1 ORDER BY [T1_1].[col1] ASC
OPTION (MAXDOP 6, MIN_GRANT_PERCENT = [MIN_GRANT])</select>
    </dsql_operation>
    <dsql_operation operation_type="ON">
    <location permanent="false" distribution="AllDistributions" />
    <sql_operations>
        <sql_operation type="statement">DROP TABLE [qtabledb].[dbo].[TEMP_ID_100]</sql_operation>
    </sql_operations>
    </dsql_operation>
```

```
    <dsql_operation operation_type="ON">
    <location permanent="false" distribution="AllComputeNodes" />
    <sql_operations>
        <sql_operation type="statement">DROP TABLE [qtabledb].[dbo].[TEMP_ID_99]</sql_operation>
    </sql_operations>
    </dsql_operation>
</dsql_operations>
</dsql_query>
```

3. Create the suggested materialized view:

```
CREATE MATERIALIZED VIEW
    mvTransactionItemsCounts
WITH
(
    DISTRIBUTION = HASH([CustomerId])
)
AS
SELECT
    CustomerId
    ,COUNT(*) AS ItemsCount
FROM
    [wwi_perf].[Sale_Hash]
GROUP BY
    CustomerId
```

4. Check the execution plan again:

```
EXPLAIN WITH_RECOMMENDATIONS
SELECT
    T.TransactionItemsCountBucket
    ,count(*) as CustomersCount
FROM
    (
        SELECT
            CustomerId,
            (
                COUNT(*) -
                (
                    SELECT
                        MIN(TransactionItemsCount)
                    FROM
                    (
                        SELECT
                            COUNT(*) as TransactionItemsCount
                        FROM
                            [wwi_perf].[Sale_Hash]
                        GROUP BY
                            CustomerId
                    ) X
                )
            ) / 100 as TransactionItemsCountBucket
        FROM
            [wwi_perf].[Sale_Hash]
        GROUP BY
            CustomerId
    ) T
GROUP BY
    T.TransactionItemsCountBucket
ORDER BY
    T.TransactionItemsCountBucket
```

The resulting execution plan indicates now the use of the `mvTransactionItemsCounts` (the `BROADCAST_MOVE` distributed SQL operation) materialized view which provides improvements to the query execution time:

```
<?xml version="1.0" encoding="utf-8"?>
<dsql_query number_nodes="5" number_distributions="60" number_distributions_per_node="12">
<sql>SELECT
    T.TransactionItemsCountBucket
    ,count(*) as CustomersCount
```

```
FROM
    (
        SELECT
            CustomerId,
            (
                COUNT(*) -
                (
                    SELECT
                        MIN(TransactionItemsCount)
                    FROM
                    (
                        SELECT
                            COUNT(*) as TransactionItemsCount
                        FROM
                            [wwi_perf].[Sale_Hash]
                        GROUP BY
                            CustomerId
                    ) X
                )
            ) / 100 as TransactionItemsCountBucket
        FROM
            [wwi_perf].[Sale_Hash]
        GROUP BY
            CustomerId
    ) T
GROUP BY
    T.TransactionItemsCountBucket
ORDER BY
    T.TransactionItemsCountBucket</sql>
<materialized_view_candidates>
    <materialized_view_candidates with_constants="False">CREATE MATERIALIZED VIEW View1 WITH
(DISTRIBUTION = HASH([Expr0])) AS
SELECT [SQLPool01].[wwi_perf].[Sale_Hash].[CustomerId] AS [Expr0],
    COUNT(*) AS [Expr1]
FROM [wwi_perf].[Sale_Hash]
GROUP BY [SQLPool01].[wwi_perf].[Sale_Hash].[CustomerId]</materialized_view_candidates>
</materialized_view_candidates>
<dsql_operations total_cost="0.0242811172881356" total_number_operations="9">
    <dsql_operation operation_type="RND_ID">
    <identifier>TEMP_ID_111</identifier>
    </dsql_operation>
    <dsql_operation operation_type="ON">
    <location permanent="false" distribution="AllComputeNodes" />
    <sql_operations>
        <sql_operation type="statement">CREATE TABLE [qtabledb].[dbo].[TEMP_ID_111] ([col] INT )
WITH(DISTRIBUTED_MOVE_FILE='');</sql_operation>
    </sql_operations>
    </dsql_operation>
    <dsql_operation operation_type="BROADCAST_MOVE">
    <operation_cost cost="0.00096" accumulative_cost="0.00096" average_rowsize="4" output_rows="1"
GroupNumber="134" />
    <source_statement>SELECT [T1_1].[col] AS [col] FROM (SELECT MIN([T2_1].[col]) AS [col] FROM
(SELECT CONVERT (INT, [T3_1].[col], 0) AS [col], 0 AS [col1] FROM (SELECT ISNULL([T4_1].[col],
CONVERT (BIGINT, 0, 0)) AS [col] FROM (SELECT SUM([T5_1].[ItemsCount]) AS [col] FROM (SELECT
[T6_1].[CustomerId] AS [CustomerId], [T6_1].[ItemsCount] AS [ItemsCount] FROM [SQLPool01].[dbo].
[mvTransactionItemsCounts] AS T6_1) AS T5_1 GROUP BY [T5_1].[CustomerId]) AS T4_1) AS T3_1 WHERE
([T3_1].[col] != CAST ((0) AS BIGINT))) AS T2_1 GROUP BY [T2_1].[col1]) AS T1_1
OPTION (MAXDOP 6, MIN_GRANT_PERCENT = [MIN_GRANT], DISTRIBUTED_MOVE(N''))</source_statement>
    <destination_table>[TEMP_ID_111]</destination_table>
    </dsql_operation>
    <dsql_operation operation_type="RND_ID">
    <identifier>TEMP_ID_112</identifier>
    </dsql_operation>
    <dsql_operation operation_type="ON">
    <location permanent="false" distribution="AllDistributions" />
    <sql_operations>
        <sql_operation type="statement">CREATE TABLE [qtabledb].[dbo].[TEMP_ID_112] ([col] INT,
[col1] BIGINT ) WITH(DISTRIBUTED_MOVE_FILE='');</sql_operation>
    </sql_operations>
```

```
    </dsql_operation>
    <dsql_operation operation_type="SHUFFLE_MOVE">
    <operation_cost cost="0.0233211172881356" accumulative_cost="0.0242811172881356"
average_rowsize="12" output_rows="95.5518" GroupNumber="140" />
    <source_statement>SELECT [T1_1].[col1] AS [col], [T1_1].[col] AS [col1] FROM (SELECT
COUNT_BIG(CAST ((0) AS INT)) AS [col], [T2_1].[col] AS [col1] FROM (SELECT (([T3_2].[col] - [T3_1].
[col]) / CAST ((100) AS INT)) AS [col] FROM (SELECT MIN([T4_1].[col]) AS [col] FROM [qtabledb].
[dbo].[TEMP_ID_111] AS T4_1) AS T3_1 INNER JOIN
(SELECT CONVERT (INT, [T4_1].[col], 0) AS [col] FROM (SELECT ISNULL([T5_1].[col], CONVERT (BIGINT,
0, 0)) AS [col] FROM (SELECT SUM([T6_1].[ItemsCount]) AS [col] FROM (SELECT [T7_1].[CustomerId] AS
[CustomerId], [T7_1].[ItemsCount] AS [ItemsCount] FROM [SQLPool01].[dbo].[mvTransactionItemsCounts]
AS T7_1) AS T6_1 GROUP BY [T6_1].[CustomerId]) AS T5_1) AS T4_1 WHERE ([T4_1].[col] != CAST ((0) AS
BIGINT))) AS T3_2
ON (0 = 0)) AS T2_1 GROUP BY [T2_1].[col]) AS T1_1
OPTION (MAXDOP 6, MIN_GRANT_PERCENT = [MIN_GRANT], DISTRIBUTED_MOVE(N''))</source_statement>
    <destination_table>[TEMP_ID_112]</destination_table>
    <shuffle_columns>col;</shuffle_columns>
    </dsql_operation>
    <dsql_operation operation_type="RETURN">
    <location distribution="AllDistributions" />
    <select>SELECT [T1_1].[col1] AS [col], [T1_1].[col] AS [col1] FROM (SELECT CONVERT (INT,
[T2_1].[col], 0) AS [col], [T2_1].[col1] AS [col1] FROM (SELECT ISNULL([T3_1].[col], CONVERT
(BIGINT, 0, 0)) AS [col], [T3_1].[col1] AS [col1] FROM (SELECT SUM([T4_1].[col1]) AS [col], [T4_1].
[col] AS [col1] FROM [qtabledb].[dbo].[TEMP_ID_112] AS T4_1 GROUP BY [T4_1].[col]) AS T3_1) AS
T2_1) AS T1_1 ORDER BY [T1_1].[col1] ASC
OPTION (MAXDOP 6, MIN_GRANT_PERCENT = [MIN_GRANT])</select>
    </dsql_operation>
    <dsql_operation operation_type="ON">
    <location permanent="false" distribution="AllDistributions" />
    <sql_operations>
        <sql_operation type="statement">DROP TABLE [qtabledb].[dbo].[TEMP_ID_112]</sql_operation>
    </sql_operations>
    </dsql_operation>
    <dsql_operation operation_type="ON">
    <location permanent="false" distribution="AllComputeNodes" />
    <sql_operations>
        <sql_operation type="statement">DROP TABLE [qtabledb].[dbo].[TEMP_ID_111]</sql_operation>
    </sql_operations>
    </dsql_operation>
</dsql_operations>
</dsql_query>
```


Exercise 5 - Avoid extensive logging

Task 1 - Explore rules for minimally logged operations

The following operations are capable of being minimally logged:

- CREATE TABLE AS SELECT (CTAS)
- INSERT..SELECT
- CREATE INDEX
- ALTER INDEX REBUILD
- DROP INDEX
- TRUNCATE TABLE
- DROP TABLE
- ALTER TABLE SWITCH PARTITION

Minimal logging with bulk load

CTAS and INSERT...SELECT are both bulk load operations. However, both are influenced by the target table definition and depend on the load scenario. The following table explains when bulk operations are fully or minimally logged:

Primary Index	Load Scenario	Logging Mode
Heap	Any	**Minimal**
Clustered Index	Empty target table	**Minimal**
Clustered Index	Loaded rows do not overlap with existing pages in target	**Minimal**
Clustered Index	Loaded rows overlap with existing pages in target	Full
Clustered Columnstore Index	Batch size >= 102,400 per partition aligned distribution	**Minimal**

Clustered Columnstore Index	Batch size < 102,400 per partition aligned distribution	Full

It is worth noting that any writes to update secondary or non-clustered indexes will always be fully logged operations.

> **IMPORTANT**
>
> A Synapse Analytics SQL pool has 60 distributions. Therefore, assuming all rows are evenly distributed and landing in a single partition, your batch will need to contain 6,144,000 rows or larger to be minimally logged when writing to a Clustered Columnstore Index. If the table is partitioned and the rows being inserted span partition boundaries, then you will need 6,144,000 rows per partition boundary assuming even data distribution. Each partition in each distribution must independently exceed the 102,400 row threshold for the insert to be minimally logged into the distribution.

Loading data into a non-empty table with a clustered index can often contain a mixture of fully logged and minimally logged rows. A clustered index is a balanced tree (b-tree) of pages. If the page being written to already contains rows from another transaction, then these writes will be fully logged. However, if the page is empty then the write to that page will be minimally logged.

Task 2 - Optimizing a delete operation

1. Check the number of transaction items for customers with ids lower than 900000 using the following query:

```sql
SELECT
    COUNT_BIG(*) as TransactionItemsCount
FROM
    [wwi_perf].[Sale_Hash]
WHERE
    CustomerId < 900000
```

2. Implement a minimal logging approach to delete transaction items for customers with ids lower than 900000. Use the following CTAS query to isolate the transaction items that should be kept:

```sql
CREATE TABLE [wwi_perf].[Sale_Hash_v2]
WITH
(
    DISTRIBUTION = ROUND_ROBIN,
    HEAP
)
AS
SELECT
    *
FROM
    [wwi_perf].[Sale_Hash]
WHERE
    CustomerId >= 900000
```

   The query should execute within a few minutes. All that would remain to complete the process would be to delete the `Sale_Heap` table and rename `Sale_Heap_v2` to `Sale_Heap`.

3. Compare the previous operation with a classical delete:

```sql
DELETE
    [wwi_perf].[Sale_Hash]
WHERE
    CustomerId < 900000
```

> **Note**
>
> The query will run for a potentially long time. Once the time exceeds significantly the time to run the previous CTAS query, you can cancel it (as you can already see the benefit of the CTAS-based approach).