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');
```

ROWS	RESERVED_SPACE	DATA_SPACE	INDEX_SPACE	UNUSED_SPACE	PDW_NODE_ID	DISTRIBUTION_ID
48215156	888024	887968	0	56	1	1
48792088	898816	898576	16	224	1	2
48504871	893368	893312	0	56	1	3
48665340	896488	896280	16	192	1	4
48411421	892000	891776	16	208	1	5
48462408	893112	892880	16	216	1	6
48324164	895168	894744	72	352	1	7
48537552	894024	893792	16	216	1	8
48553774	893736	893520	16	200	1	9
48313655	890392	890336	0	56	1	10
48560050	894384	894152	16	216	1	11
48280358	891696	891280	40	376	1	12
48133061	886344	886120	16	208	1	13
48715018	897320	897112	16	192	1	14
48539358	894496	894264	16	216	1	15
41117947	761032	760840	16	176	2	16

00:00:00 Query executed successfully.

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
322127	9465
559682	9448
592004	9289
325395	9179
268885	9134
420390	9055
405722	8957
549076	8849
185880	8836
382373	8794
915880	8778
976729	8739
705332	8735
436059	8673
673714	8643

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
```

Results Messages

View Table Chart Export results

Search

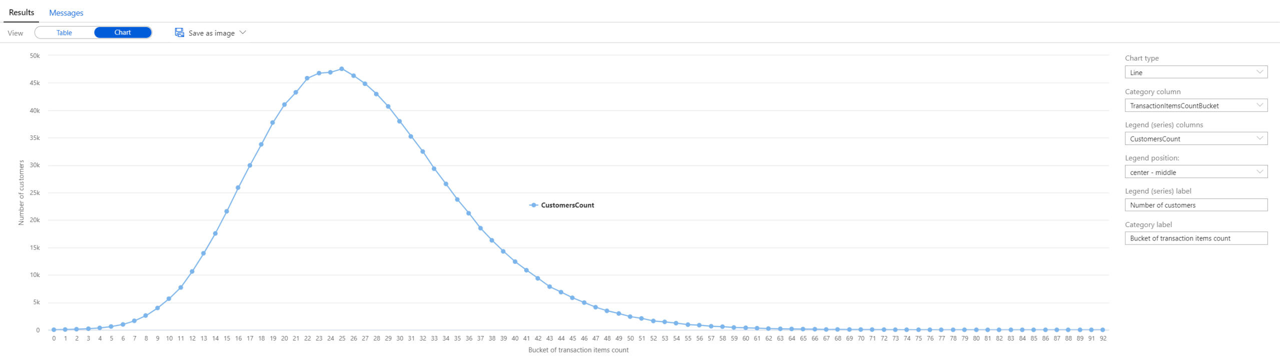
CUSTOMERID	TRANSACTIONITEMSCOUNT
98718	184
712472	203
606484	204
639663	211
630462	224
710198	226
725622	226
714291	228
169153	231
207561	232
897971	247
676782	249
242199	250
363701	254
49778	255

Notice the largest number of transaction items is 9465 and the smallest is 184.

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(*) - 184) / 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 cvasi-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
INNER JOIN sys.tables t
    ON s.[schema_id] = t.[schema_id]
```

```sql
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:

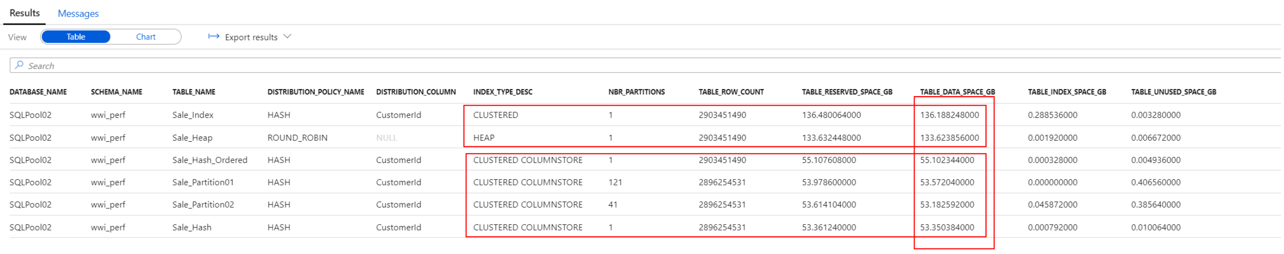
Table Name	Description
sys.schemas	All schemas in the database.
sys.tables	All tables in the database.
sys.indexes	All indexes in the database.
sys.columns	All columns in the database.
sys.pdw_table_mappings	Maps each table to local tables on physical nodes and distributions.
sys.pdw_nodes_tables	Contains information on each local table in each distribution.

Table Name	Description
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

DATABASE_NAME	SCHEMA_NAME	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_SPACE_GB
SQLPool02	wwi_perf	Sale_Index	HASH	CustomerId	CLUSTERED	1	2903451490	136.480064000	136.188248000	0.288536000	0.003280000
SQLPool02	wwi_perf	Sale_Heap	ROUND_ROBIN	NULL	HEAP	1	2903451490	133.632448000	133.623856000	0.001920000	0.006672000
SQLPool02	wwi_perf	Sale_Hash_Ordered	HASH	CustomerId	CLUSTERED COLUMNSTORE	1	2903451490	55.107608000	55.102344000	0.000328000	0.004936000
SQLPool02	wwi_perf	Sale_Partition01	HASH	CustomerId	CLUSTERED COLUMNSTORE	121	2896254531	53.978600000	53.572040000	0.000000000	0.406560000
SQLPool02	wwi_perf	Sale_Partition02	HASH	CustomerId	CLUSTERED COLUMNSTORE	41	2896254531	53.614104000	53.182592000	0.045872000	0.385640000
SQLPool02	wwi_perf	Sale_Hash	HASH	CustomerId	CLUSTERED COLUMNSTORE	1	2896254531	53.361240000	53.350384000	0.000792000	0.010064000

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:

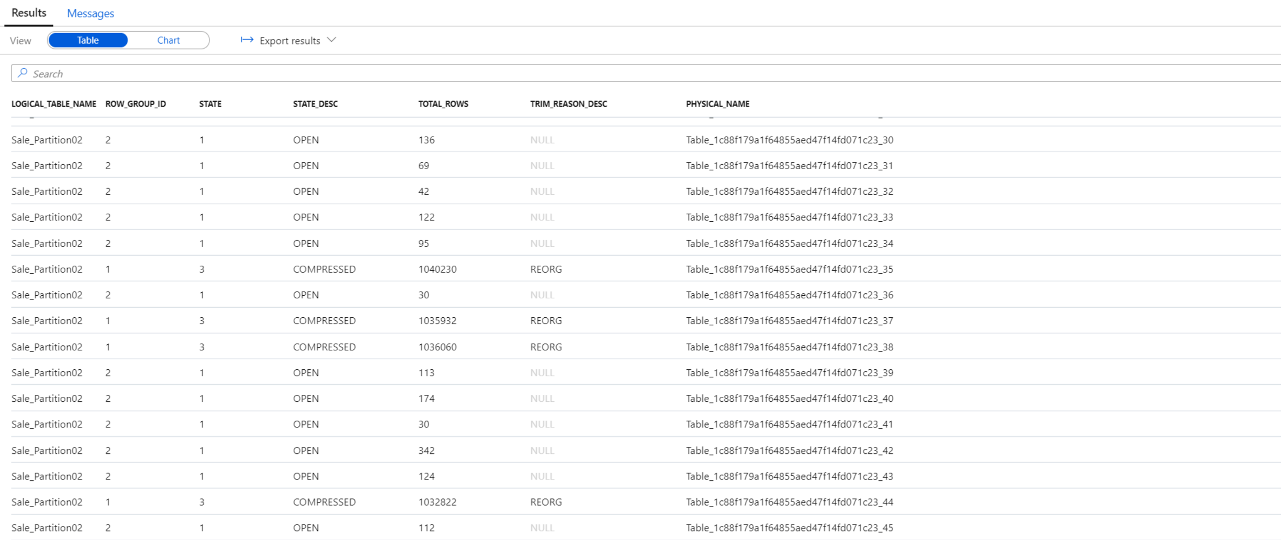
Name	Description
`UNKNOWN_UPGRADED_FROM_PREVIOUS_VERSION`	Occurred when upgrading from the previous version of SQL Server.
`NO_TRIM`	The row group was not trimmed. The row group was compressed with the maximum of 1,048,476 rows. The number of rows could be less if a subset of rows was deleted after delta 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_Partition02` table using the following query:

```
SELECT
    *
FROM
    [wwi_perf].[vColumnStoreRowGroupStats]
WHERE
    Logical_Table_Name = 'Sale_Partition02'
```

2. Explore the results of the query:



LOGICAL_TABLE_NAME	ROW_GROUP_ID	STATE	STATE_DESC	TOTAL_ROWS	TRIM_REASON_DESC	PHYSICAL_NAME
Sale_Partition02	2	1	OPEN	136	NULL	Table_1c88f179a1f64855aed47f14fd071c23_30
Sale_Partition02	2	1	OPEN	69	NULL	Table_1c88f179a1f64855aed47f14fd071c23_31
Sale_Partition02	2	1	OPEN	42	NULL	Table_1c88f179a1f64855aed47f14fd071c23_32
Sale_Partition02	2	1	OPEN	122	NULL	Table_1c88f179a1f64855aed47f14fd071c23_33
Sale_Partition02	2	1	OPEN	95	NULL	Table_1c88f179a1f64855aed47f14fd071c23_34
Sale_Partition02	1	3	COMPRESSED	1040230	REORG	Table_1c88f179a1f64855aed47f14fd071c23_35
Sale_Partition02	2	1	OPEN	30	NULL	Table_1c88f179a1f64855aed47f14fd071c23_36
Sale_Partition02	1	3	COMPRESSED	1035932	REORG	Table_1c88f179a1f64855aed47f14fd071c23_37
Sale_Partition02	1	3	COMPRESSED	1036060	REORG	Table_1c88f179a1f64855aed47f14fd071c23_38
Sale_Partition02	2	1	OPEN	113	NULL	Table_1c88f179a1f64855aed47f14fd071c23_39
Sale_Partition02	2	1	OPEN	174	NULL	Table_1c88f179a1f64855aed47f14fd071c23_40
Sale_Partition02	2	1	OPEN	30	NULL	Table_1c88f179a1f64855aed47f14fd071c23_41
Sale_Partition02	2	1	OPEN	342	NULL	Table_1c88f179a1f64855aed47f14fd071c23_42
Sale_Partition02	2	1	OPEN	124	NULL	Table_1c88f179a1f64855aed47f14fd071c23_43
Sale_Partition02	1	3	COMPRESSED	1032822	REORG	Table_1c88f179a1f64855aed47f14fd071c23_44
Sale_Partition02	2	1	OPEN	112	NULL	Table_1c88f179a1f64855aed47f14fd071c23_45

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:

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

4. 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_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_8be1fd5ccc3b435f90f9486d0afa462e_2
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_8be1fd5ccc3b435f90f9486d0afa462e_3
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_8be1fd5ccc3b435f90f9486d0afa462e_4
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_8be1fd5ccc3b435f90f9486d0afa462e_5
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_8be1fd5ccc3b435f90f9486d0afa462e_6
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_8be1fd5ccc3b435f90f9486d0afa462e_7
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_8be1fd5ccc3b435f90f9486d0afa462e_8
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_8be1fd5ccc3b435f90f9486d0afa462e_9
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_8be1fd5ccc3b435f90f9486d0afa462e_10
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_8be1fd5ccc3b435f90f9486d0afa462e_11
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_8be1fd5ccc3b435f90f9486d0afa462e_12
Sale_Hash_Ordered	3	3	COMPRESSED	1048576	NO_TRIM	Table_8be1fd5ccc3b435f90f9486d0afa462e_13
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_8be1fd5ccc3b435f90f9486d0afa462e_14
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_8be1fd5ccc3b435f90f9486d0afa462e_15
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_8be1fd5ccc3b435f90f9486d0afa462e_16
Sale_Hash_Ordered	4	3	COMPRESSED	1048576	NO_TRIM	Table_8be1fd5ccc3b435f90f9486d0afa462e_17

There is a significant difference in the rowgroup states from the previous one. This highlight 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`:

```
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:

```
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):

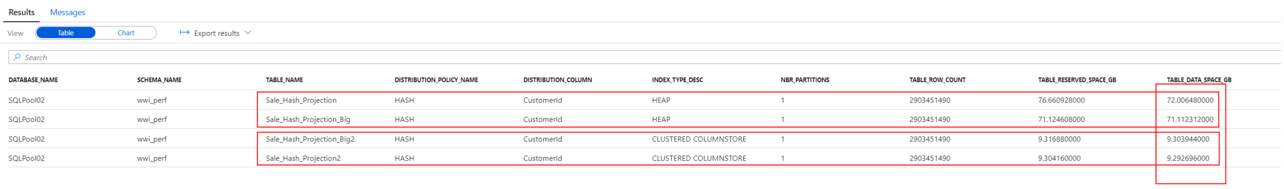
```
SELECT 'Sale_Hash_Projection', COUNT_BIG(*) FROM [wwi_perf].
[Sale_Hash_Projection]
UNION
SELECT 'Sale_Hash_Projection2', COUNT_BIG(*) FROM [wwi_perf].
[Sale_Hash_Projection]
UNION
SELECT 'Sale_Hash_Projection_Big', COUNT_BIG(*) FROM [wwi_perf].
```

```
[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:



DATABASE_NAME	SCHEMA_NAME	TABLE_NAME	DISTRIBUTION_POLICY_NAME	DISTRIBUTION_COLUMN	INDEX_TYPE_DESC	NBR_PARTITIONS	TABLE_ROW_COUNT	TABLE_RESERVED_SPACE_GB	TABLE_DATA_SPACE_GB
SQLPool02	wwi_perf	Sale_Hash_Projection	HASH	CustomerId	HEAP	1	2903451490	76.660928000	72.006480000
SQLPool02	wwi_perf	Sale_Hash_Projection_Big	HASH	CustomerId	HEAP	1	2903451490	71.124608000	71.112312000
SQLPool02	wwi_perf	Sale_Hash_Projection_Big2	HASH	CustomerId	CLUSTERED COLUMNSTORE	1	2903451490	9.316880000	9.303944000
SQLPool02	wwi_perf	Sale_Hash_Projection2	HASH	CustomerId	CLUSTERED COLUMNSTORE	1	2903451490	9.304160000	9.292696000

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):

```
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 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 [SQLPool02].[wwi_perf].[Sale_Hash].[CustomerId] AS [Expr0],
    COUNT(*) AS [Expr1]
FROM [wwi_perf].[Sale_Hash]
GROUP BY [SQLPool02].[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 [SQLPool02].[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 [SQLPool02].[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:

```sql
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 [SQLPool02].[wwi_perf].[Sale_Hash].[CustomerId] AS [Expr0],
    COUNT(*) AS [Expr1]
FROM [wwi_perf].[Sale_Hash]
GROUP BY [SQLPool02].[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">
```

```xml
    <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
[SQLPool02].[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 [SQLPool02].[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

Primary Index	Load Scenario	Logging Mode
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:

```
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:

```
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:

```
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).