Materialized Query Tables: The Key Ingredient

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Agenda

- What are MQTs
- Populating and maintaining MQTs
- MQT Strategy
- Tools to help
- Misc considerations

What are MQTs

Fundamental Idea

Save the results of a query, to reuse….
Instead of rerunning the query again.

Save the results in a permanent SQLTable

Description

- By running the appropriate aggregate query one time and storing the results in an SQL table to be reused for subsequent queries
  - **it is possible to enhance query performance significantly.**
  - **It is possible to REDUCE resource impact of query processing**
- MQTs can improve response time for complex SQL queries, especially queries that involve some of the following:
  - Aggregated or summarized data that covers one or more subject areas
  - Joined and aggregated data covering a set of tables
  - Commonly accessed subset of rows

Creating an MQT

```
CREATE TABLE Sale_Geo_Reg_YR_MON _MQT
  AS
  (SELECT  Geography,
           Region,
           Year,
           Month,
           SUM(Revenue) AS Total_Revenue,
           SUM(Quantity) AS Total_Quantity,
           COUNT(*) AS Rows_per_Group
     FROM Sales_Transaction
     GROUP BY Geography,
           Region,
           Year,
           Month)
DATA INITIALLY IMMEDIATE
REFRESH DEFERRED
ENABLE QUERY OPTIMIZATION
MAINTAINED BY USER;
```

Geography, Region, Year, Month, total_revenue, Total_Quanitity and Rows_per_Group are COLUMNS in the new table SALE_GEO_REG_YR_MON_ MQT

Base versus MQT

- Sales_transaction has 10 billion rows
  - 10 Geographies, 4 regions per geo, 3 years of data.
  - 200 bytes each = 2,000,000,000,000
- Sale_GEO_REG_YR_MON_MQT
  - 10 *4* 3* 12 = 1440 rows
  - ~ 40 bytes per row = 57,600

What are MQTs cont.

- Or, any **other query** that could be answered using those results

Queries allowed to use that MQT

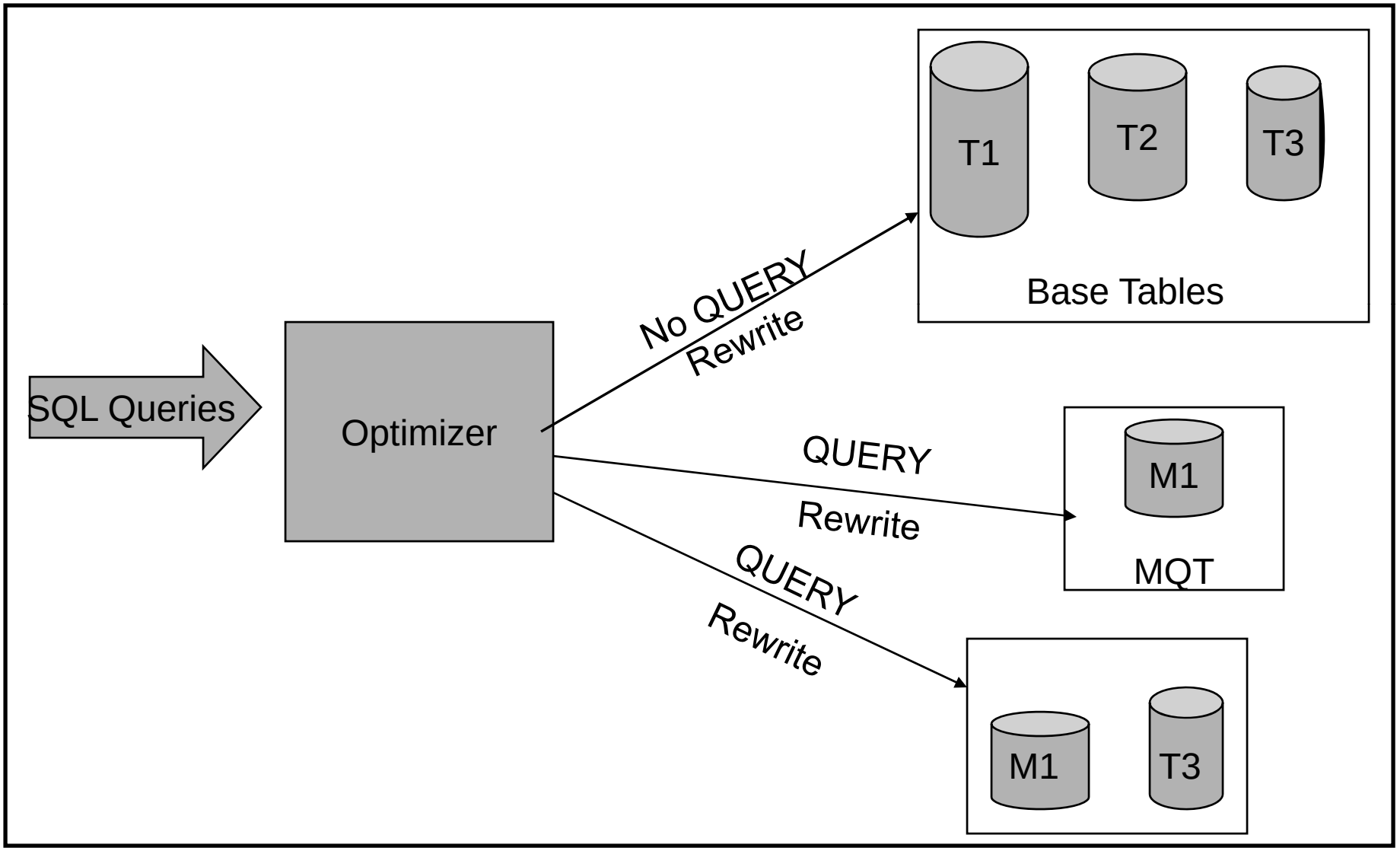
```
SELECT Geography, Region,    Year,
   Month,
      SUM(Revenue) AS Total_Revenue,
      SUM(Quantity) AS Total_Quantity,
 FROM Sales_Transaction
GROUP BY Geography,
                Region,
                Year,
                Month;
```

```
SELECT Geography, Year,
 SUM(Revenue) AS Total_Revenue,
 SUM(Quantity) AS Total_Quantity,
FROM Sales_Transaction
WHERE Year IN (2004, 2005)
GROUP BY Geography, Year;
```

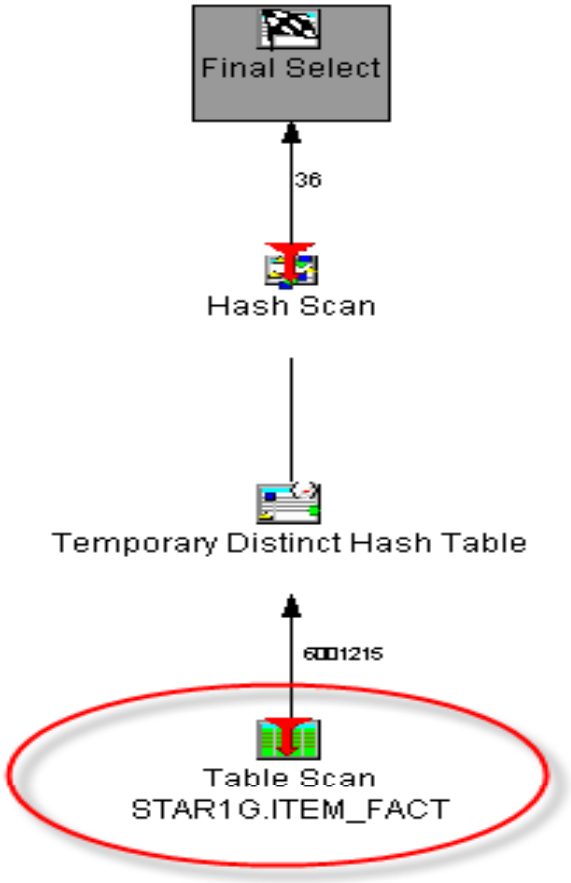
```
SELECT Geography, Region,
AVG(Revenue) AS Avg_Revenue,
AVG(Quantity) AS Avg_Quantity,
FROM SALES_Transaction
GROUP BY Geography
Region;
```

```
SELECT Year, Month,
      SUM(Revenue) AS Total_Revenue,
      SUM(Quantity) AS Total_Quantity,
 FROM Sales_Transaction
WHERE MONTH= 12
GROUP BY  YEAR, Month
ORDER BY YEAR;
```

QUERY REWRITE



Query Rewrite Example

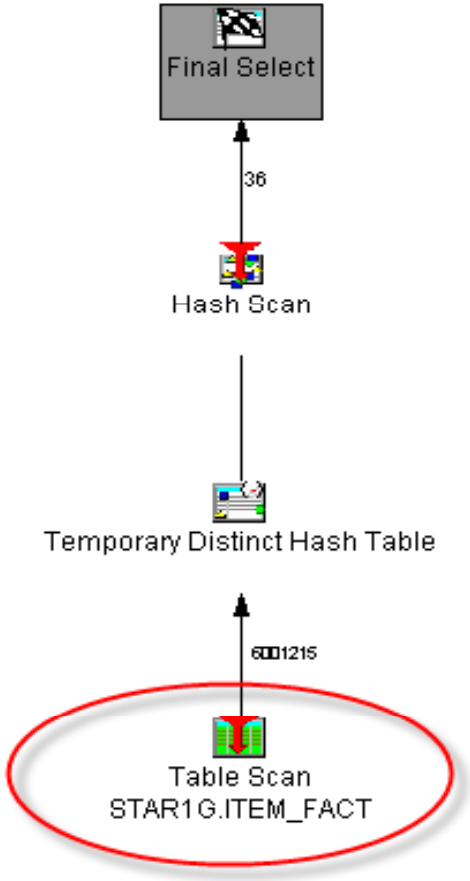



```
SELECT year, quarter, month,
        SUM(revenue_w_tax) AS srevenue_w_tax,
        SUM(revenue_wo_tax) AS srevenue_wo_tax,
        SUM(profit_w_tax) AS sprofit_w_tax,
        SUM(profit_wo_tax) AS sprofit_wo_tax,
        SUM(quantity) AS squantity,
        COUNT(*) as number_items_per_group
FROM    ITEM_FACT
GROUP BY year, quarter, month;
```

Without MQT...
Scan and aggregate
6,000,000 rows

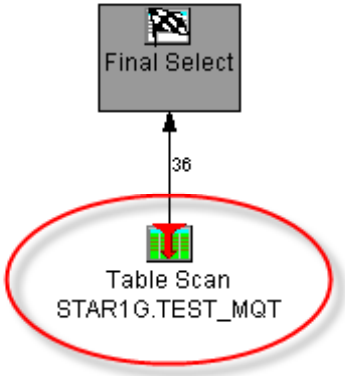
Query Rewrite Example

Before...




```
SELECT year, quarter, month,
        SUM(revenue_w_tax) AS srevenue_w_tax,
        SUM(revenue_wo_tax) AS srevenue_wo_tax,
        SUM(profit_w_tax) AS sprofit_w_tax,
        SUM(profit_wo_tax) AS sprofit_wo_tax,
        SUM(quantity) AS squantity,
        COUNT(*) as number_items_per_group
FROM    TEST_MQT
GROUP BY year, quarter, month;
```

Base table(s) replaced by MQT



Without MQT...
Scan and aggregate
6,000,000 rows

With MQT...
Scan 36 rows

MQTs and Join Queries

- You need to create MQTs so they can be used by Join Queries
  - Include the join in the MQT definition
  - OR, include the Join column in the MQT so that you can Join to it

Join Example

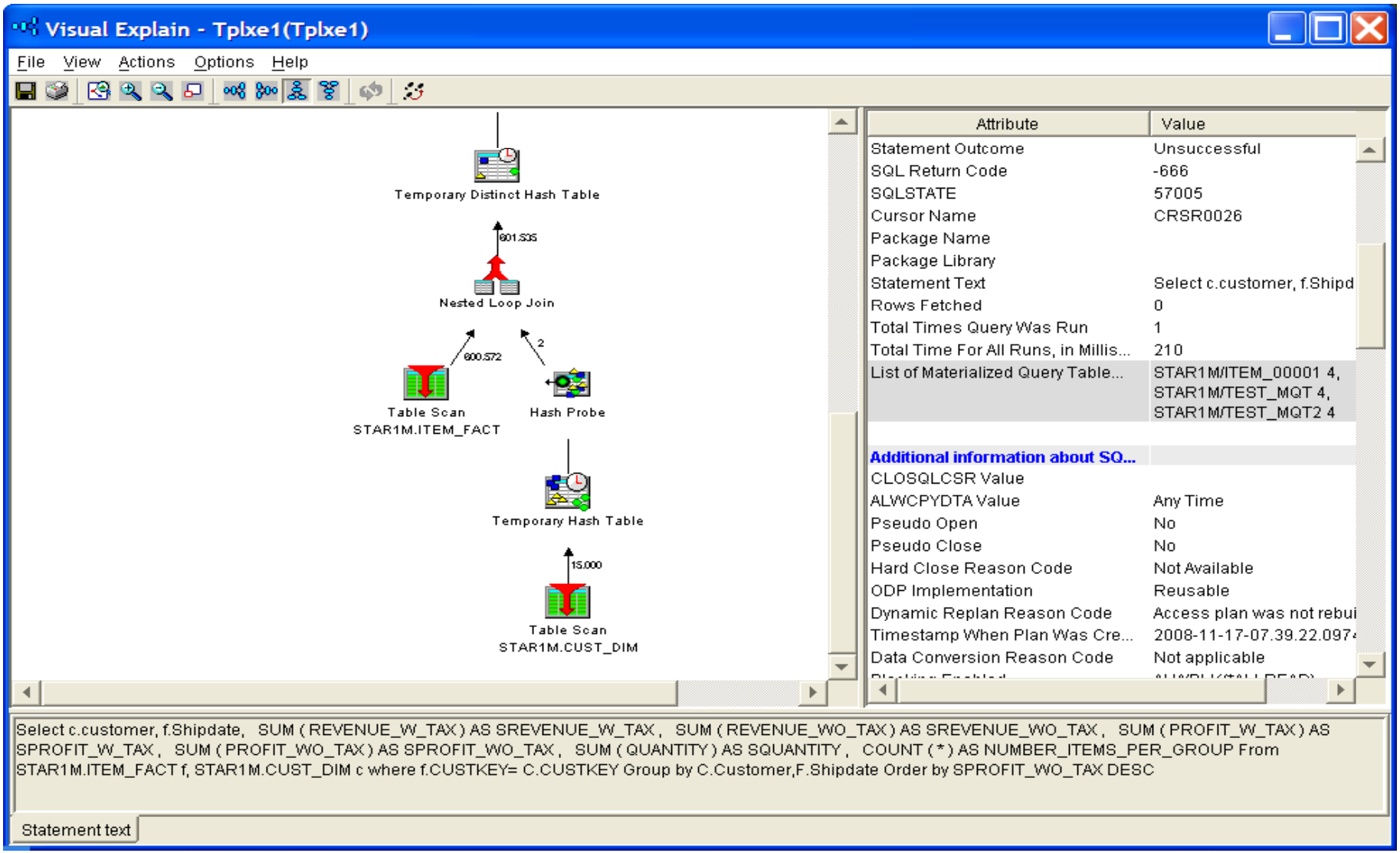
MQT

```
CREATE TABLE STAR1M.ITEM_REV_PROF_DAY
   AS (
   SELECT SHIPDATE , SUM ( REVENUE_W_TAX ) AS SREVENUE_W_TAX ,
   SUM ( REVENUE_WO_TAX ) AS SREVENUE_WO_TAX ,
   SUM ( PROFIT_W_TAX ) AS SPROFIT_W_TAX ,
   SUM ( PROFIT_WO_TAX ) AS SPROFIT_WO_TAX , SUM ( QUANTITY ) AS SQUANTITY ,
   COUNT ( * ) AS NUMBER_ITEMS_PER_GROUP

   FROM STAR1M.ITEM_FACT
   GROUP BY SHIPDATE ) DATA INITIALLY DEFERRED  REFRESH DEFERRED MAINTAINED BY
   USER
   ENABLE QUERY OPTIMIZATION ;
```

QUERY

```
Select C.customer, F.Shipdate,
   SUM ( REVENUE_W_TAX ) AS SREVENUE_W_TAX ,
   SUM ( REVENUE_WO_TAX ) AS SREVENUE_WO_TAX ,
   SUM ( PROFIT_W_TAX ) AS SPROFIT_W_TAX ,
   SUM ( PROFIT_WO_TAX ) AS SPROFIT_WO_TAX ,
   SUM ( QUANTITY ) AS SQUANTITY ,
   COUNT ( * ) AS NUMBER_ITEMS_PER_GROUP

From STAR1M.ITEM_FACT f, STAR1M.CUST_DIM c
where f.CUSTKEY= C.CUSTKEY
Group by C.Customer,F.Shipdate  Order by SPROFIT_WO_TAX DESC;
```

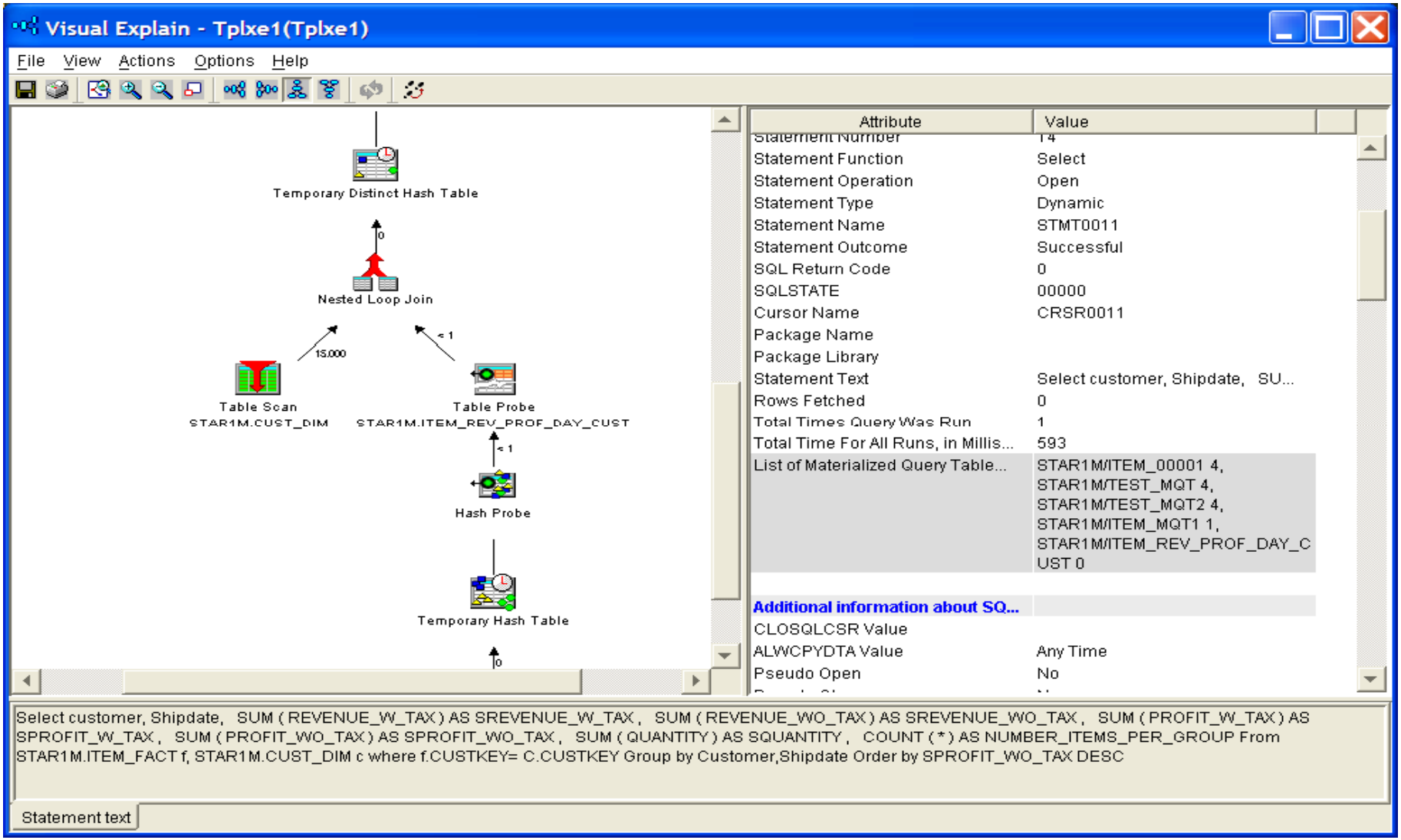
Can’t use that MQT



Including the Join Column in the MQT

```
CREATE TABLE STAR1M.ITEM_REV_PROF_DAY_CUST
  AS (
  SELECT SHIPDATE , CUSTKEY ,
  SUM ( REVENUE_W_TAX ) AS SREVENUE_W_TAX ,
  SUM ( REVENUE_WO_TAX ) AS SREVENUE_WO_TAX ,
  SUM ( PROFIT_W_TAX ) AS SPROFIT_W_TAX ,
  SUM ( PROFIT_WO_TAX ) AS SPROFIT_WO_TAX ,
  SUM ( QUANTITY ) AS SQUANTITY ,
  COUNT ( * ) AS NUMBER_ITEMS_PER_GROUP
  FROM STAR1M.ITEM_FACT
  GROUP BY SHIPDATE , CUSTKEY )
  DATA INITIALLY DEFERRED REFRESH DEFERRED MAINTAINED
  BY USER
  ENABLE QUERY OPTIMIZATION ;
```

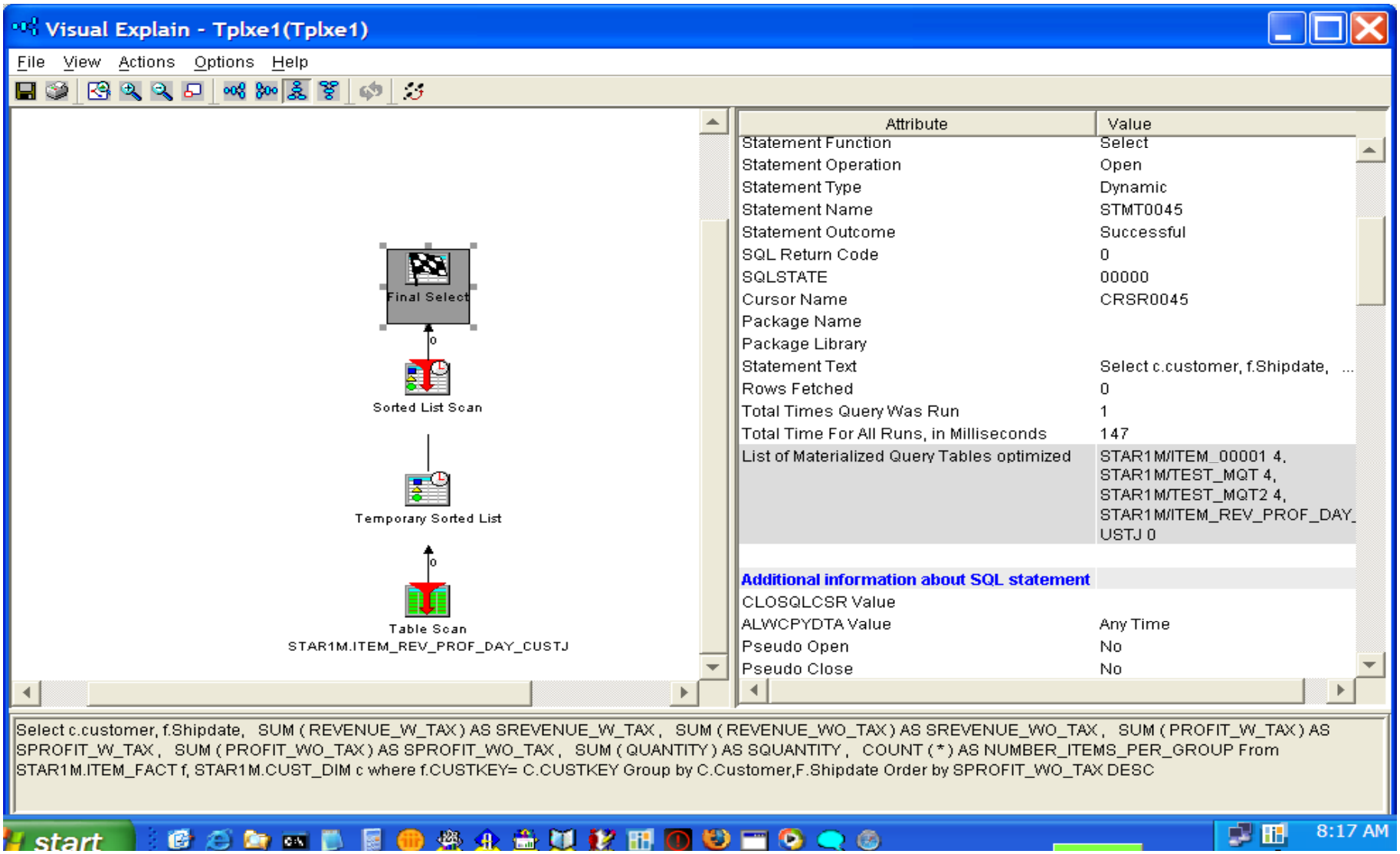
Using the MQT with the added Join Column



Include the Join in the MQT

```
CREATE TABLE STAR1M.ITEM_REV_PROF_DAY_CUSTJ
  AS (
  SELECT c.customer,f.SHIPDATE ,
  SUM ( REVENUE_W_TAX ) AS SREVENUE_W_TAX ,
  SUM ( REVENUE_WO_TAX ) AS SREVENUE_WO_TAX ,
  SUM ( PROFIT_W_TAX ) AS SPROFIT_W_TAX ,
  SUM ( PROFIT_WO_TAX ) AS SPROFIT_WO_TAX ,
  SUM ( QUANTITY ) AS SQUANTITY ,
  COUNT ( * ) AS NUMBER_ITEMS_PER_GROUP
  FROM STAR1M.ITEM_FACT F , Star1m.CUST_DIM C
  where f.CUSTKEY= C.CUSTKEY
  GROUP BY SHIPDATE , C.Customer )
  DATA INITIALLY DEFERRED REFRESH DEFERRED MAINTAINED
  BY USER
  ENABLE QUERY OPTIMIZATION ;
```

Join IN MQT definition



Considerations

- DB2 for IBM i does not automatically maintain the MQTs as the data changes in the base tables.
- The decision to implement MQTs depends on answers to the following questions:
  - Is it acceptable if the query gets different results depending on whether the query uses the MQT or the base tables directly?
  - What is the acceptable latency of data for the query?
  - Are the performance benefits of implementing MQTs significant enough to offset the overhead of their creation and maintenance?

Create parameters

CREATE TABLE -MQT name-
AS(SELECT-grouping columns- -aggregate/summary columns-
FROM-table(s)
WHERE-selection columns-
GROUP BY-grouping columns-
ORDER BY-ordering columns-)

DATA INITIALLY *IMMEDIATE* *Or* DATA INITIALLY *DEFERRED*
/* Insert data at creation or not */
REFRESH *DEFERRED* *Or* REFRESH *IMMEDIATE*
/* Rerun defining query deferred or immediately when base changes */
***ENABLE* QUERY OPTIMIZATION or *DISABLE* QUERY OPTIMIZATION**
/* Allow optimizer to implicitly use this or not
MAINTAINED BY *USER* *or* MAINTAINED BY *SYSTEM*
/* Who maintains MQT contents, only User supported */

VALUES IN RED NOT SUPPORTED

QAQQINI setting to allow use

- **MATERIALIZED_QUERY_TABLE_USAGE** - This option controls the query optimizer's recognition and use of MQTs:
  - *DEFAULT - The default value is *NONE.
  - *NONE - MQTs are not used in query optimization or implementation.
  - *ALL – The user-maintained, refresh-deferred query tables can be used.
  - *USER - user-maintained MQTs can be used.
- **MATERIALIZED_QUERY_TABLE_REFRESH_AGE** - This option further determines which MQTs are eligible to be used, based on the last time a REFRESH TABLE statement was done:
  - *DEFAULT - The default value is 0. No MQTs can be used.
  - *ANY - Any tables indicated by the MATERIALIZED_QUERY_TABLE_USAGE QAQQINI parameter can be used.
  - Timestamp_duration - Only tables indicated by the MATERIALIZED_QUERY_TABLE_USAGE QAQQINI option that have a REFRESH TABLE performed within the specified timestamp duration are used.

Populating and Maintaining MQTs

Consider Cost of Initial population

- **DATA INITIALLY IMMEDIATE Or DATA INITIALLY DEFERRED At Create time?**
  - Need to understand this cost and schedule to batch window if needed
  - Submit multiple queries running concurrently in separate Jobs to populate distinct sets of rows from the base table(s).

JOB1

INSERT INTO Year_Customer_MQT (SELECT Year, Customer, SUM(Revenue) AS Total_Revenue, SUM(Quantity) AS Total_Quantity, COUNT(*) AS Rows_per_Group
FROM Transaction_table **WHERE Year = 2003**
GROUP BY Year, Customer);

JOB2

INSERT INTO Year_Customer_MQT (SELECT Year, Customer, SUM(Revenue) AS Total_Revenue,
SUM(Quantity) AS Total_Quantity, COUNT(*) AS Rows_per_Group
FROM Transaction_table **WHERE Year = 2004**
GROUP BY Year, Customer);

JOB3

INSERT INTO Year_Customer_MQT (SELECT Year, Customer, SUM(Revenue) AS Total_Revenue,
SUM(Quantity) AS Total_Quantity, COUNT(*) AS Rows_per_Group
FROM Transaction_table **WHERE Year = 2005**
GROUP BY Year, Customer);

Consider Repopulation Cost

- **Option 1:** Issue the **REFRESH TABLE** statement:

REFRESH TABLE Sale_Geo_Reg_YR_MON _MQT ;

- Be aware that this is a full refresh of the MQT and causes the following: (Could be very Expensive!!!)
  - Any indexes on the MQT are removed.
  - The contents of the MQT are removed.
  - The underlying MQT query is run.
  - The MQT is repopulated from the base tables.
  - Any indexes on the MQT are recreated.

Maintenance Strategy

- **Option 2:** Repopulate entire Table, by employing parallel Jobs same as you might have when MQT was originally populated.

1. Disable MQT
2. Drop Indexes
3. Clear MQT (CLRPFM is probably the best)
4. Submit Multiple parallel Insert jobs
5. Recreate indexes using SMP
6. enable MQT

Maintenance Strategy

- **Option 3:** Extract changes since last maintenance and update MQTs programmatically

Insert into Sale_Geo_Reg_YR_MON _MQT

select Geography, Region, *Year, Month,*
SUM(Revenue) AS Total_Revenue,
SUM(Quantity) AS Total_Quantity,
COUNT(*) AS Rows_per_Group
FROM Sales_Transaction
Where Transaction_Date > LastMQTmaintenance_Date
GROUP BY Geography, Region, Year, Month;

Or

Use Update if some of the data for a summary is already "In progress" in the MQT.

Maintenance Strategy

OR

- Use a trigger on the base tables to automatically reflect the base table changes in the MQTs
  - After Insert
  - After Update
  - After Delete
- Recommend doing the MQT table change asynchronous to the base table change
  - Send record images in a message to a queue that can be serviced by the MQT maintenance job(s).

MQT Strategy

When do they provide benefit?

- MQTs provide the most benefit when the queries are frequently aggregating or summarizing similar data from many rows
- MQTs provide the most benefit when user queries are frequently aggregating or summarizing data that results in only a few groups.
- Highly selective short running queries will not likely benefit from MQT
  - Where INVOICE_ID= 8675309
- The more often the MQT has to be refreshed, the less effective the MQT might be. This assumes minimal latency between the base tables and the MQTs. If the MQTs require refreshing less often and there is an adequate window of time to perform the refreshes, more MQTs can be employed.

MQT creation

- The general steps for implementing MQT are:
  - Analyze the data model and queries
  - Design and layout the MQT definitions
  - Create and verify the MQTs
    - Verify requires use of Optimizer feedback tools
  - Populate the MQTs
    - Considering the Cost of doing this
  - Test and tune the MQTs
    - Requires use of Optimizer feedback
  - Design and layout the MQT refresh strategies
    - Need to consider this before ever creating and enabling MQTs
  - Test and tune the MQT refresh strategies

Consider the hierarchy in your data.

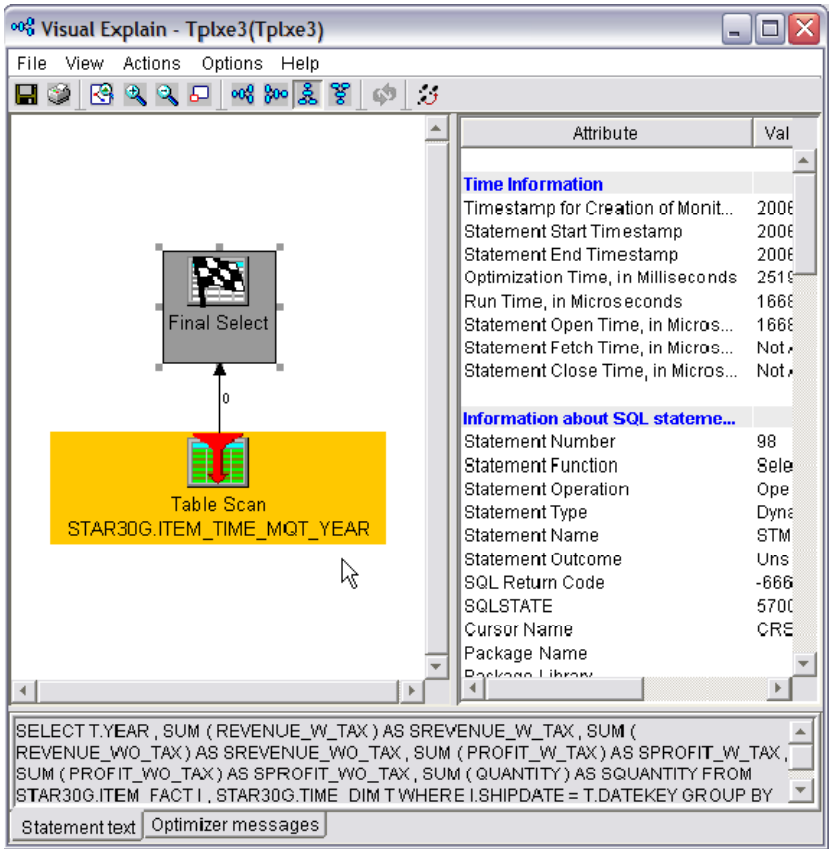
- Create more granular MQTs and let those rows get re-summarized for the higher level of summarization
  - MQT --> GROUP BY YEAR, QUARTER, MONTH, WEEK, DAY
  - GROUP BY YEAR, QUARTER, MONTH, WEEK (7 MQT rows per result)
  - GROUP BY YEAR, QUARTER, MONTH (~30 MQT rows per result)
  - GROUP BY YEAR, QUARTER (~90 MQT rows Per Result)
  - GROUP BY YEAR (365 MQT rows Per result)

Tools to help

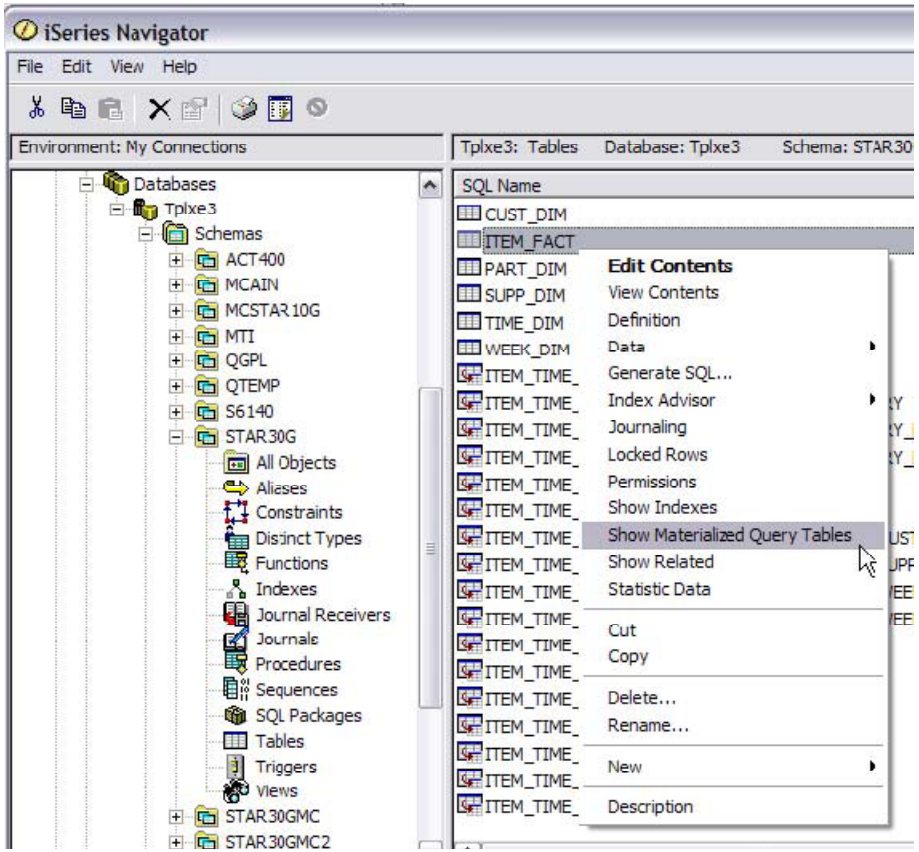
Finding Queries that can benefit from MQTs

- Utilize SQE plan cache to see expensive statements and understand how often they are run.
  - Via System i navigator show statements (V6R1 version is recommended)
- May look for statements that are run very frequently
- Take snapshot of plan cache, or DB monitor to look for common aggregations
- Use visual explain to see MQT reason codes (documented in Database Performance and Query Optimization guide)

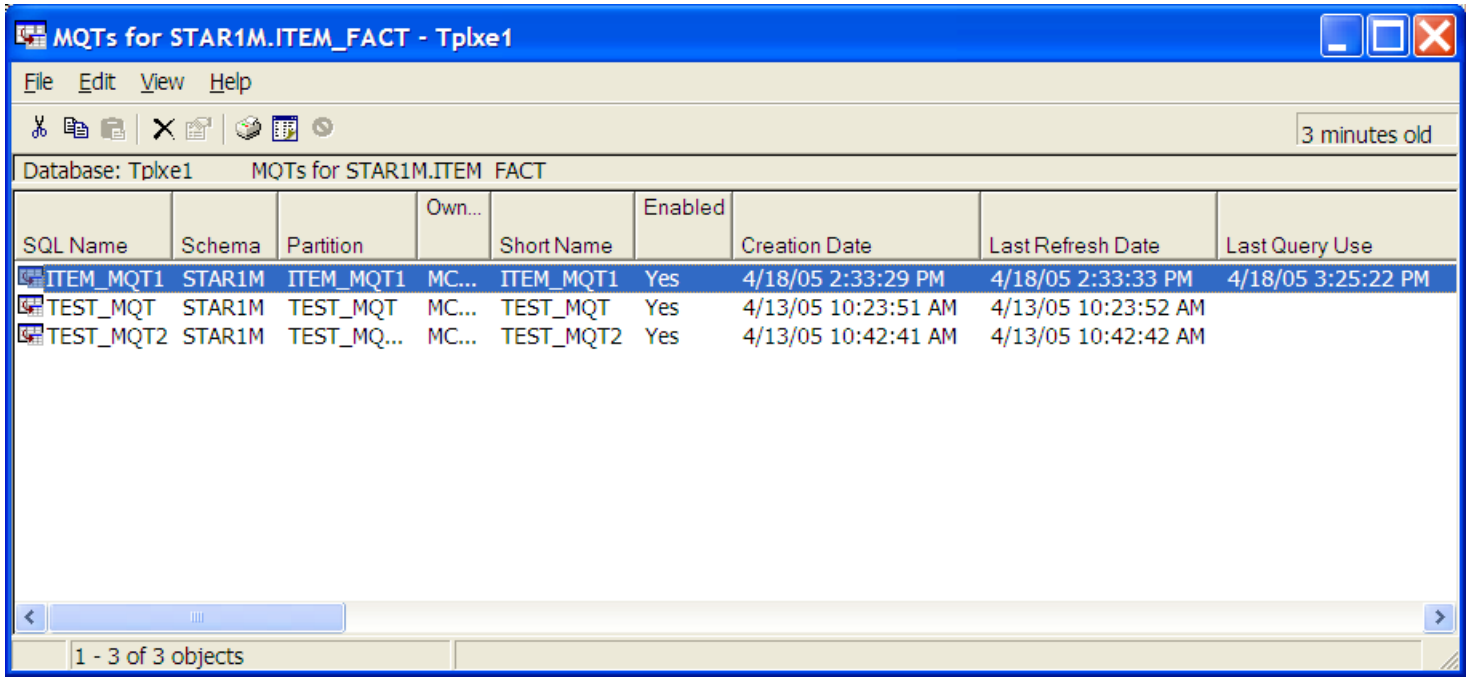
Visual Explain Can highlight MQTs



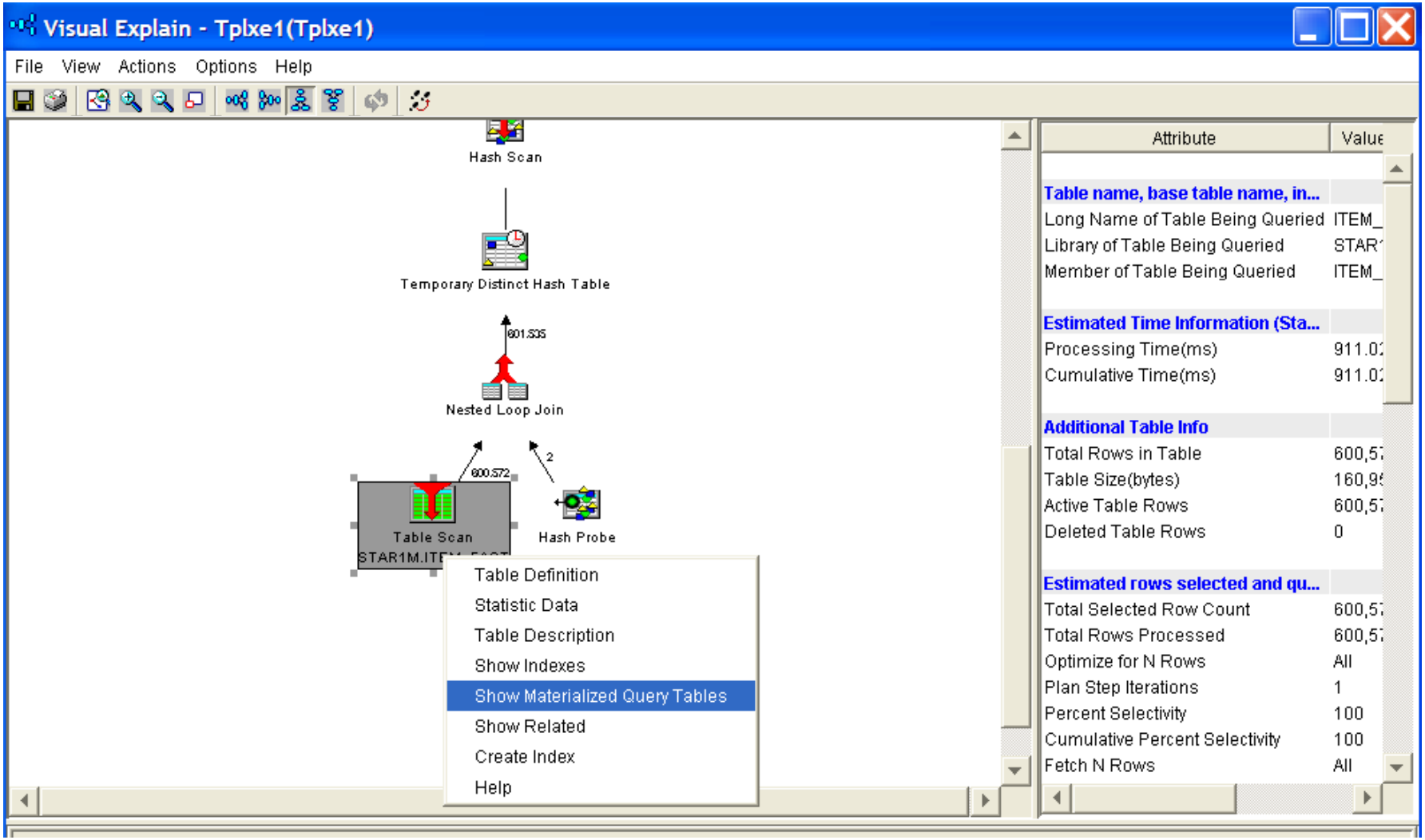
MQTs related to a table and usage statistics



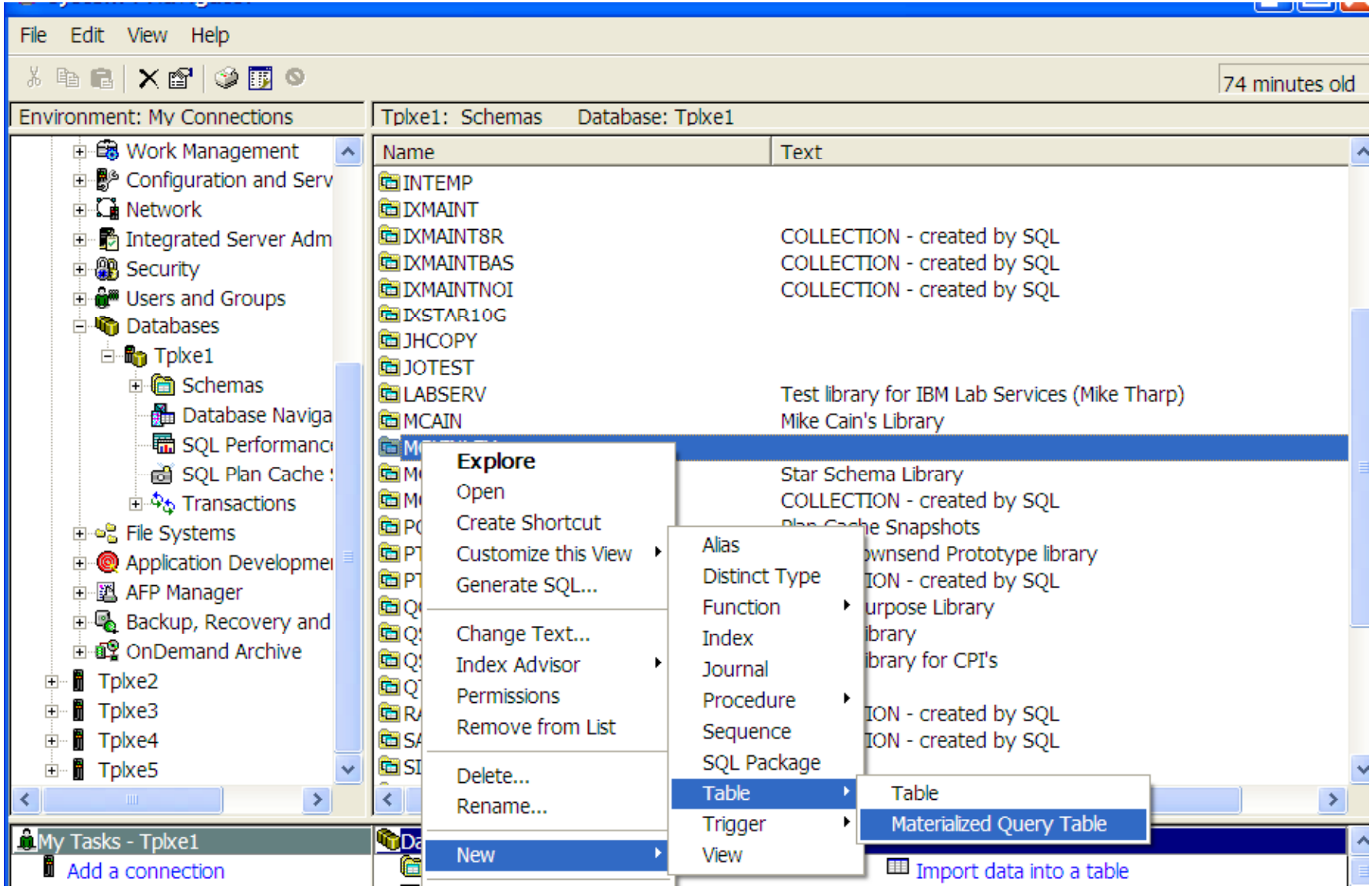
I can see MQTs that exist over a table



See list of MQTs from Visual Explain Table Icon



Use GUI to create



Find existing MQTs

```
select Table_name, Table_Schema,
  Table_Type, Enabled FROM
  qsys2.systables
 where TABLE_TYPE='M';
```

Considerations

Resources

- Temporary space when creating and populating the MQTs and associated indexes
- Permanent space to house the MQTs and associated indexes
- Processing resources when creating and maintaining the MQTs and associated indexes
- Time available to create and maintain the MQTs and associated indexes

You can alter an existing table and add/remove the MQT designation.

```
ALTER TABLE Sales_Aggregation
ADD MATERIALIZED QUERY
  (SELECT Geography,
          Region,
          Year,
            Month,
            SUM(Revenue) AS Total_Revenue,
            SUM(Quantity) AS Total_Quantity,
            COUNT(*) AS Rows_per_Group
  FROM SALES_Transaction
  GROUP BY Geography, Region, Year, Month)
DATA INITIALLY DEFERRED
REFRESH DEFERRED
ENABLE QUERY OPTIMIZATION
MAINTAINED BY USER;
```

Getting better performance

- MQTs need indexes too
  - Even If they are small
  - Especially helps if there is selection in the query so that we can probe a small number of rows in the MQT
  - For smaller number of columns Look for perfect index that has all the commonly used fields. Allows for Index only Access.
  - Since, MQT may not be changed as frequently, the index maintenance may not be high overhead.

Miscellaneous tips

- Too many MQTs increase optimization time
- SQE Only
- Mainly use for summarization, not de-normalization.
- Consider explicitly querying the MQTs
- Could use them from Views
- Save restore
  - MQTs put in Check Pending (REASON CODE 19) when restored (see V5R4 PTF (SI33106) . Read special instructions.

- Cascading Creation/Maintenance is a good strategy
  - MQT_YQMD Group by YEAR, QUARTER, Month, DAY
  - MQT_YQ Group by YEAR , QUARTER populate this using MQT_YQMD

Additional info

- **YOU MUST READ THE FOLLOWING PAPER !!!!!**
  - **Creating and using materialized query tables (MQT) in IBM DB2 for i**
    - http://www-03.ibm.com/servers/enable/site/education/abstracts/438a_abs.html
- See DB2 for i Database Performance and Query Optimization guide
- SQL Programmers guide
- SQL Reference

Summary

- MQTs can provide significant benefit. IF LIVE DATA IS NOT REQUIRED.
- System does NOT automatically maintain MQT
- Look for expensive queries and queries run a large number of times.
  - Making 30 second queries run sub second might be huge benefit
- Test MQTs usage, Creation and Maintenance before going live
- MQTs need indexes.
- Learn to use the DB2 for i optimizer feedback tools
- READ “Creating and using materialized query table (MQT) in IBM DB2 for i5/OS” Paper

Questions?