2

Accessing and Retrieving Data

Power BI Desktop contains a rich set of connectors and transformation capabilities that support the integration and enhancement of data from many different sources. These features are all driven by a powerful functional language and query engine, M, which leverages source system resources when possible and can greatly extend the scope and robustness of the data retrieval process beyond what's possible via the standard query editor interface alone. As with almost all BI projects, the design and development of the data access and retrieval process has significant implications for the analytical value, scalability, and sustainability of the overall Power BI solution.

In this chapter, we dive into Power BI Desktop's Get Data experience and walk through the process of establishing and managing data source connections and queries. Examples are provided of using the Power Query Editor interface and the M language directly, to construct and refine queries to meet common data transformation and cleansing needs. In practice and as per the examples, a combination of both tools is recommended to aid the query development process.

A full explanation of the M language and its implementation in Power BI is outside the scope of this book, but additional resources and documentation are included in the sections titled *There's more...* and *See also*.

The recipes included in this chapter are as follows:

- Viewing and Analyzing M Functions
- Managing Queries and Data Sources
- Using DirectQuery
- Importing Data

- Applying Multiple Filters
- Selecting and Renaming Columns
- Transforming and Cleansing Source Data
- Creating Custom Columns
- Combining and Merging Queries
- Selecting Column Data Types
- Visualizing the M Library
- Profile Source Data
- Diagnosing Queries

Technical Requirements

The following are required to complete the recipes in this chapter:

- Power BI Desktop
- SQL Server 2019 or newer with the **AdventureWorksDW2019** database installed. This database and instructions for installing it are available here: `http://bit.ly/2OVQfG7`

Viewing and Analyzing M Functions

Every time you click on a button to connect to any of Power BI Desktop's supported data sources or apply any transformation to a data source object, such as changing a column's data type, one or multiple M expressions are created reflecting your choices. These M expressions are automatically written to dedicated M documents and, if saved, are stored within the Power BI Desktop file as Queries. M is a functional programming language like F#, and it is important that Power BI developers become familiar with analyzing, understanding, and later, writing and enhancing the M code that supports their queries.

Getting ready

To prepare for this recipe, we will first build a query through the user interface that connects to the **AdventureWorksDW2019** SQL Server database, retrieves the **DimGeography** table, and then filters this table to a single country, such as the United States:

1. Open Power BI Desktop and click on **Get Data** from the **Home** tab of the ribbon. Select **SQL Server** from the list of database sources. For future reference, if the data source is not listed in **Common data sources**, more data sources are available by clicking **More...** at the bottom of the list.

2. A dialog window is displayed asking for connectivity information. Ensure that **Data Connectivity mode** is set to **Import**. Enter the name of your SQL server as well as the **AdventureWorksDW2019** database. In *Figure 2.1*, my SQL server is installed locally and running under the instance **MSSQLSERVERDEV**. Thus, I set the server to be **localhost\MSSQLSERVERDEV** to specify both the server (localhost) and the instance. If you leave the **Database** field blank, this will simply result in an extra navigation step to select the desired database.

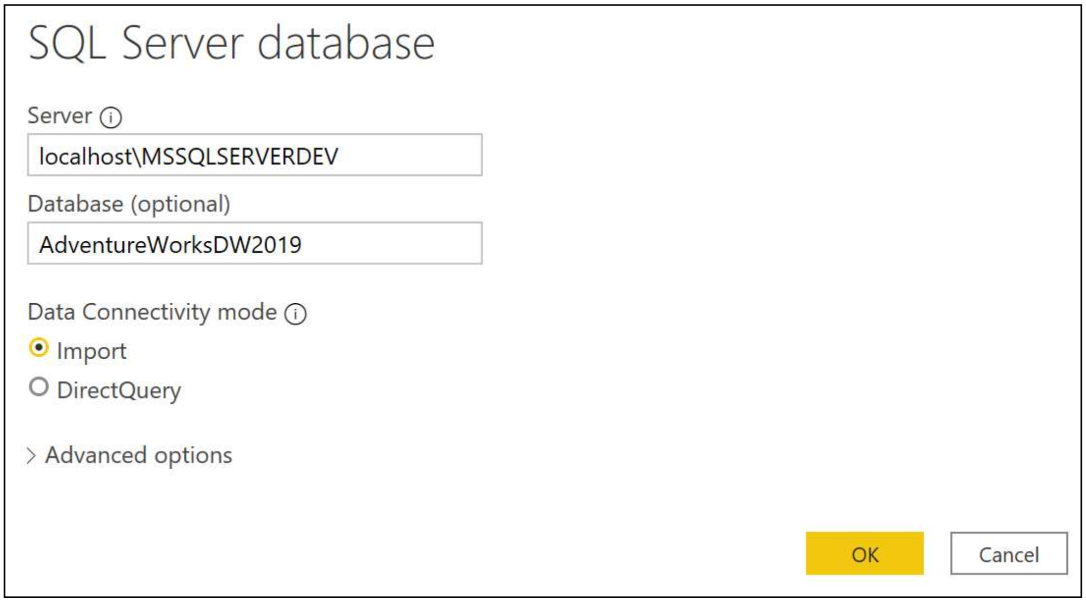


Figure 2.1: SQL Server Get Data dialog

3. If this is the first time connecting to this database from Power BI, you may be prompted for some credentials. In addition, you may also be warned that an encrypted connection cannot be made to the server. Simply enter the correct credentials for connecting and click the **Connect** button. For the encryption warning, simply click the **OK** button to continue.
4. A navigation window will appear, with the different objects and schemas of the database. Select the **DimGeography** table from the **Navigator** window and click the **Transform Data** button.
5. The Power Query Editor launches in a new window with a query called **DimGeography**; preview data from that table is displayed in the center of the window. In the Power Query Editor window, use the scroll bar at the bottom of the central display area to find the column called **EnglishCountryRegionName**. You can also select a column and then click **Go to Column** in the ribbon of the **View** menu to search for and navigate to a column quickly. Click the small button in the column header next to this column to display a sorting and filtering drop-down menu.

Uncheck the **(Select All)** option to deselect all values and then check the box next to a country, such as the **United States,** before clicking the **OK** button.

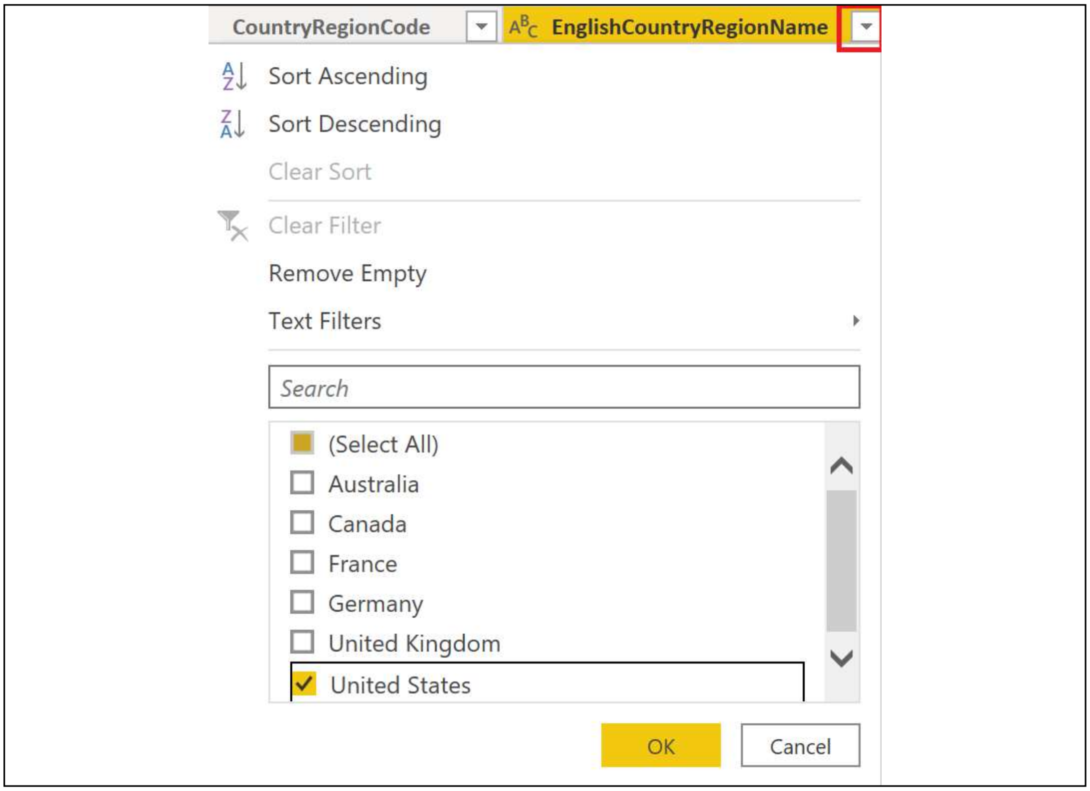


Figure 2.2: Filtering for United States only in the Query Editor

Note that the button for the **EnglishCountryRegionName** column changes to display a funnel icon. Also notice that, in the **Query Settings** pane on the right side of the window, a new option under **APPLIED STEPS** has appeared called **Filtered Rows**.

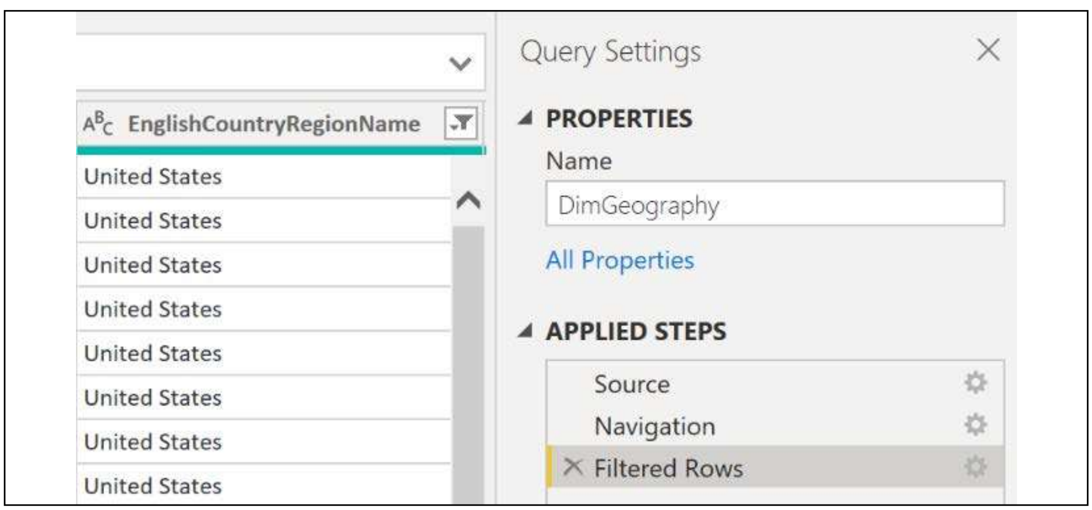


Figure 2.3: The Query Settings pane in the Query Editor

How to View and Analyze M Functions

There are two methods for viewing and analyzing the M functions comprising a query; they are as follows:

- Formula bar
- Advanced Editor

The formula bar exposes the M function for the current step only. This formula bar appears just above the column headers for the preview data in the central part of the window. If you do not see this formula bar, click the **View** tab and check the box next to **Formula Bar** in the **Layout** section of the ribbon. All such areas of interest are boxed in red in *Figure 2.4*.

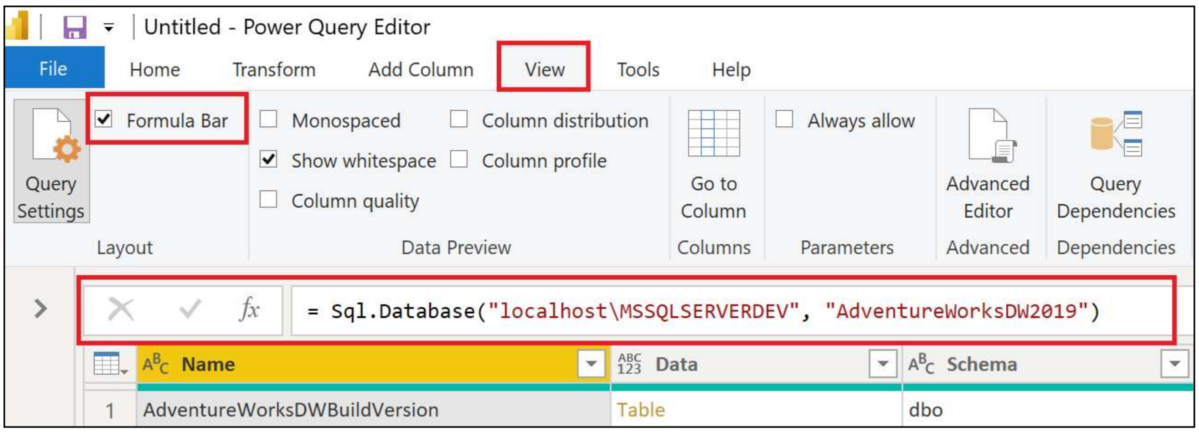


Figure 2.4: The Power Query Editor formula bar

When the **Source** step is selected under **APPLIED STEPS** in the **Query Settings** pane, as seen in *Figure 2.3*, we see the connection information specified on the initial dialog after selecting **Get Data** and then **SQL Server**. The M function being used is `Sql.Database`. This function is accepting two parameters: the server name, `localhost\MSSQLSERVERDEV`, and the database name, `AdventureWorksDW2019`. Clicking on other steps under **APPLIED STEPS** exposes the formulas for those steps, which are technically individual M expressions.

The formula bar is useful to quickly understand the M code behind a particular query step. However, it is more convenient and often essential to view and edit all the expressions in a centralized window. This is the purpose of the **Advanced Editor**. To launch the **Advanced Editor**, follow these steps:

1. Click on the **Home** tab and then select **Advanced Editor** from the **Query** section of the ribbon, as shown in *Figure 2.5*. Alternatively, the **Advanced Editor** can also be accessed from the **View** tab, shown in *Figure 2.4*.

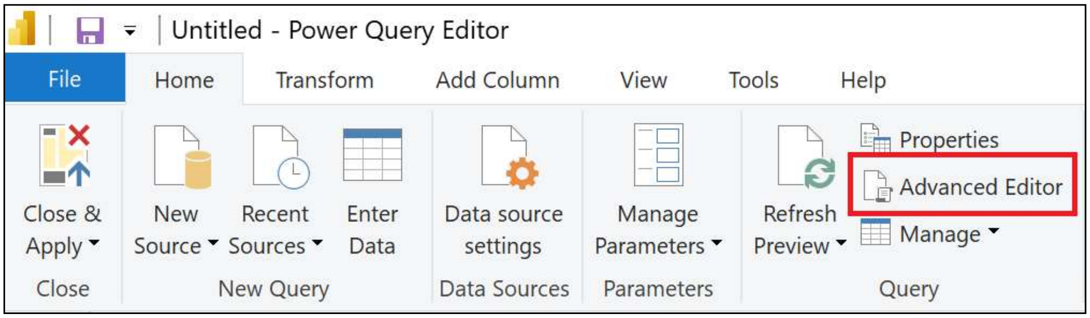


Figure 2.5: Advanced Editor on the Home tab of the Query Editor

2. The **Advanced Editor** dialog is displayed, exposing all M functions and comments that comprise the query. The M code can be directly edited from within this dialog.

Figure 2.6: The Advanced Editor view of the DimGeography query

As shown in *Figure 2.6*, using the **Advanced Editor** will mean that all of the Power Query code that comprises the query can be viewed in one place.

How it works

The majority of queries created for Power BI follow the `let...in` structure, as per this recipe. Within the `let` block, there are multiple steps with dependencies among those steps. For example, the second step, **dbo_DimGeography**, references the previous step, **Source**. Individual expressions are separated by commas, and the expression referred to following the `in` keyword is the expression returned by the query. The individual step expressions are technically known as "variables".

Variable names in M expressions cannot have spaces without being preceded by a hash sign and enclosed in double quotes. When the Query Editor graphical interface is used to create M queries, this syntax is applied automatically, along with a name describing the M transformation applied. This behavior can be seen in the **Filtered Rows** step in *Figure 2.6.* Applying short, descriptive variable names (with no spaces) improves the readability of M queries.

Note the three lines below the `let` statement. These three lines correspond to the three **APPLIED STEPS** in our query: **Source**, **Navigation**, and **Filtered Rows**. The query returns the information from the last step of the query, **Filtered Rows**. As more steps are applied, these steps will be inserted above the `in` statement and the line below this will change to reference the final step in the query.

M is a case-sensitive language. This includes referencing variables in M expressions (`RenameColumns` versus `Renamecolumns`) as well as the values in M queries. For example, the values "Apple" and "apple" are considered unique values in an M query.

It is recommended to use the Power Query Editor user interface when getting started with a new query and when learning the M language. After several steps have been applied, use **Advanced Editor** to review and optionally enhance or customize the M query. As a rich, functional programming language, there are many M functions and optional parameters not exposed via the Power Query Editor's graphical user interface. Going beyond the limits of the Power Query Editor enables more robust data retrieval, integration, and data mashup processes.

The M engine also has powerful "lazy evaluation" logic for ignoring any redundant or unnecessary variables, as well as short-circuiting evaluation (computation) once a result is determinate, such as when one side (operand) of an `OR` logical operator is computed as `True`. Lazy evaluation allows the M query engine to reduce the required resources for a given query by ignoring any unnecessary or redundant steps (variables). The order of evaluation of the expressions is determined at runtime—it doesn't have to be sequential from top to bottom.

In the following example, presented in *Figure 2.7*, a step for retrieving `Canada` was added and the `"Filtered Rows"` step for filtering the results for the `United States` was ignored. Since the `CanadaOnly` variable satisfies the overall `let` expression of the query, only the `Canada` query is issued to the server as if the `"Filtered Rows"` step were commented out or omitted.

```
let
    Source = Sql.Database("localhost\MSSQLSERVERDEV", "AdventureWorksDW2019"),
    dbo_DimGeography = Source{[Schema="dbo",Item="DimGeography"]}[Data],
    CanadaOnly = Table.SelectRows(dbo_DimGeography, each ([EnglishCountryRegionName] = "Canada")),
    #"Filtered Rows" = Table.SelectRows(dbo_DimGeography, each ([EnglishCountryRegionName] = "United States"))
in
    CanadaOnly
```

Figure 2.7: Revised query that ignores the "Filtered Rows" step to evaluate Canada only

As a review of the concepts covered thus far and for future reference, *Table 2.1* presents a glossary of the main concepts of the M language utilized in this book.

Concept	Definition
Expression	Formulas evaluated to yield a single value. Expressions can reference other values, such as functions, and may include operators.
Value	The result of evaluating an expression. Values can be categorized into types which are either primitive, such as text ("abc"), or structured kinds, such as tables and lists.

Function	A value that produces a new one based on the mapping of input values to the parameters of the function. Functions can be invoked by passing parameter values.
Type	A value that classifies other values. The structure and behavior of values are restricted based on the classification of their type, such as Record, List, or Table.
`let`	An expression that allows a set of unique expressions to be assigned names (variables) and evaluated (if necessary) when evaluating the expression following the in expression in a let...in construct.
Variable	A unique, named expression within an environment to be conditionally evaluated. Variables are represented as Applied Steps in the Query Editor.
Environment	A set of variables to be evaluated. The global environment containing the M library is exposed to root expressions.
Evaluation	The computation of expressions. Lazy evaluation is applied to expressions defined within let expressions; evaluation occurs only if needed.
Operators	A set of symbols used in expressions to define the computation. The evaluation of operators depends on the values to be operated on.

Table 2.1: M Language elements

There's more...

M queries are not intended as a substitute for the data loading and transformation workloads typically handled by enterprise data integration and orchestration tools such as **Azure Data Factory** (**ADF**), Azure Databricks, or **SQL Server Integration Services** (**SSIS**). However, just as BI professionals carefully review the logic and test the performance of SQL stored procedures and ETL packages supporting their various cubes and reporting environments, they should also review the M queries created to support Power BI models and reports. When developing retrieval processes for Power BI models, consider these common ETL questions:

- How are queries impacting the source systems?
- Can we make our queries more resilient to changes in source data so that they avoid failure?
- Are our queries efficient and simple to follow and support, or are there unnecessary steps and queries?
- Are our queries delivering sufficient performance to the BI application?
- Is our process flexible, such that we can quickly apply changes to data sources and logic?
- Can some or all of the required transformation logic be implemented in a source system such as the loading process for a data warehouse table or a SQL view?

One of the top performance and scalability features of M's query engine is called Query Folding. If possible, the M queries developed in Power BI Desktop are converted ("folded") into SQL statements and passed to source systems for processing.

If we use the original version of the query from this recipe, as shown in *Figure 2.6*, we can see Query Folding in action. The query from this recipe was folded into the following SQL statement and sent to the server for processing, as opposed to the M query engine performing the processing locally. To see how this works, perform the following:

1. Right-click on the **Filtered Rows** step in the **APPLIED STEPS** section of the **Query Settings** pane, and select **View Native Query.**

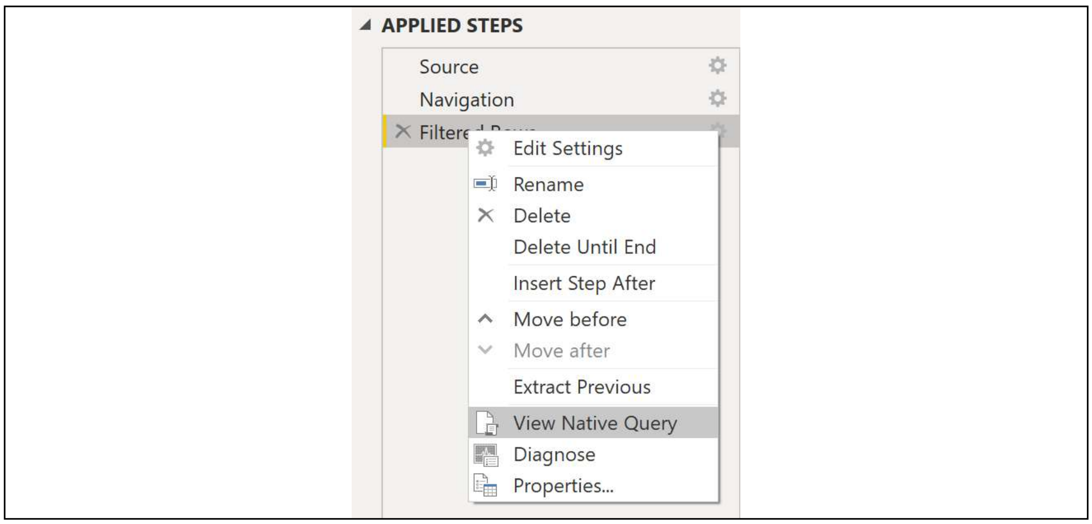


Figure 2.8: View Native Query in Query Settings

2. The **Native Query** dialog is then displayed, as shown in *Figure 2.9*.

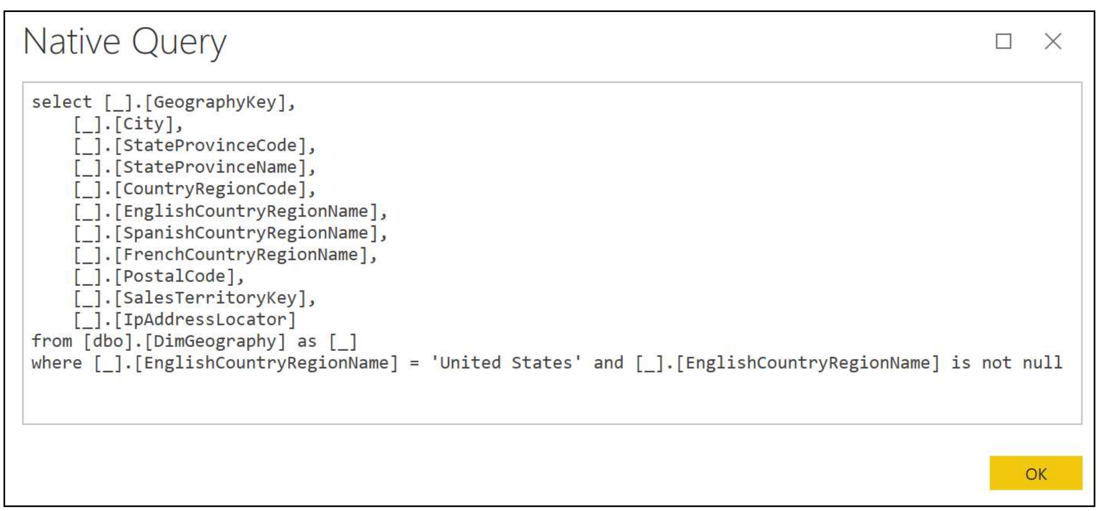


Figure 2.9: The SQL statement generated from the DimGeography M query

Finding and revising queries that are not being folded to source systems is a top technique for enhancing large Power BI datasets. See the *Pushing Query Processing Back to Source Systems* recipe of *Chapter 11*, *Enhancing and Optimizing Existing Power BI Solutions*, for an example of this process.

The M query engine also supports partial query folding. A query can be "partially folded", in which a SQL statement is created resolving only part of an overall query. The results of this SQL statement would be returned to Power BI Desktop (or the on-premises data gateway) and the remaining logic would be computed using M's in-memory engine with local resources. M queries can be designed to maximize the use of the source system resources, by using standard expressions supported by query folding early in the query process. Minimizing the use of local or on-premises data gateway resources is a top consideration for improving query performance.

There are limits, however, to query folding. For example, no folding takes place once a native SQL query has been passed to the source system, such as when passing a SQL query directly through the **Get Data** dialog using the **Advanced options**. *Figure 2.10* displays a query specified in the **Get Data** dialog, which is included in the **Source** step.

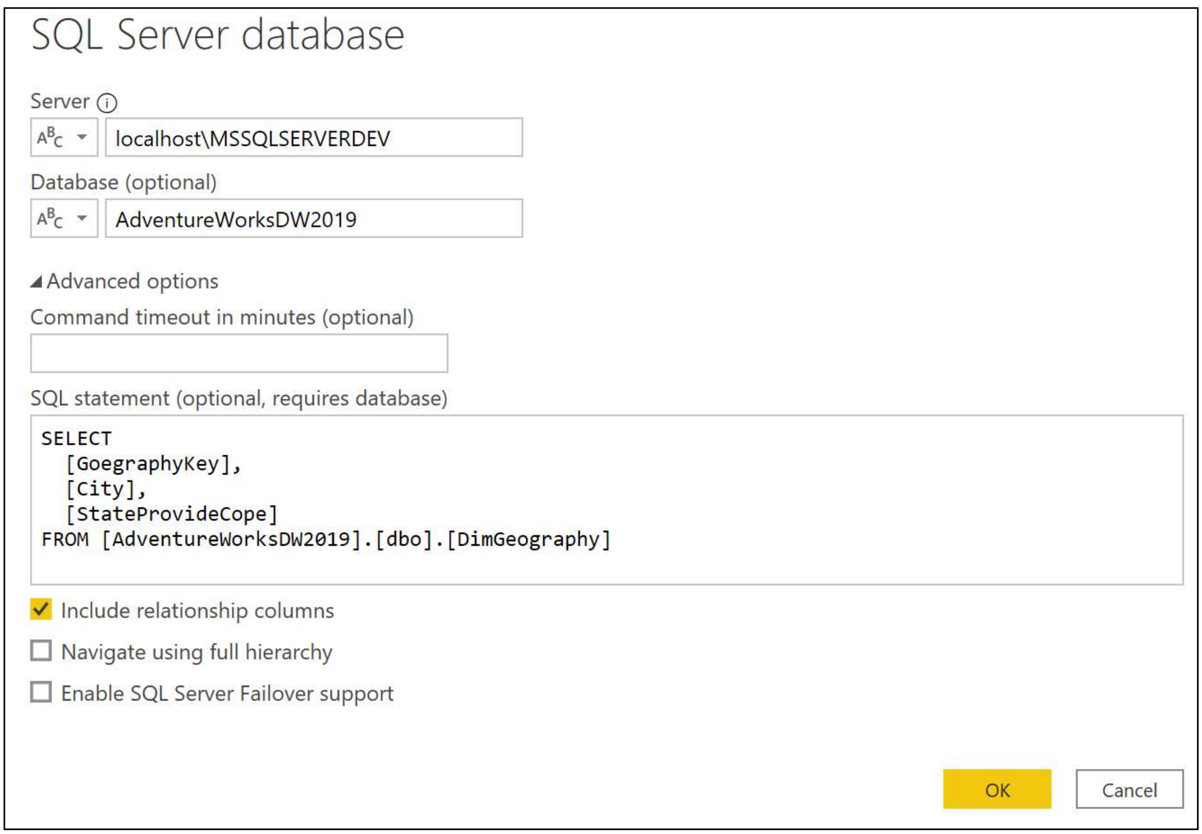


Figure 2.10: Providing a user-defined native SQL query

Any transformations applied after this native query will use local system resources. Therefore, the general implication for query development with native or user-defined SQL queries is that if they are used, try to include all required transformations (that is, joins and derived columns), or use them to utilize an important feature of the source database that is not being utilized by the folded query, such as an index.

Some other things to keep in mind regarding Query Folding are the following:

- Not all data sources support Query Folding, such as text and Excel files.
- Not all transformations available in the Query Editor or via M functions are directly supported by some data sources.
- The privacy levels defined for the data sources will also impact whether folding is used or not.
- SQL statements are not parsed before they are sent to the source system.
- The `Table.Buffer` function can be used to avoid query folding. The table output of this function is loaded into local memory, and transformations against it will remain local.

See also

- Power Query M language specification: `http://bit.ly/2oaJWwv`
- Power Query M Function reference: `http://bit.ly/3bLKJ1M`

Managing Queries and Data Sources

There are two primary components of queries in Power BI: the data source and the query logic executed against this source. The data source includes the connection method (**DirectQuery** or **Import**), a privacy setting, and the authentication credentials. The query logic consists of the M expressions represented as queries in the Query Editor and stored internally as M documents.

In a typical corporate BI tool, such as **SQL Server Reporting Services** (**SSRS**), the properties of a data source such as the server and database name are defined separately from the queries that reference them. In Power BI Desktop, however, by default, each individual query created explicitly references a given data source (for example, server A and database B). This creates an onerous, manual process of revising each query if it becomes necessary to change the source environment or database.

This issue is addressed in the following steps by using dedicated M queries to centralize and isolate the data source information from the individual queries. Additionally, detail and reference information is provided on managing source credentials and data source privacy levels.

Getting ready

To prepare for this recipe, we will create a query from a database, which will serve as the source for other queries via the standard **Get Data** and Power Query Editor experience described in the previous recipe. To create this query, perform the following steps:

1. Open Power BI Desktop.
2. If you have already connected to your SQL Server, you can find the connection under **Recent sources** on the **Home** tab. Otherwise, on the **Home** tab, select **Get Data** from the ribbon, and choose **SQL Server**.
3. Select a table or view, and click on **Transform Data** to import the data.
4. The **Power Query Editor** window will launch and a preview of the data will appear. In this example, we have chosen the `DimEmployee` table from the **AdventureWorksDW2019** database on our local SQL Server instance **MSSQLSERVERDEV**. The full code of the query can be viewed in the **Advanced Editor** window but is also shown below.

```
let
    Source = Sql.Database("localhost\MSSQLSERVERDEV",
"AdventureWorksDW2019"),
    dbo_DimEmployee = Source{[Schema="dbo",Item="DimEmployee"]}[Data]
in
    dbo_DimEmployee
```

5. Copy just the **Source** line (in bold in the previous step).
6. Close the **Advanced Editor** window by clicking the **Cancel** button.
7. Remain in the **Power Query Editor** window.

How to Manage Queries and Data Sources

In this example, a separate data source connection query is created and utilized by individual queries. By associating many individual queries with a single (or a few) data source queries, it is easy to change the source system or environment, such as when switching from a **Development** environment to a **User Acceptance Testing** (**UAT**) environment. We will then further separate out our data source queries and our data load queries using query groups. To start isolating our data source queries from our data load queries, follow these steps:

1. Create a new, blank query by selecting **New Source** from the ribbon of the **Home** tab and then select **Blank Query**.

2. Open the **Advanced Editor** and replace the **Source** line with the line copied from the query created in **Getting ready**. Be certain to remove the comma (,) at the end of the line. The line prior to the `in` keyword should never have a comma at the end of it. Your query should look like the following:

```
let
    Source = Sql.Database("localhost\MSSQLSERVERDEV",
"AdventureWorksDW2019")
in
    Source
```

3. Click the **Done** button to close the **Advanced Editor** window.
4. Rename the query by clicking on the query and editing the **Name** in the **Query Settings** pane. Alternatively, in the **Queries** pane, right-click the query and choose **Rename**. Give the source query an intuitive name, such as `AdWorksDW`.
5. Now click on the original query created in the *Getting ready* section above. Open the **Advanced Editor**. Replace the **Source** step expression of the query with the name of the new query. As you type the name of the query, **AdWorksDW**, you will notice that IntelliSense will suggest possible values. The query should now look like the following:

```
let
    Source = AdWorksDW,
    dbo_DimEmployee = Source{[Schema="dbo",Item="DimEmployee"]}[Data]
in
    dbo_DimEmployee
```

6. Click the **Done** button to come out of **Advanced Editor**. The preview data refreshes but continues to display the same data as before.

We can take this concept of isolating our data source queries from data loading queries further by organizing our queries into query groups. You should also use query groups to help isolate data source and staging queries from queries loaded to the dataset. To see how query groups work, follow these steps:

1. Duplicate the revised data loading query that loads the **DimEmployee** table, created in **Getting ready**. Simply right-click the query in the **Queries** pane and choose **Duplicate**.
2. With the new query selected in the **Queries** pane, click the gear icon next to the **Navigation** step in the **APPLIED STEPS** area of the **Query Settings** pane.
3. Choose a different dimension table or view, such as **DimAccount**, and then click the **OK** button. Dimension tables and views start with "Dim".

4. Rename this new query to reflect the new table or view being loaded.
5. Create a new group by right-clicking in a blank area in the **Queries** window and then selecting **New Group...**
6. In the **New Group** dialog, name the group **Data Sources** and click the **OK** button.
7. Create another new group and name this group **Dimensions**.
8. Move the **AdWorksDW** query to the **Data Sources** group by either dragging and dropping in the **Queries** pane or right-clicking the query and choosing **Move To Group...**, and then select the group.
9. Move the other queries to the **Dimensions** group.
10. Finally, ensure that the query in the **Data Source** group is not actually loaded as a separate table in the data model. Right-click on the query and uncheck the **Enable Load** option. This makes the query available to support data retrieval queries but makes the query invisible to the model and report layers. The query name will now be italicized in the **Queries** pane.

Your **Queries** pane should now look similar to that in *Figure 2.11*:

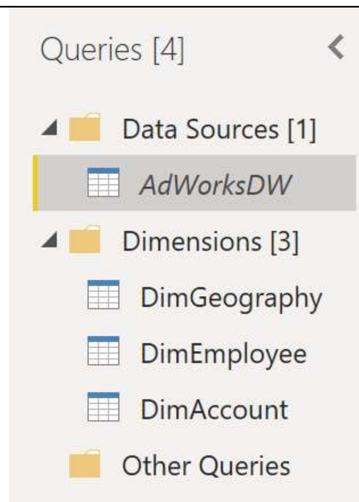


Figure 2.11: Queries organized into query groups

How it works

The **Query Dependencies** view in Power Query provides a visual representation of the relationships between the various queries. You can access this dialog by using the **View** tab and then selecting **Query Dependencies** in the ribbon.

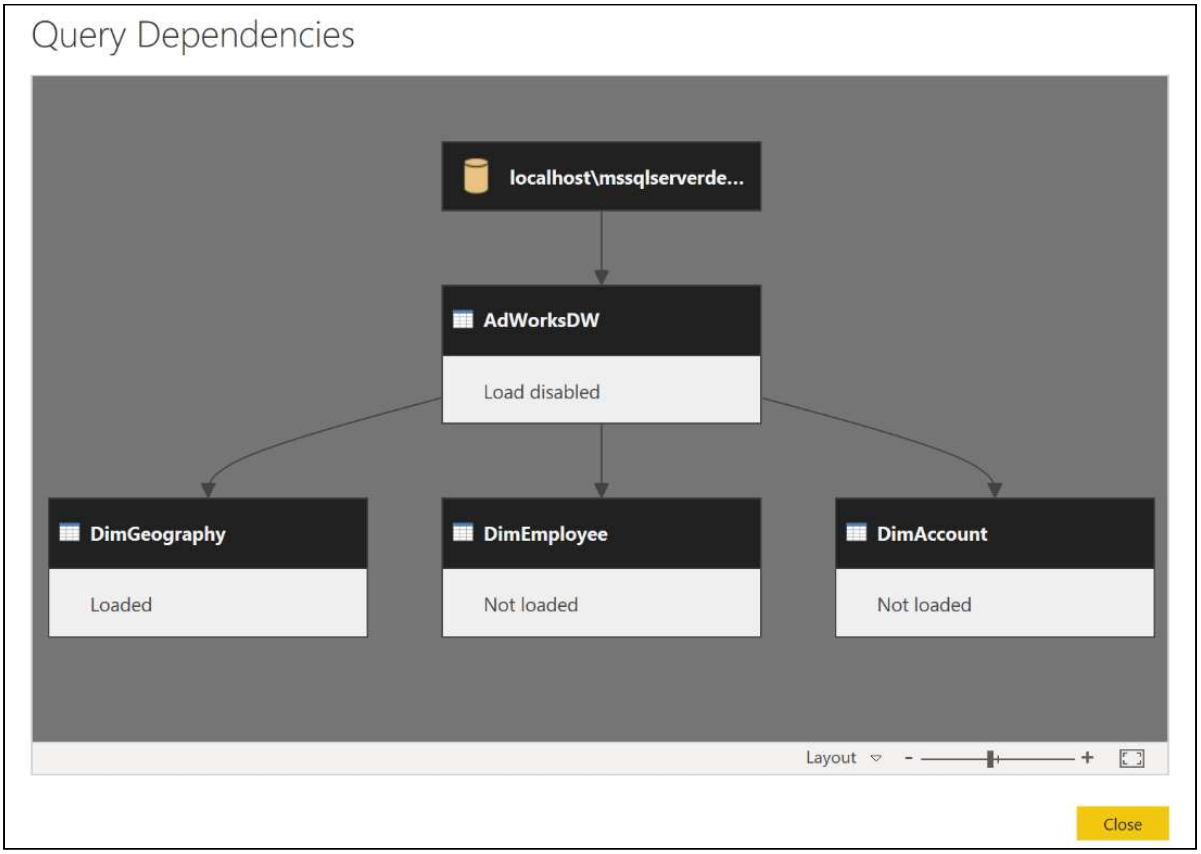


Figure 2.12: The Query Dependencies View in Query Editor

In this example, a single query with only one expression is used by multiple queries, but more complex interdependencies can be designed to manage the behavior and functionality of the retrieval and analytical queries. This recipe illustrates the broader concept used in later recipes called "composability", where functions call other functions; this is one of the primary strengths of functional programming languages such as M, DAX, R, and F#.

There's more...

Power BI Desktop saves data source credentials for each data source defined, as well as a privacy level for that source. It is often necessary to modify these credentials as passwords change. In addition, setting privacy levels on data sources helps prevent confidential information from being exposed to external sources during the Query Folding process. Data source credentials and settings are not stored in the PBIX file, but rather on the computer of the installed application.

To manage data source credentials and privacy levels, perform the following steps:

1. From Power BI Desktop (not the Power Query Editor), click on **File** in the menu, then click **Options and settings**, and finally click **Data source settings**.
2. Click on the **Global Permissions** radio button such that your settings are persisted into other Power BI Desktop reports.
3. Select a data source.
4. Click the **Edit Permissions** button.
5. From the **Edit Permissions** dialog, you can click the **Edit** button under the **Credentials** heading to set the authentication credentials for the data source. In addition, you can set the privacy level for the data source using the drop-down under the **Privacy Level** heading. Click **OK** to save your settings.

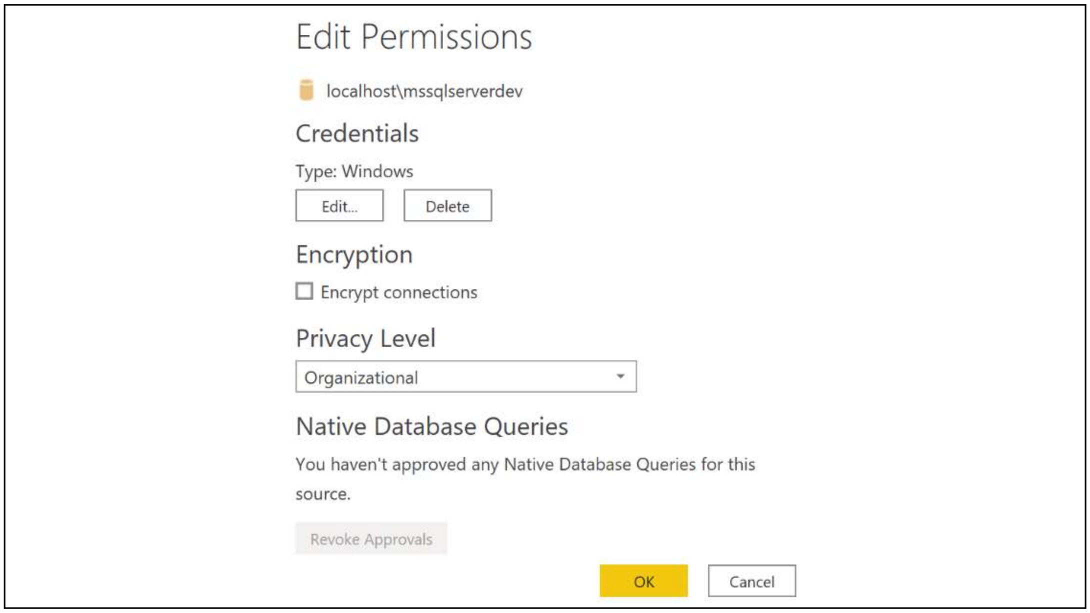


Figure 2.13: Edit credentials and privacy level for a data source

Definitions of the available **Privacy Level** settings are provided in *Table 2.2*.

Privacy Setting	Description
None	No privacy level defined.
Private	A Private data source is completely isolated from other data sources during query retrieval. For example, marking a text file Private would prevent that data from being processed on an external server.
Organizational	An Organizational data source is isolated from all public data sources but is visible to other organizational data sources during retrieval.

Public	A Public data source is visible to other sources. Only files, internet sources, and workbook data can be marked as Public.

Table 2.2: Privacy Level Settings

Just as relational databases such as SQL Server consider many potential query plans, the M engine also searches for the most efficient methods of executing queries, given that the data sources and query logic are defined. In the absence of data source privacy settings, the M engine is allowed to consider plans that merge disparate data sources. For example, a local text file of customer names can be merged with an external or third-party server, given the better performance of the server. Defining privacy settings isolates data sources from these operations thus increasing the likelihood of local resource usage, and hence query performance may be reduced.

See also

- Authentication with a data source: `http://bit.ly/30It2tV`
- Power BI Desktop privacy levels: `http://bit.ly/29blFBR`

Using DirectQuery

One of the most valuable features of Power BI is its deep support for real-time and streaming datasets, with the ability to provide immediate visibility to business processes and events as this data is created or updated. As Power BI Desktop's data modeling engine reflects the latest **Analysis Services** features, it becomes feasible to design DirectQuery models or composite models (DirectQuery and import) in Power BI Desktop, and thus avoid the scalability limitations and scheduled refresh requirements of models based on importing data.

The three most common candidates for DirectQuery or composite model projects are as follows:

- The data model would consume an exorbitant amount of memory if all tables were fully loaded into memory. Even if the memory size is technically supported by large Power BI Premium capacity nodes, this would be a very inefficient and expensive use of company resources as most BI queries only access aggregated data representing a fraction of the size. Composite models which mix DirectQuery and Dual storage mode tables with in-memory aggregation tables is the recommended architecture for large models going forward.
- Access to near-real-time data is of actionable or required value to users or other applications, such as is the case with notifications. For example, an updateable Nonclustered Columnstore index could be created on OLTP disk-based tables or memory-optimized tables in SQL Server to provide near-real-time access to database transactions.

- A high-performance and/or read-optimized system is available to service report queries, such as a SQL Server or Azure SQL Database, with the Clustered Columnstore index applied to fact tables.

This recipe walks through the primary steps in designing the data access layer that supports a DirectQuery model in Power BI Desktop. As these models are not cached into memory and dynamically convert the DAX queries from report visualizations to SQL statements, guidance is provided to maintain performance. Additional details, resources, and documentation on DirectQuery's current limitations and comparisons with the default import mode are also included to aid your design decision.

Getting ready

1. Choose a database to serve as the source for the DirectQuery data model.
2. Create a logical and physical design of the fact and dimension tables of the model including the relationship keys and granularity of the facts. The AdventureWorksDW database is a good example of data designed in this manner.
3. Determine or confirm that each fact-to-dimension relationship has referential integrity. Providing this information to the DirectQuery model allows for more performant inner join queries.
4. Create view objects in the source database to provide efficient access to the dimensions and facts defined in the physical design.

Be aware that DirectQuery models are limited to a single source database and not all databases are supported for DirectQuery. If multiple data sources are needed, such as SQL Server and Oracle, or Teradata and Excel, then the default Import mode model, with a scheduled refresh to the Power BI Service, will be the only option.

How to use DirectQuery

For this recipe, we will use the **AdventureWorksDW2019** database that has been used thus far in this chapter. To implement this recipe, follow these steps:

1. Create a new Power BI Desktop file.
2. From the **Home** tab, click on **Get Data** in the ribbon and then **SQL Server**.
3. In the **Data Connectivity mode** section, choose the **DirectQuery** radio option.

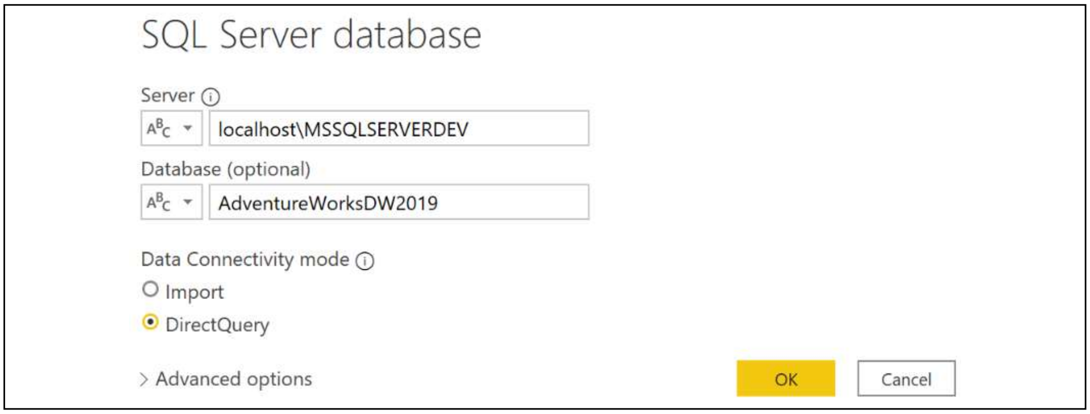


Figure 2.14: Creating a DirectQuery data source

4. Select a table or view to be used by the model via the **Navigator** dialog, such as the **FactResellerSales** table, and then click the **Transform Data** button.
5. Duplicate the initial query and revise the **Navigation** step to reference an additional view supporting the model, such as the **DimReseller**. This can be done by editing the `Item` in the formula bar or by clicking on the gear icon next to the **Navigation** step under **APPLIED STEPS** in the **Query Settings** pane. Also, rename this query to reflect the data being referenced.

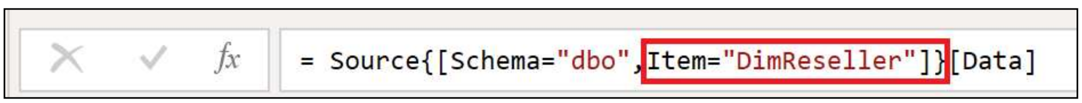


Figure 2.15: Editing the Navigation step in the formula bar

6. Repeat *step 5* for all required facts and dimensions. For example:
   - `DimEmployee`
   - `DimPromotion`
   - `DimCurrency`
   - `DimSalesTerritory`
7. Click the **Close and Apply** button.

The **Report Canvas** view will confirm that the model is in **DirectQuery** mode via the status bar at the bottom right (see *Figure 2.16*). In addition, the **Data** view in the left-hand pane, which is visible for import models, will not be visible.

Figure 2.16: DirectQuery Status in Power BI Desktop

How it works

The M transformation functions supported in DirectQuery are limited by compatibility with the source system. The Power Query Editor will advise when a transformation is not supported in **DirectQuery** mode, per *Figure 2.17*.

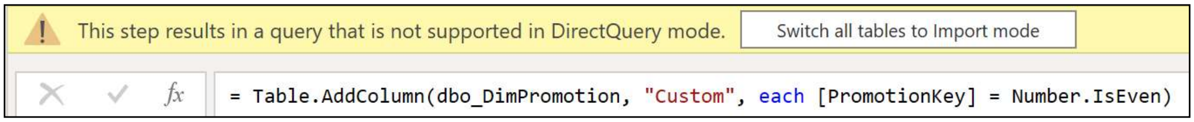


Figure 2.17: A warning in Query Editor that the IsEven function is not supported in DirectQuery mode

Given this limitation and the additional complexity the M-based transforms would add to the solution, it is recommended that you embed all the necessary logic and transforms in the source relational layer. Ideally, the base tables in the source database themselves would reflect these needs. As a secondary option, a layer of views can be created to support the DirectQuery model.

If the database objects themselves cannot be revised, the `Value.Native` M function can be used to directly pass the SQL statement from Power BI Desktop to the source database, as per *Figure 2.18*.

Figure 2.18: The Value.Native function used to pass a SQL statement to a source system

As report visualizations are refreshed or interacted with in Power BI, the DAX queries from each visualization are translated into SQL statements, utilizing the source SQL statements to return the results. Be aware that Power BI does cache query results with DirectQuery models. Therefore, when accessing a recently utilized visual, a local cache may be used rather than a new query sent to the source.

The SQL statements passed from Power BI to the DirectQuery data source include all columns from the tables referenced by the visual.

For example, a Power BI visual with **SalesAmount** from the **FactResellerSales** table grouped by **ResellerName** from **DimReseller** would result in a SQL statement that selects the columns from both tables and implements the join defined in the model. However, as the SQL statement passed embeds these source views as derived tables, the relational engine is able to generate a query plan that only scans the required columns to support the join and aggregation.

There's more...

The performance and scalability of DirectQuery models are primarily driven by the relational data source. A denormalized star schema with referential integrity and a system that is isolated from OLTP workloads is recommended if near real-time visibility is not required. Additionally, in-memory and columnar features available to supported DirectQuery sources are recommended for reporting and analytical queries.

By default, DirectQuery models generate outer join SQL queries to ensure that measures return the correct value even if there's not a related dimension. However, you can configure DirectQuery models to send inner join queries. This is done by editing the relationship between tables in the modeling view by checking the **Assume referential integrity** setting (see *Figure 2.19*). Along with source system resources, this is one of the top factors contributing to the DirectQuery model's performance.

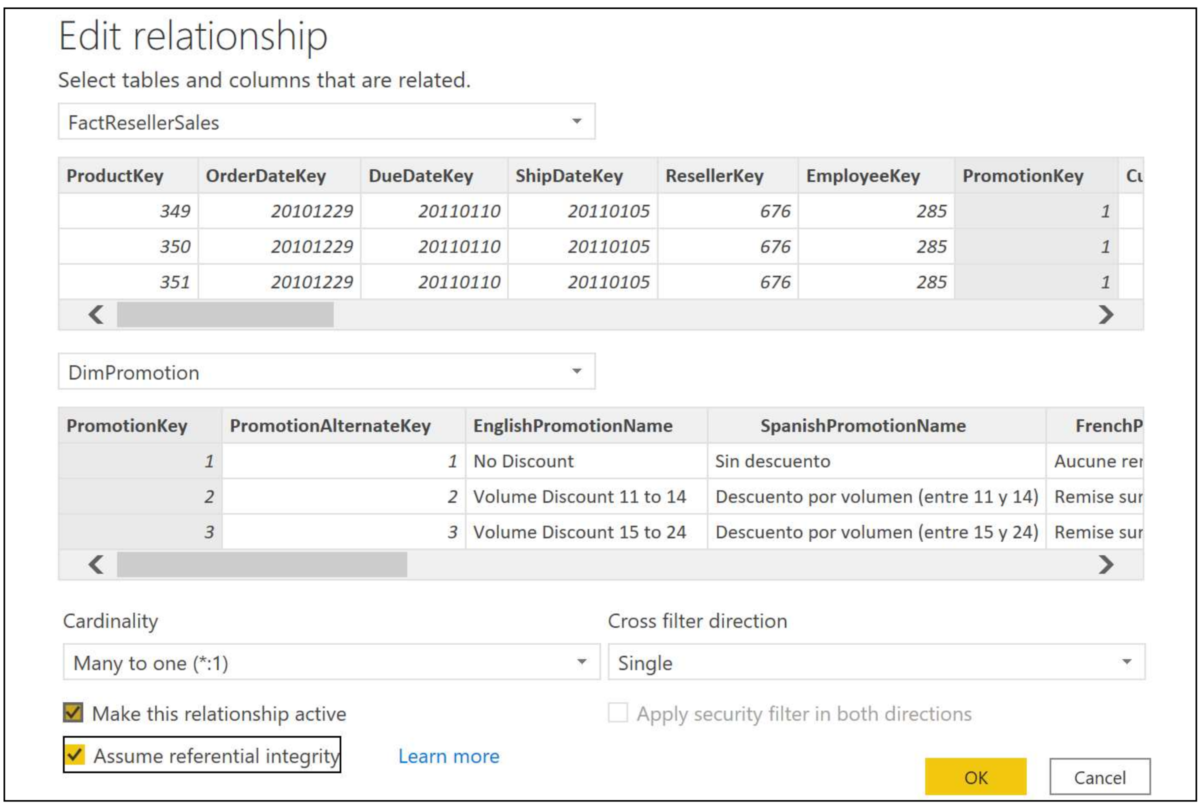


Figure 2.19: Activating referential integrity assumption in relationships

Of course, you should ensure that there is referential integrity in the source before enabling this setting; otherwise, incorrect results could be returned.

The design of the source relational schema and the hardware resources of this system can, of course, greatly impact the performance of DirectQuery models.

A classic star-schema design with denormalized tables is recommended to reduce the required join operations at query time. Optimizing relational fact tables with column store technologies such as the Clustered Columnstore Index for SQL Server and table partitions will also significantly benefit DirectQuery models.

See also

- Power BI Desktop DirectQuery documentation: `http://bit.ly/2nUoLOG`
- The *Power BI data sources* documentation provides a detailed list of data sources broken down by the connectivity options supported: `http://bit.ly/30N5ofG`

Importing Data

Import is the default data connectivity mode for Power BI Desktop. Import models created in Power BI Desktop use the same in-memory, columnar compressed storage engine (VertiPaq) featured in Analysis Services Tabular 2016+ import models. Import mode models support the integration of disparate data sources (for example, SQL Server and DB2) and allow more flexibility in developing metrics and row-level security roles via full support for all DAX functions.

There are some limits for Import mode datasets, however. For example, Power BI Pro license users cannot publish Power BI Desktop files to shared capacity in the Power BI service that are larger than 1GB. Power BI Premium (dedicated, isolated hardware) supports datasets of 10GB in size and larger (with large datasets enabled, dataset size is limited by the Premium capacity size or the maximum size set by the administrator). With such large datasets, it is important to consider employing incremental refresh where only new and changed data is refreshed and imported, instead of the entire dataset being refreshed.

This recipe describes a process of using M and the Query Editor to develop the Import mode queries for a standard star-schema analytical model. A **staging query** approach is introduced as a means of efficiently enhancing the dimensions of a model. In addition, tips are included for using fewer resources during the refresh and avoiding refresh failures from revised source data. More details of these methods are included in other recipes in this chapter.

Getting ready

In this example, the **DimProduct**, **DimProductSubcategory**, and **DimProductCategory** tables from the **AdventureWorksDW2019** database are integrated into a single import query. This query includes all product rows, only the English language columns, and user-friendly names. Many-to-one relationships have been defined in the source database.

To prepare for this recipe, do the following:

1. Open Power BI Desktop.
2. Create an Import mode data source query called **AdWorksDW**. This query should be similar to the following:

```
let
    Source = Sql.Database("localhost\MSSQLSERVERDEV",
"AdventureWorksDW2019")
in
    Source
```

3. Isolate this query in a query group called **Data Sources**.
4. Disable loading of this query.

For additional details on performing these steps, see the *Managing Queries and Data Sources* recipe in this chapter.

How to import data

To implement this recipe, perform the following steps:

1. Right-click **AdWorksDW** and choose **Reference**. This creates a new query that references the **AdWorksDW** query as its source.
2. Select this new query and, in the preview data, find the **DimProduct** table in the **Name** column. Click on the **Table** link in the **Data** column for this row.
3. Rename this query **DimProduct**.
4. Repeat *steps 1 – 3* for the **DimProductCategory** and **DimProductSubcategory** tables.
5. Create a new query group called **Staging Queries**.
6. Move the **DimProduct**, **DimProductCategory**, and **DimProductSubcategory** queries to the **Staging Queries** group.

7. Disable loading for all queries in the **Staging Queries** group. Your finished set of queries should look similar to *Figure 2.20*.

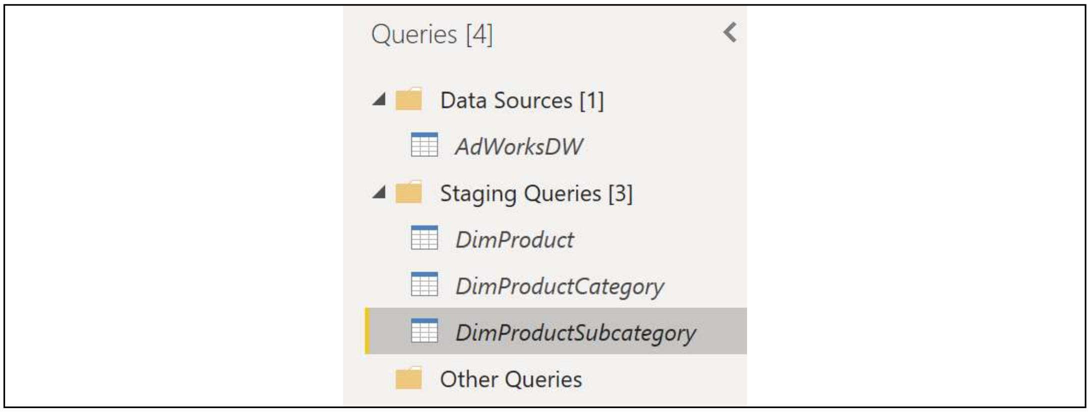


Figure 2.20: Staging Queries

The italics indicate that the queries will not be loaded into the model.

8. Create a new **Blank Query** and name this query **Products**.
9. Open the **Advanced Editor** for the **Products** query.
10. In the **Products** query, use the `Table.NestedJoin` function to join the `DimProduct` and `DimProductSubcategory` queries. This is the same function that is used if you were to select the **Merge Queries** option in the ribbon of the **Home** tab. A left outer join is required to preserve all `DimProduct` rows, since the foreign key column to `DimProductCategory` allows null values.
11. Add a `Table.ExpandColumns` expression to retrieve the necessary columns from the `DimProductSubcategory` table. The **Products** query should now have the following code:

```
let
    ProductSubCatJoin =
        Table.NestedJoin(
            DimProduct,"ProductSubcategoryKey",
            DimProductSubcategory,"ProductSubcategoryKey",
            "SubCatColumn",JoinKind.LeftOuter
        ),

    ProductSubCatColumns =
        Table.ExpandTableColumn(
            ProductSubCatJoin,"SubCatColumn",
            {"EnglishProductSubcategoryName","ProductCategoryKey"},
            {"Product Subcategory", "ProductCategoryKey"}
        )
in
    ProductSubCatColumns
```

The `NestedJoin` function inserts the results of the join into a column (`SubCatColumn`) as table values. The second expression converts these table values into the necessary columns from the **DimProductSubcategory** query and provides the simple `Product Subcategory` column name, as shown in *Figure 2.21*.

Product Subcategory	ProductCategoryKey
Helmets	4
Helmets	4
Helmets	4
Helmets	4
Helmets	4
Helmets	4
Socks	3
Socks	3

Figure 2.21: Product Subcategory Columns Added

The query preview in the **Power Query Editor** will expose the new columns at the far right of the preview data.

12. Add another expression beneath the `ProductSubCatColumns` expression with a `Table.NestedJoin` function that joins the previous expression (the **Product to Subcategory** join) with the `DimProductCategory` query.
13. Just like *step 8*, use a `Table.ExpandTableColumn` function in a new expression to expose the required **Product Category** columns.

```
        ),

    ProductCatJoin =
        Table.NestedJoin(
            ProductSubCatColumns,"ProductCategoryKey",
            DimProductCategory,"ProductCategoryKey",
            "ProdCatColumn",JoinKind.LeftOuter
        ),

    ProductCatColumns =
        Table.ExpandTableColumn(
            ProductCatJoin,"ProdCatColumn",
            {"EnglishProductCategoryName"}, {"Product Category"}
        )
in
    ProductCatColumns
```

Be certain to add a comma after the `ProductSubCatColumns` expression. In addition, be sure to change the line beneath the `in` keyword to `ProductCatColumns`.

The expression `ProductCatJoin` adds the results of the join to `DimProductCategory` (the right table) to the new column (`ProdCatColumn`). The next expression, `ProductCatColumns` adds the required **Product Category** columns and revises the `EnglishProductCategoryName` column to `Product Category`. A left outer join was necessary with this join operation as well since the product category foreign key column on `DimProductSubcategory` allows null values.

14. Add an expression after the `ProductCatColumns` expression that selects the columns needed for the load to the data model with a `Table.SelectColumns` function.
15. In addition, add a final expression to rename these columns via `Table.RenameColumns` to eliminate references to the English language and provide spaces between words.

```
        ),

    SelectProductColumns =
        Table.SelectColumns(ProductCatColumns,
            {
                "ProductKey", "EnglishDescription",
                "EnglishProductName", "Product Subcategory", "Product
Category"
            }
        ),
    RenameProductColumns =
        Table.RenameColumns(SelectProductColumns,
            {
                {"EnglishDescription", "Product Description"},
                {"EnglishProductName", "Product Name"}
            }
        )
in
    RenameProductColumns
```

Be certain to add a comma after the `ProductCatColumns` expression. In addition, change the line beneath the `in` keyword to `RenameProductColumns`.

The preview in the **Power Query Editor** for the **Products** query should now be similar to that shown in *Figure 2.22*.

	ProductKey	Product Description	Product Name	Product Subcategory	Product Category
212	212	Universal fit, well-vented, light...	Sport-100 Helmet, Red	Helmets	Accessories
213	213	Universal fit, well-vented, light...	Sport-100 Helmet, Red	Helmets	Accessories
214	214	Universal fit, well-vented, light...	Sport-100 Helmet, Red	Helmets	Accessories
215	215	Universal fit, well-vented, light...	Sport-100 Helmet, Black	Helmets	Accessories
216	216	Universal fit, well-vented, light...	Sport-100 Helmet, Black	Helmets	Accessories
217	217	Universal fit, well-vented, light...	Sport-100 Helmet, Black	Helmets	Accessories

Figure 2.22: Product Query Results

It is not necessary to rename the `ProductKey` column since this column will be hidden from the reporting layer. In practice, the product dimension would include many more columns. Closing and applying the changes results in only the **Products** table being loaded into the model.

The denormalized `Products` table now supports a three-level hierarchy in the Power BI Desktop model to significantly benefit reporting and analysis.

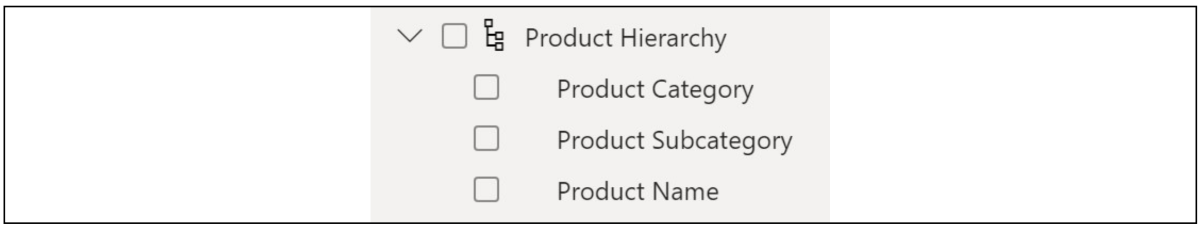


Figure 2.23: Product Hierarchy

How it works

The default join kind for `Table.NestedJoin` is a left outer join. However, as other join kinds are supported (for example, inner, anti, and full outer), explicitly specifying this parameter in expressions is recommended. Left outer joins are required in the **Products** table example, as the foreign key columns on `DimProduct` and `DimProductSubcategory` both allow null values. Inner joins implemented either via `Table.NestedJoin` or `Table.Join` functions are recommended for performance purposes otherwise. Additional details on the joining functions as well as tips on designing inline queries as an alternative to staging queries are covered in the *Combining and Merging Queries* recipe in this chapter.

When a query joins two tables via a `Table.NestedJoin` or `Table.Join` function, a column is added to the first table containing a **Table** object that contains the joined rows from the second table. This column must be expanded using a `Table.ExpandTableColumn` function, which generates additional rows as specified by the join operation.

Once all rows are generated by the join and column expansion operations, the specific columns desired in the end result can be specified by the `Table.SelectColumns` operation; these columns can then be renamed as desired using the `Table.RenameColumns` function.

There's more...

Using **Import** mode, we can do many things to enhance our queries to aid in report development and display. One such example is that we can add additional columns to provide automatic sorting of an attribute in report visuals. Specifically, suppose that we wish for the United States regional organizations to appear next to one another by default in visualizations. By default, since the **Organization** column in the **DimOrganization** table in **AdventureWorksDW2019** is a text column, the Central Division (a part of the USA), appears between Canada and France based upon the default alphabetical sorting of text columns. We can modify a simple query that pulls the **DimOrganization** table to add a numeric sorting column. To see how this works, follow these steps:

1. Using the same Power BI file used for this recipe, open the **Power Query Editor**, right-click the **AdWorksDW** query, and select **Reference**.
2. Choose the **DimOrganization** table and rename the query to **DimOrganization**.
3. Open the **Advanced Editor** window for the **DimOrganization** query.
4. Add a `Table.Sort` expression to the import query for the **DimOrganization** dimension. The columns for the sort should be at the parent or higher level of the hierarchy.
5. Add an expression with the `Table.AddIndexColumn` function that will add a sequential integer based on the table sort applied in the previous step. The completed query should look something like the following:

```
let
    Source = AdWorksDW,
    dbo_DimOrganization =
        Source{[Schema="dbo",Item="DimOrganization"]}[Data],
    OrgSorted =
        Table.Sort(
            dbo_DimOrganization,
            {
                {"ParentOrganizationKey", Order.Ascending},
                {"CurrencyKey", Order.Ascending}
            }
        ),
    OrgSortIndex = Table.AddIndexColumn(OrgSorted,"OrgSortIndex",1,1)
in
    OrgSortIndex
```

6. Finally, with the Ctrl key pressed, select the **OrganizationKey**, **OrganizationName**, and **OrgSortIndex** columns by clicking their column headers. Right-click on the **OrgSortIndex** column and choose to **Remove Other Columns**. The preview data should now show as presented in *Figure 2.24*.

	OrganizationKey	OrganizationName	OrgSortIndex
1	1	AdventureWorks Cycle	1
2	10	Pacific Operations	2
3	9	European Operations	3
4	2	North America Operations	4
5	8	Canadian Division	5
6	14	USA Operations	6
7	11	France	7
8	12	Germany	8
9	13	Australia	9
10	3	Northeast Division	10
11	4	Northwest Division	11
12	5	Central Division	12
13	6	Southeast Division	13
14	7	Southwest Division	14

Figure 2.24: Modified Organization Dimension Query

With this expression, the table is first sorted by the `ParentOrganizationKey` column and then by the `CurrencyKey` column. The new index column starts at the first row of this sorted table with an incremental growth of one per row. The net effect is that all of the US divisions are grouped together at the end of the table.

We can now use this new index column to adjust the default alphanumeric sorting behavior of the **OrganizationName** column. To see how this works, perform the following steps:

1. Choose **Close & Apply** to exit Power Query Editor to load the **DimOrganization** table.
2. In the **Data View**, select the `OrganizationName` column.
3. From the **Column tools** tab, set the **Sort by column** drop-down to the **OrgSortIndex** column.

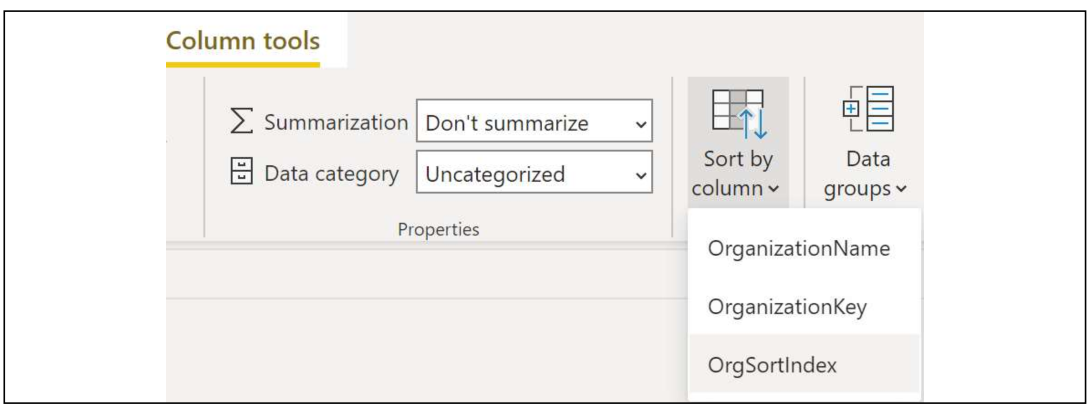


Figure 2.25: Sort By in Data View

4. Finally, right-click on the **OrgSortIndex** column and select **Hide in report view**.

Visuals using the `OrganizationName` column will now sort the values by their parent organization such that the USA organizations appear together (but not alphabetically).

Figure 2.26: Organization automatically sorted

See also

- Dataset modes in the Power BI service: `http://bit.ly/30P2HKF`
- Data reduction techniques for Import modeling: `http://bit.ly/30RsMZI`

Applying Multiple Filters

The application of precise and often complex filter conditions has always been at the heart of business intelligence, and Power BI Desktop supports rich filtering capabilities across its query, data model, and visualization components. In many scenarios, filtering at the query level via the Query Editor and M functions is the optimal choice, as this reduces the workload of both Import and DirectQuery data models and eliminates the need for re-applying the same filter logic across multiple reports or visualizations.

Although the Query Editor graphical interface can be used to configure filtering conditions, this recipe demonstrates M's core filtering functions and the use of M in common multi-condition filter scenarios. The M expression queries constructed in this recipe are intended to highlight some of the most common filtering use cases.

Note that applying data transformations as part of a data warehouse ETL (extract-transform-load) or ELT (extract-load-transform) process is generally preferable to using Power Query (M). BI teams and developers should be careful to avoid creating Power BI datasets that significantly deviate from existing "sources of truth".

The following eight filtering queries will be developed in this recipe:

- United States customers only
- Customers with three or more children
- Customers with null values for either the middle name or title columns
- Customers with first purchase dates between 2012 and 2013
- Customers in management with the female gender or a bachelor's education
- The top 100 customers based on income
- A list of distinct sales territory countries
- Dates less than or equal to the current date and more than ten years prior to the current date

Getting ready

To prepare for this recipe, import the `DimCustomer` and **DimDate** tables from the **AdventureWorksDW2019** database by doing the following:

1. Open Power BI Desktop and choose **Transform data** from the ribbon of the **Home** tab to open the **Power Query Editor**.
2. Create an **Import** mode data source query called `AdWorksDW`. This query should be similar to the following:

```
let
    Source = Sql.Database("localhost\MSSQLSERVERDEV",
"AdventureWorksDW2019")
in
    Source
```

3. Isolate this query in a query group called **Data Sources**.
4. Right-click `AdWorksDW` and choose **Reference**.
5. Choose the `DimCustomer` table and rename the query `DimCustomer`.
6. Repeat *steps 4* and *5* for the `DimDate` table.
7. Group the dimension queries into a query group called **Base Queries**.
8. Disable the loading of all queries.

9. For the `DimCustomer` query, find the `DimGeography` column. In the column header, click the diverging arrows icon, uncheck **(Select All Columns)**, and then check the box next to `CountryRegionCode` and **DimSalesTerritory** before clicking the **OK** button.

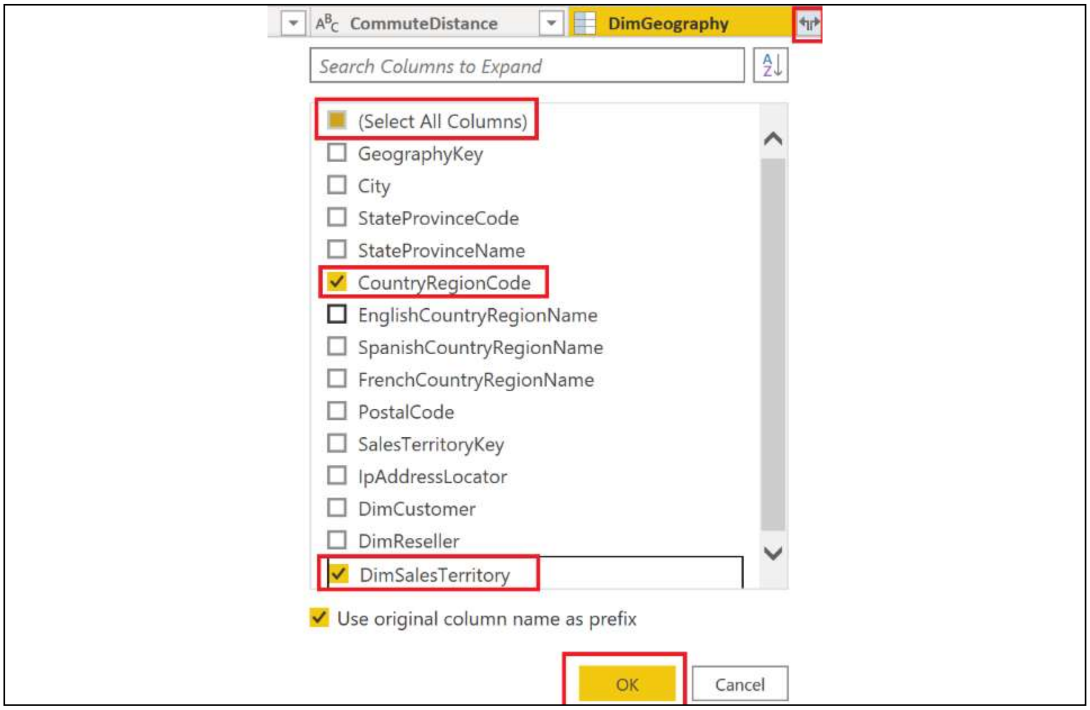


Figure 2.27: Expanding DimGeography to Include CountryRegionCode and DimSalesTerritory

10. Now expand **DimGeography.DimSalesTerritory** and only select the **SalesTerritoryCountry** column.
11. Rename the **DimGeography.CountryRegionCode** column to **CountryCode** and the **DimGeography.DimSalesTerritory.SalesTerritoryCountry** column to **SalesTerritoryCountry**.

For additional details on performing these steps, see the *Managing Queries and Data Sources* recipe in this chapter.

How to Apply Multiple Functions

To implement this recipe, use the following steps:

1. Right-click the **DimCustomer** query, choose **Reference**, and then open the **Advanced Editor** window for this query. Use the `Table.SelectRows` function to apply the US query predicate and rename the query **United States Customers**. The finished query should appear the same as the following:

```
let
    Source = DimCustomer,
    USCustomers = Table.SelectRows(Source, each [CountryCode] = "US")
in
    USCustomers
```

2. Repeat *step 1*, but this time filter on the `TotalChildren` column for `>=` **3** and rename this query **Customers w3+ Children**:

```
let
    Source = DimCustomer,
    ThreePlusChildFamilies = Table.SelectRows(Source, each
[TotalChildren] >=3)
in
    ThreePlusChildFamilies
```

3. Repeat *step 1*, but this time use the conditional logic operator `or` to define the filter condition for blank values in the `MiddleName` or `Title` columns. Use lowercase literal `null` to represent blank values. Name this query **Missing Titles or Middle Names**:

```
let
    Source = DimCustomer,
    MissingTitleorMiddleName =
        Table.SelectRows(
            Source, each [MiddleName] = null or [Title] = null
        )
in
    MissingTitleorMiddleName
```

4. Repeat *step 1*, but this time use the `#date` literal to apply the **2012-2013** filter on the `DateFirstPurchase` column. Rename this query **2012-2013 First Purchase Customers**:

```
let
    Source = DimCustomer,
    BetweenDates =
        Table.SelectRows(
            Source,
            each [DateFirstPurchase] >= #date(2012,01,01) and
                 [DateFirstPurchase] <= #date(2013,12,31)
        )
in
    BetweenDates
```

5. Repeat *step 1*, but this time use parentheses to define the filter conditions for an `EnglishOccupation` of `Management`, and either the female gender (`F`), or `Bachelors` education. The parentheses ensure that the `or` condition filters are isolated from the filter on `Occupation`. Rename this query **Management and Female or Bachelors**:

```
let
    Source = DimCustomer,
    MgmtAndFemaleOrBachelors =
        Table.SelectRows(
            Source,
            each [EnglishOccupation] = "Management" and
            ([Gender] = "F" or [EnglishEducation] = "Bachelors")
        )
in
    MgmtAndFemaleOrBachelors
```

6. Right-click the `United States Customers` query, select **Reference**, and open the **Advanced Editor**. This time, use the `Table.Sort` function to order this table by the `YearlyIncome` column. Finally, use the `Table.FirstN` function to retrieve the top 100 rows. Rename this query to **Top US Customers by Income**.

```
let
    Source = #"United States Customers",
    SortedByIncome =
        Table.Sort(
            Source,
            {{"YearlyIncome", Order.Descending}}
        ),
    TopUSIncomeCustomers = Table.FirstN(SortedByIncome,100)
in
    TopUSIncomeCustomers
```

7. Repeat *step 1*, but this time use the `List.Distinct` and `List.Sort` functions to retrieve a distinct list of values from the `SalesTerritoryCountry` column. Rename this query **Customer Sales Territory List**.

```
let
    Source = DimCustomer,
    SalesTerritoryCountryList = List.Distinct(Source[SalesTerritoryCount
ry]),
    OrderedList = List.Sort(SalesTerritoryCountryList,Order.Ascending)
in
    OrderedList
```

8. Group the queries created thus far into a **Customer Filter Queries** query group.

9. Create a new query by referencing **DimDate** and open the **Advanced Editor**. Use the `DateTime.LocalNow`, `DateTime.Date`, and `Date.Year` functions to retrieve the trailing ten years from the current date. Rename this query **Trailing Ten Years from Today** and place this query in its own group, **Date Filter Queries**.

```
let
    Source = DimDate,
    TrailingTenYearsFromToday =
        Table.SelectRows(
            Source,
            each
                [FullDateAlternateKey] <= DateTime.Date(DateTime.
LocalNow) and
                [CalendarYear] >= Date.Year(DateTime.LocalNow) - 10
        )
in
    TrailingTenYearsFromToday
```

How it works

The `Table.SelectRows` function is the primary table-filtering function in the M language, and is functionally aligned with the `FROM` and `WHERE` clauses of SQL. Observe that variable names are used as inputs to M functions, such as the `Source` line being used as the first parameter to the `Table.SelectRows` function.

Readers should not be concerned with the `each` syntax of the `Table.SelectRows` function. In many languages, this would suggest row-by-row iteration, but when possible, the M engine *folds* the function into the `WHERE` clause of the SQL query submitted to the source system.

In the queries **United States Customers**, **Customers w3+ Children**, **Missing Titles or Middle Names**, and **Management and Female or Bachelors**, notice the various forms of the `each` selection condition. The syntax supports multiple comparison operators as well as complex logic, including the use of parenthesis to isolate logical tests.

In the **2012-2013 First Purchase Customers** query, the `#date` literal function is used to generate the comparison values. Literals are also available for `DateTime (#datetime)`, `Duration (#duration)`, `Time (#time)`, and `DateTimeZone (#datetimezone)`.

In the **Top US Customers by Income** query, the `Table.Sort` function is used to sort the rows by a specified column and sort order. The `Table.Sort` function also supports multiple columns as per the *Importing Data* recipe in this chapter. The `Table.FirstN` function is then used to return 100 rows starting from the very top of the sorted table. In this example, the set returned is not deterministic due to ties in income.

The **Customer Sales Territory List** query returns a list instead of a table. This is evident from the different icon present in the **Queries** pane for this query versus the others. Lists are distinct from tables in M, and one must use a different set of functions when dealing with lists rather than tables. A list of distinct values can be used in multiple ways, such as a dynamic source of available input values to parameters.

Finally, in the **Trailing 10 Yrs from Today** query, the current date and year are retrieved from the `DateTime.LocalNow` function and then compared to columns from the date dimension with these values.

There's more...

With simple filtering conditions, as well as in proof-of-concept projects, using the UI to develop filter conditions may be helpful to expedite query development. However, the developer should review the M expressions generated by these interfaces, as they are only based on the previews of data available at design time, and logical filter assumptions can be made under certain conditions.

To access the **Filter Rows** dialog, click on the drop-down button in a column header and then choose the **Text Filters** option, before specifying a starting filtering condition.

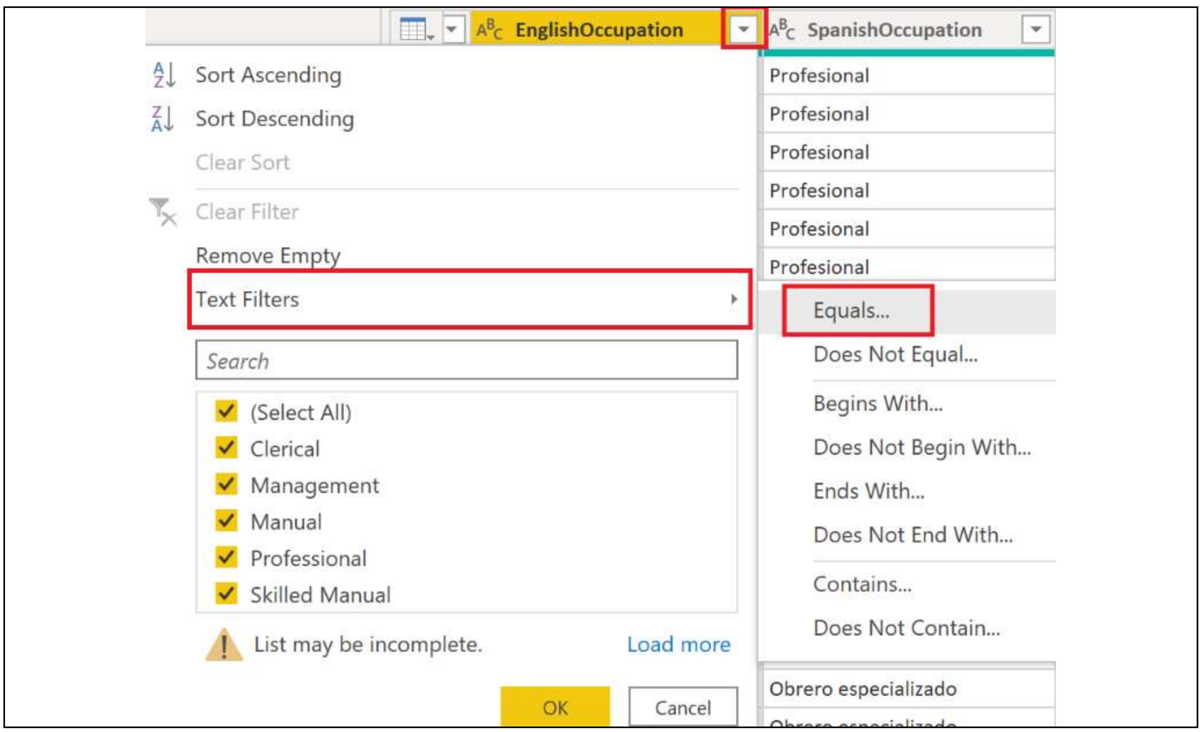


Figure 2.28: Accessing the Filter Rows dialog

The **Basic** option of the **Filter Rows** dialog only allows you to work with the currently selected column. However, by clicking on the **Advanced** radio button, you can work with any column in the table.

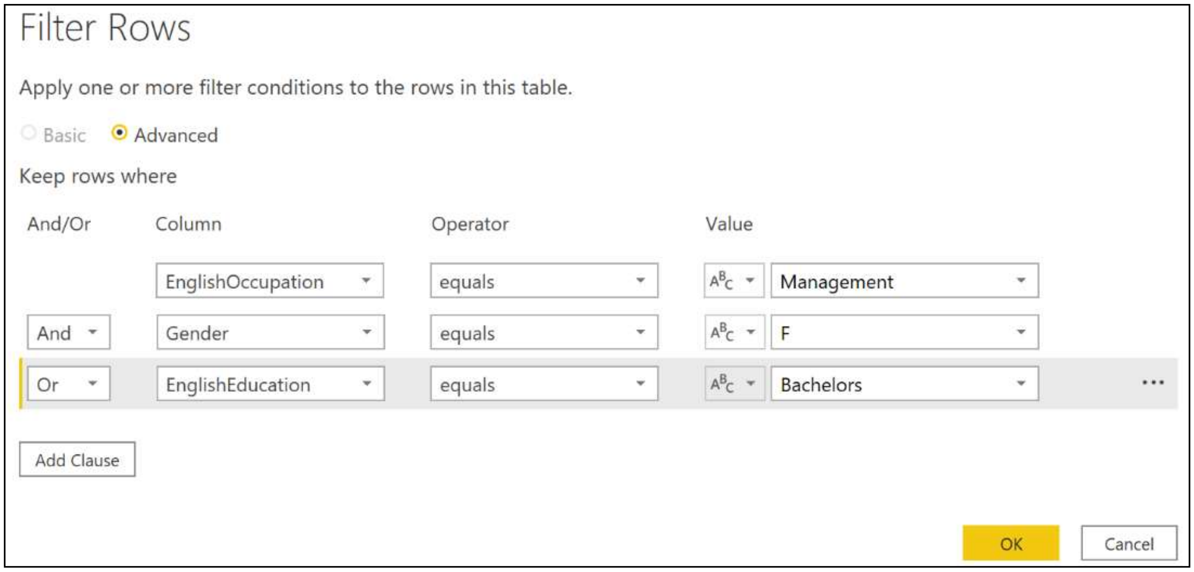


Figure 2.29: Advanced Filter Rows dialog in the Query Editor

Despite this, even the **Advanced** version of the **Filter Rows** dialog does not provide the ability to group logical filtering criteria. While the dialog in *Figure 2.29* looks like it recreates the query for **Management and Female or Bachelors**, the generated M code does not include the parenthesis that groups the **Gender** and **EnglishEducation** clauses. Thus, the code generated would have to be edited manually in the **Advanced Editor** to return the same results as the original **Management and Female or Bachelors** query. The M code generated by the **Filter Rows** dialog shown in *Figure 2.29* generates the following code:

```
Table.SelectRows(
    Source,
    each
        [EnglishOccupation] = "Management" and
        [Gender] = "F" or
        [EnglishEducation] = "Bachelors"
)
```

See also

- `Table.SelectRows`: `http://bit.ly/3bSkEyj`
- `Table.Sort`: `http://bit.ly/3qPaeUo`
- `Table.FirstN`: `http://bit.ly/3ttb0In`
- `List.Distinct`: `http://bit.ly/3lnCqwq`

- `List.Sort`: `http://bit.ly/30QLEb1`
- *10 Common Mistakes You Do In #PowerBI #PowerQuery – Pitfall #3*: `http://bit.ly/2nLX6QW`

Selecting and Renaming Columns

The columns selected in data retrieval queries impact the performance and scalability of both import and DirectQuery data models. For Import models, the resources required by the refresh process and the size of the compressed data model are directly impacted by column selection. Specifically, the cardinality of columns drives their individual memory footprint and memory per column. This correlates closely to query duration when these columns are referenced in measures and report visuals. For DirectQuery models, the performance of report queries is directly affected. Regardless of the model type, the way in which this selection is implemented also impacts the robustness of the retrieval process. Additionally, the names assigned to columns (or accepted from the source) directly impact the Q&A or natural language query experience.

This recipe identifies columns to include or exclude in a data retrieval process and demonstrates how to select those columns as well as the impact of those choices on the data model. In addition, examples are provided for applying user-friendly names and other considerations for choosing to retrieve or eliminate columns of data for retrieval.

Getting ready

To get ready for this recipe, import the **DimCustomer** table from the **AdventureWorksDW2019** database by doing the following:

1. Open Power BI Desktop and choose **Transform data** from the ribbon of the **Home** tab to open the **Power Query Editor**.
2. Create an **Import** mode data source query called `AdWorksDW`. This query should be similar to the following:

```
let
    Source = Sql.Database("localhost\MSSQLSERVERDEV",
"AdventureWorksDW2019")
in
    Source
```

3. Isolate this query in a query group called **Data Sources**.
4. Right-click `AdWorksDW` and choose **Reference**.
5. Select the `DimCustomer` table in the data preview area and rename this query `DimCustomer`.

For additional details on performing these steps, see the *Managing Queries and Data Sources* recipe in this chapter.

How to Select and Rename Columns

To implement this recipe, use the following steps in Advanced Editor:

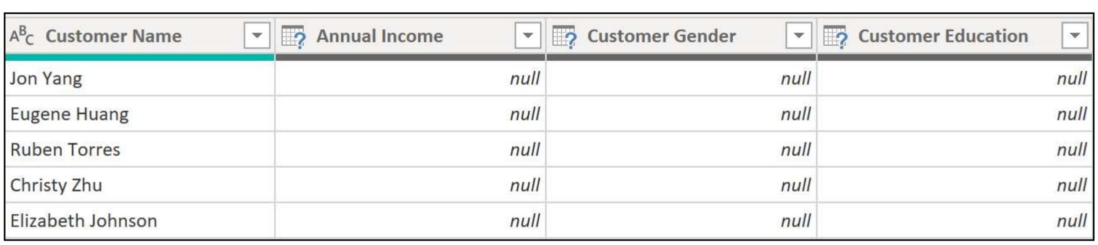
1. Create a name column from the first and last names via the `Table.AddColumn` function.

```
CustomerNameAdd =
    Table.AddColumn(
        dbo_DimCustomer, "Customer Name",
        each [FirstName] & " " & [LastName],
        type text
    )
```

2. Use the `Table.SelectColumns` function to select 10 of the 30 available columns now available in the **DimCustomer** table.

```
SelectCustCols =
    Table.SelectColumns(CustomerNameAdd,
        {
            "CustomerKey", "Customer Name", "Annual Income",
            "Customer Gender", "Customer Education",
"MaritalStatus",
            "Customer Phone Number", "CommuteDistance",
"AddressLine1",
            "TotalChildren"
        }, MissingField.UseNull
    )
```

Note that some of the column names specified do not actually exist. This is on purpose and will be fixed in the next step. But note that instead of generating an error, `null` values are displayed for those columns.



Customer Name	Annual Income	Customer Gender	Customer Education
Jon Yang	null	null	null
Eugene Huang	null	null	null
Ruben Torres	null	null	null
Christy Zhu	null	null	null
Elizabeth Johnson	null	null	null

Figure 30: Non-existent columns return null instead of error

Use the `Table.RenameColumns` function to apply intuitive names for users and benefit the Q&A engine for natural language queries. Insert this statement above your `SelectCustCols` statement and adjust as appropriate. The full query should now be similar to the following:

```
let
    Source = AdWorksDW,
    dbo_DimCustomer = Source{[Schema="dbo",Item="DimCustomer"]}[Data],
    CustomerNameAdd =
        Table.AddColumn(
            dbo_DimCustomer, "Customer Name",
            each [FirstName] & " " & [LastName],
            type text
        ),
    #"Renamed Columns" =
        Table.RenameColumns(CustomerNameAdd,
            {
                {"YearlyIncome", "Annual Income"},
                {"Gender", "Customer Gender"},
                {"EnglishEducation", "Customer Education"},
                {"Phone", "Customer Phone Number"}
            }
        ),
    SelectCustCols =
        Table.SelectColumns(#"Renamed Columns",
            {
                "CustomerKey", "Customer Name", "Annual Income",
                "Customer Gender", "Customer Education",
"MaritalStatus",
                "Customer Phone Number", "CommuteDistance",
"AddressLine1",
                "TotalChildren"
            }, MissingField.UseNull
        )
in
    SelectCustCols
```

How it works

The `Table.AddColumn` function concatenates the `FirstName` and `LastName` columns and includes an optional final parameter that specifies the column type as `text`.

The `Table.SelectColumns` function specifies the columns to retrieve from the data source. Columns not specified are excluded from retrieval.

A different method of accomplishing this same effect would be to use the `Table.RemoveColumns` function. However, in this case, 20 columns would need to be removed versus explicitly defining 10 columns to keep. To avoid query failure if one of the source columns changes or is missing, it is better to specify and name 10 than 20 columns. Query resilience can further be improved by using the optional parameter for `Table.SelectColumns`, `MissingField.UseNull`. Using this parameter, if the column selected is not available, the query still succeeds and simply inserts `null` values for this column for all rows.

Another advantage of using the `Table.SelectColumns` function is that columns can be reordered as selected columns are retrieved and presented in the order specified. This can be helpful for the query design process and avoids the need for an additional expression with a `Table.ReorderColumns` function. The initial column order of a query loaded to the data model is respected in the **Data** view. However, the field list exposed in the **Fields** pane in both the **Report** and **Data** views of Power BI Desktop is automatically alphabetized.

For import data models, you might consider removing a column that represents a simple expression of other columns from the same table. For example, if the `Extended Amount` column is equal to the multiplication of the `Unit Price` and `Order Quantity` columns, you can choose to only import these latter two columns. A DAX measure can instead compute the `Extended Amount` value. This might be done to keep model sizes smaller. This technique is not recommended for DirectQuery models, however.

Use the `Table.RenameColumns` function to rename columns in order to remove any source system indicators, add a space between words for non-key columns, and apply dimension-specific names such as `Customer Gender` rather than `Gender`. The `Table.RenameColumns` function also offers the `MissingField.UseNull` option.

There's more...

Import models are internally stored in a columnar compressed format. The compressed data for each column contributes to the total disk size of the file. The primary factor of data size is a column's cardinality. Columns with many unique values do not compress well and thus consume more space. Eliminating columns with high cardinality can reduce the size of the data model and thus the overall file size of a PBIX file. However, it is the size of the individual columns being accessed by queries that, among other factors, drives query performance for import models.

See also

- `Table.SelectColumns`: `http://bit.ly/38Qk7Lt`
- `Table.RenameColumns`: `http://bit.ly/3rTVfd4`
- `Table.RemoveColumns`: `http://bit.ly/3cJju7p`
- `Table.ReorderColumns`: `http://bit.ly/3cEoOJg`

- `Table.AddColumn`: `http://bit.ly/3vGJZ6b`
- Power BI Documentation on preparing data for Q&A: `http://bit.ly/2nBLAGc`

Transforming and Cleansing Data

The transformations applied within Power BI's M queries serve to protect the integrity of the data model and to support enhanced analysis and visualization. The specific transformations to implement varies based on data quality, integration needs, and the goals of the overall solution. However, at a minimum, developers should look to protect the integrity of the model's relationships and to simplify the user experience via denormalization and standardization. Additionally, developers should check with owners of the data source to determine whether certain required transformations can be implemented in the source, or perhaps made available via SQL view objects such that Power Query (M) expressions are not necessary.

This recipe demonstrates how to protect a model from duplicate values within the source data that can prevent forming proper relationships within the data model, which may even result in query failures. While a simple scenario is used, this recipe demonstrates scenarios you may run into while attempting to merge multiple data sources and eliminating duplicates.

Getting ready

To prepare, start by importing the **DimProduct** and **FactResellerSales** tables from the **AdventureWorksDW2019** database by doing the following:

1. Open Power BI Desktop and choose **Transform data** from the ribbon of the **Home** tab to open the **Power Query Editor**.
2. Create an **Import** mode data source query called **AdWorksDW**. This query should be similar to the following:

```
let
    Source = Sql.Database("localhost\MSSQLSERVERDEV",
"AdventureWorksDW2019")
in
    Source
```

3. Isolate this query in a query group called **Data Sources**.
4. Right-click **AdWorksDW** and choose **Reference**, select the **DimProduct** table in the data preview area, and rename this query **DimProduct**. Right-click the **EnglishProductName** column and select **Remove Other Columns**.
5. Repeat the previous step, but this time choose **FactResellerSales**. Expand the **DimProduct** column and only choose **EnglishProductName**. Rename this column to **EnglishProductName**.

6. Drag the **DimProduct** and **FactResellerSales** queries into the **Other Queries** group and apply the queries to the data model.
7. In the **Model** view of Power BI Desktop, attempt to form a relationship between the tables using the **EnglishProductName** columns from both tables. Note the warning that is displayed.

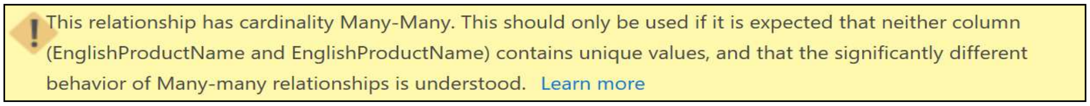


Figure 2.31: Many-Many relationship cardinality warning

For additional details on performing these steps, see the *Managing Queries and Data Sources* recipe in this chapter.

How to Transform and Cleanse Data

We wish to remove duplicates from the **EnglishProductName** column in our **DimProduct** query. To implement this recipe, use the following steps:

1. Remove any leading and trailing empty spaces in the `EnglishProductName` column with a `Text.Trim` function.
2. Create a duplicate column of the `EnglishProductName` key column with the `Table.DuplicateColumn` function and name this new column `Product Name`.
3. Add an expression to force uppercase on the `EnglishProductName` column via the `Table.TransformColumns` function. This new expression must be applied before the duplicate removal expressions are applied.
4. Add an expression to the **DimProduct** query with the `Table.Distinct` function to remove duplicate rows.
5. Add another `Table.Distinct` expression to specifically remove duplicate values from the `EnglishProductName` column.
6. Drop the capitalized `EnglishProductName` column via `Table.RemoveColumns`.

   The final query should resemble the following:

```
let
    Source = AdWorksDW,
    dbo_DimProduct = Source{[Schema="dbo",Item="DimProduct"]}[Data],
    RemoveColumns = Table.SelectColumns(dbo_DimProduct,{"EnglishProductN
ame"}),
    TrimText =
        Table.TransformColumns(
            RemoveColumns,{"EnglishProductName",Text.Trim}
        ),
```

```
            DuplicateKey =
                Table.DuplicateColumn(
                    TrimText,"EnglishProductName","Product Name"
                ),
            UpperCase =
                Table.TransformColumns(
                    DuplicateKey,{{"EnglishProductName", Text.Upper}}
                ),
            DistinctProductRows = Table.Distinct(UpperCase),
            DistinctProductNames =
                Table.Distinct(
                    DistinctProductRows, {"EnglishProductName"}
                ),
            RemoveEnglishProductName =
                Table.RemoveColumns(
                    DistinctProductNames,"EnglishProductName"
                )
        in
            RemoveEnglishProductName
```

How it works

In the `TrimText` expression, the `Trim.Text` function removes white space from the beginning and end of a column. Different amounts of empty space make those rows distinct within the query engine, but not necessarily distinct within the model. Therefore, it is always a good idea to use `Trim.Text` first and then remove duplicate rows and values.

In the next expression, `DuplicateKey`, the `Table.DuplicateColumn` function is used to duplicate the column where we will be removing duplicate values. We give this new column the name that we desire for our final column. This is done because we will need to transform the values in the column we are removing duplicates from, in order to account for mixed cases such as "Fender Set" and "Fender set". Thus, we wish to preserve the original values and casing by using this duplicate column.

In order to eliminate mixed casing issues, the `UpperCase` expression changes all values in the `EnglishProductName` column to uppercase using the `Table.TransformColumns` function, and specifying `Text.Upper`. The M engine considers mixed casing values unique, but the data model engine does not.

The next two expressions, `DistinctProductRows` and `DistinctProductNames`, simply demonstrate two different methods of using the `Table.Distinct` function. The first, `DistinctProductRows`, eliminates rows where the entire row (all column values) are identical. The second version looks only at the values in a single column when determining whether or not the row is a duplicate.

At this point, the query is now resilient to duplicate values and rows, mixed cases, and spaces. However, the `EnglishProductName` column is now in the uppercase format. Since we preserved a copy of the original values and casing in our `Product Name` column, we can simply drop the `EnglishProductName` column using the `Table.RemoveColumns` function.

We can now form a one-to-many relationship between our **DimProduct** and **FactResellerSales** tables.

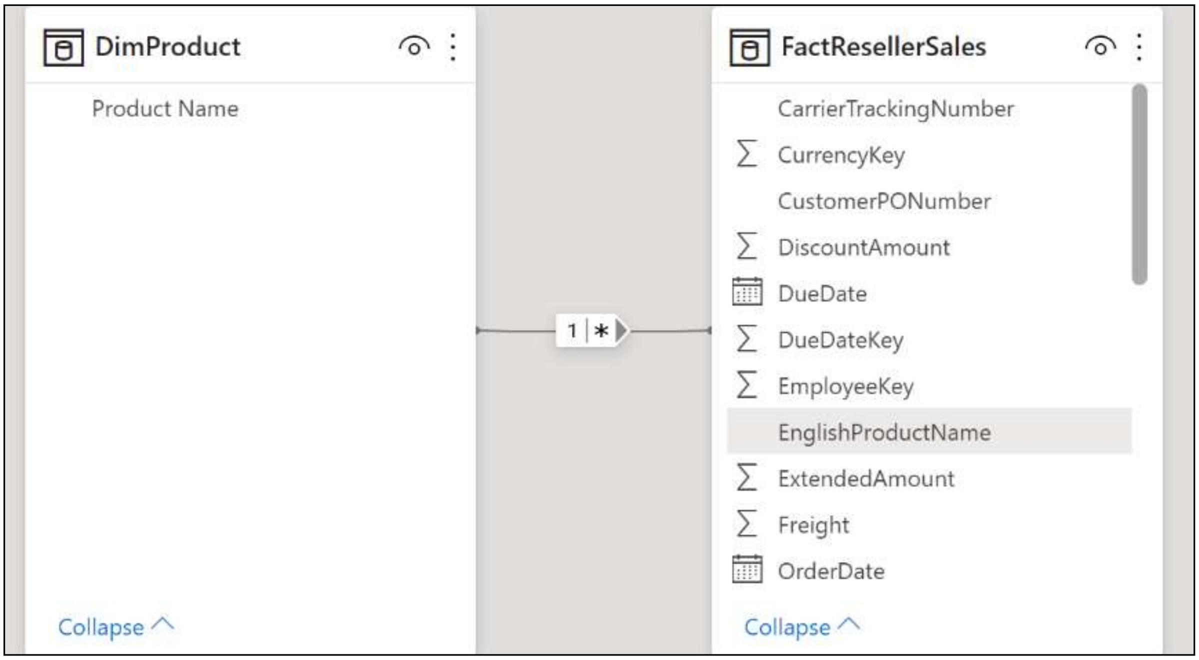


Figure 2.32: Simple one-to-many relationship model

There's more...

To support troubleshooting, create a query that accesses the same source table and retrieves the values from the `EnglishProductName` column with more than one row.

```
let
    Source = AdWorksDW,
    dbo_DimProduct = Source{[Schema="dbo",Item="DimProduct"]}[Data],
    RemoveColumns = Table.SelectColumns(dbo_DimProduct,{"EnglishProductName"}),
    TrimText =
        Table.TransformColumns(
            RemoveColumns,{"EnglishProductName",Text.Trim}
        ),
    UpperCase =
        Table.TransformColumns(
            TrimText,{{"EnglishProductName", Text.Upper}}
```

```
        ),
    GroupedRows =
        Table.Group(
            UpperCase, {"EnglishProductName"},
            {{"Rows", each Table.RowCount(_), Int64.Type}}
        ),
    Duplicates = Table.SelectRows(GroupedRows, each [Rows] > 1)
in
    Duplicates
```

The `EnglishProductName` column is selected, trimmed, converted to uppercase, grouped, and then filtered to always retrieve any duplicate key values. Disable the loading of this query, as the query would only exist for troubleshooting purposes.

See also

- `Table.SelectColumns`: `http://bit.ly/38Qk7Lt`
- `Table.RemoveColumns`: `http://bit.ly/3cJju7p`
- `Table.TransformColumns`: `http://bit.ly/3tsdxm2`
- `Table.DuplicateColumn`: `http://bit.ly/3cIF63X`
- `Table.Distinct`: `http://bit.ly/38V8mmN`
- `Text.Trim`: `http://bit.ly/3eUmAZ0`
- `Text.Upper`: `http://bit.ly/3vFW2R6`
- M functions reference for text: `http://bit.ly/2nUYjnw`

Creating Custom Columns

Business users often extend the outputs of existing reports and data models with additional columns to help them analyze and present data. The logic of these columns is generally implemented through Excel formulas or as calculated DAX columns. A superior solution, particularly if the logic cannot quickly be migrated to a data warehouse or IT resource, is to create the columns via the Power Query Editor and M language.

Developing custom columns can also significantly enhance the ease of use and analytical power of data models and the visualizations they support. In this recipe, columns are created to apply a custom naming format and simplify the analysis of a customer dimension via existing columns.

Getting ready

To get ready for this recipe, import the `DimCustomer` table from the **AdventureWorksDW2019** database by doing the following:

1. Open Power BI Desktop and choose **Transform data** from the ribbon of the **Home** tab to open the **Power Query Editor**.
2. Create an Import mode data source query called `AdWorksDW`. This query should be similar to the following:

    ```
    let
        Source = Sql.Database("localhost\MSSQLSERVERDEV",
    "AdventureWorksDW2019")
    in
        Source
    ```

3. Isolate this query in a query group called **Data Sources**.
4. Right-click `AdWorksDW` and choose **Reference**, select the `DimCustomer` table in the data preview area, and rename this query `DimCustomer`.

For additional details on performing these steps, see the *Managing Queries and Data Sources* recipe in this chapter.

How to Create Custom Columns

To implement this recipe, perform the following steps:

1. Use `Table.SelectColumns` to retrieve the required source columns from the `DimCustomer` table, `FirstName`, `LastName`, `MiddleName`, `Title` and `BirthDate`.

    ```
    let
        Source = AdWorksDW,
        dbo_DimCustomer = Source{[Schema="dbo",Item="DimCustomer"]}[Data],
        SelectColumns =
            Table.SelectColumns(dbo_DimCustomer,
                {"FirstName", "LastName", "MiddleName", "Title",
    "BirthDate"}
            )
    in
        SelectColumns
    ```

2. Write a `Table.AddColumns` function with an `if...then` expression that accounts for the different scenarios given a target format of `Mr. John A. Doe`:

    ```
        NameFormatTble =
            Table.AddColumn(
                SelectColumns,"Formatted Name", each
    ```

```
                if [Title] = null and [MiddleName] = null
                    then [FirstName] & " " & [LastName]
                else if [Title] = null
                    then [FirstName] & " " & Text.
Range([MiddleName],0,1)
                            & ". " & [LastName]
                else
                    [Title] & " " & [FirstName] & " "
                        & Text.Range([MiddleName],0,1) & ". " &
[LastName]
        )
```

3. Add variables that allow the expression to support the comparison between the current system date and the `BirthDate` column.

```
let
    CurrentDate = DateTime.Date(DateTime.LocalNow()),
    CurrentYear = Date.Year(CurrentDate),
    CurrentMonth = Date.Month(CurrentDate),
    CurrentDay = Date.Day(CurrentDate),

    Source = AdWorksDW,
```

4. Use the `Table.AddColumn` function to create `Customer Year`, `Customer Month`, and `Customer Day` columns based upon the `BirthDate` column.

```
    AddCustomerYear =
        Table.AddColumn(
            NameFormatTble, "Customer Year", each Date.
Year([BirthDate]),
            Int64.Type
        ),
    AddCustomerMonth =
        Table.AddColumn(
            AddCustomerYear, "Customer Month", each Date.
Month([BirthDate]),
            Int64.Type
        ),
    AddCustomerDay =
        Table.AddColumn(
            AddCustomerMonth, "Customer Day", each Date.
Day([BirthDate]),
            Int64.Type
        )
```

5. Add an `Age` column via an `if...then` expression.

```
CustomerAge =
    Table.AddColumn(
        AddCustomerDay,"Customer Age", each
        if [Customer Month] < CurrentMonth
            then CurrentYear - [Customer Year]
        else if [Customer Month] > CurrentMonth
            then CurrentYear - [Customer Year] - 1
        else if [Customer Day] < CurrentDay
            then CurrentYear - [Customer Year]
        else CurrentYear - [Customer Year] - 1
    )
```

6. Add a `Customer Age Segment` column via the column computed in *step 4*.

```
CustomerSegment =
    Table.AddColumn(
        CustomerAge, "Customer Age Segment", each
        if [Customer Age] < 30 then "Less than 30"
        else if [Customer Age] < 40 then "30 to 39"
        else if [Customer Age] < 50 then "40 to 49"
        else if [Customer Age] < 60 then "50 to 59"
        else "60 or Older"
    )
```

How it works

In the `NameFormatTble` expression the `Table.AddColumn` function is used, coupled with an `if...then` expression. M is a case-sensitive language, so writing `IF` instead of `if` or `Table.Addcolumn` instead of `Table.AddColumn` will return an error. `if...then` expressions follow the following structure:

```
if <condition1> then <result1> else <result2>
```

All three inputs (`condition1`, `result1`, and `result2`) accept M expressions. `if` expressions can be nested together with the following structure:

```
if <condition1> then <result1> else if <condition2> then <result2> else
<result3>
```

The equivalent of a SQL CASE expression is not available in M. However, the order of conditions specified in `if...then` expressions drives the evaluation process. Multiple conditions could be true but the second and later conditions will be discarded and not evaluated. If the value produced by the `if` condition is not a logical value, an error is raised.

The three `if...then` conditions in the `NameFormatTble` expression account for all scenarios to return the formatted name, since the query must account for nulls in the `Middle Name` and `Title` columns, as well as different values in the `Middle Name` column. `Text.Range` is used to extract the first character of the middle name.

For the variables `CurrentDate`, `CurrentYear`, `CurrentMonth`, and `CurrentDay`, the `DateTime.LocalNow` function is used as the source for the current date; it is then used for year, month, and day.

For the `AddCustomerYear`, `AddCustomerMonth`, and `AddCustomerDay` expressions, the `Int64.Type` value is passed to the optional type parameter of `Table.AddColumn` to set the new columns as whole numbers.

For the `CustomerAge` and `CustomerSegment` expressions, nested `if…then` expressions are used. This method is used because, currently, the equivalent of a `DATEDIFF` function (T-SQL, DAX) with date intervals like `Year`, `Month`, `Week`, and so on, are not available in M. A `Duration.Days` function can be used for day intervals and additional duration functions are available for hour, minute, and second intervals.

The `CustomerAge` expression compares the `CurrentMonth` and `CurrentDay` variables against the values of the customer columns created in the `AddCustomerMonth` and `AddCustomerDay` expressions in order to compute the age of the customer using the `CurrentYear` variable and the column created by the `AddCustomerYear` expression. The column created by the `CustomerAge` column is then used in the `CustomerSegement` expression to derive the age segmentation column. The new custom columns can be used to support various visualizations based upon the ages and segmentation of customers.

There's more...

The Power Query Editor provides graphical user interfaces for adding columns. These interfaces provide mechanisms for adding columns that are an alternative to writing out the code manually. In essence, the M code for the added columns is generated as an output from these interfaces.

One such interface is the **Column From Examples** feature, which allows users to simply type examples of a desired column's output. The engine determines which M functions and series of steps to add to the query that return results consistent with the examples provided. To explore this feature, follow these steps:

1. Create a new query referencing the **AdWorksDW** query.
2. Select the **DimCustomer** table.
3. Select the **Title**, **FirstName**, **MiddleName**, **LastName**, and **BirthDate** columns and remove all other columns.

4. Select the **Add Column** tab and then choose the **Column From Examples** button in the ribbon.

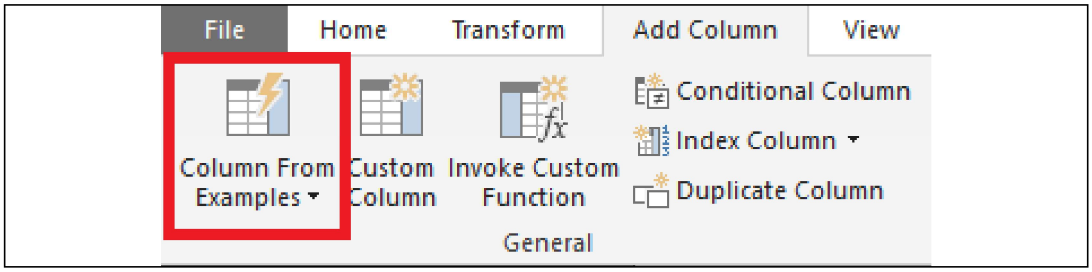


Figure 2.33: Column From Examples feature

5. Type the customer's `FirstName`, `MiddleName`, and `LastName` values into the first row and hit the **Enter** key. Notice that the rest of the rows are automatically calculated based upon this first row.

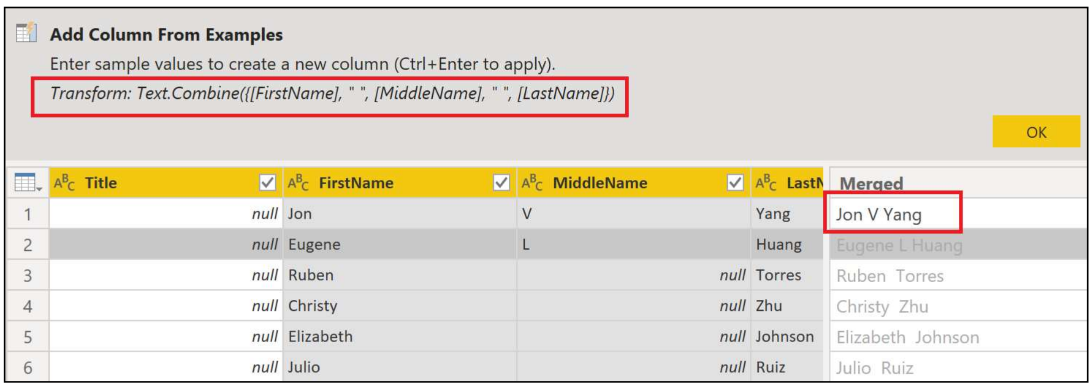


Figure 2.34: Column From Examples interface

6. Click the **OK** button to accept the transformation.

Another interface for adding columns is the **Condition Column** feature. This feature provides a method of creating conditional columns as an alternative to writing out the `if...then` expressions. To see how this feature operates, follow these steps:

1. Select the **Add Column** tab and then select **Conditional Column** from the ribbon.

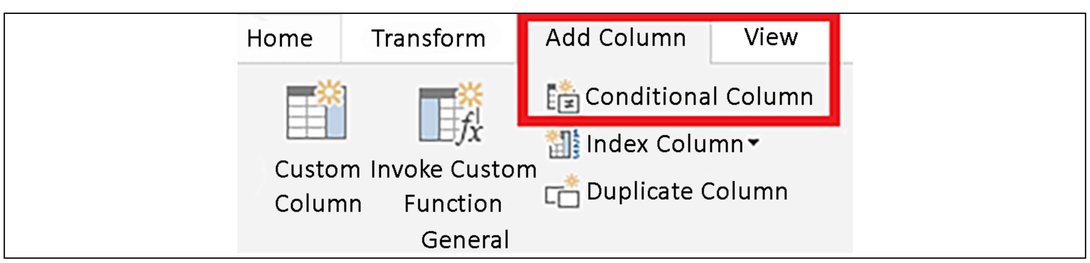


Figure 2.35: Conditional Column feature

2. Fill in the fields on the **Add Conditional Column** dialog, using the **Add Clause** button to add additional `else if` statements; click the **OK** button to exit the dialog and create the new column.

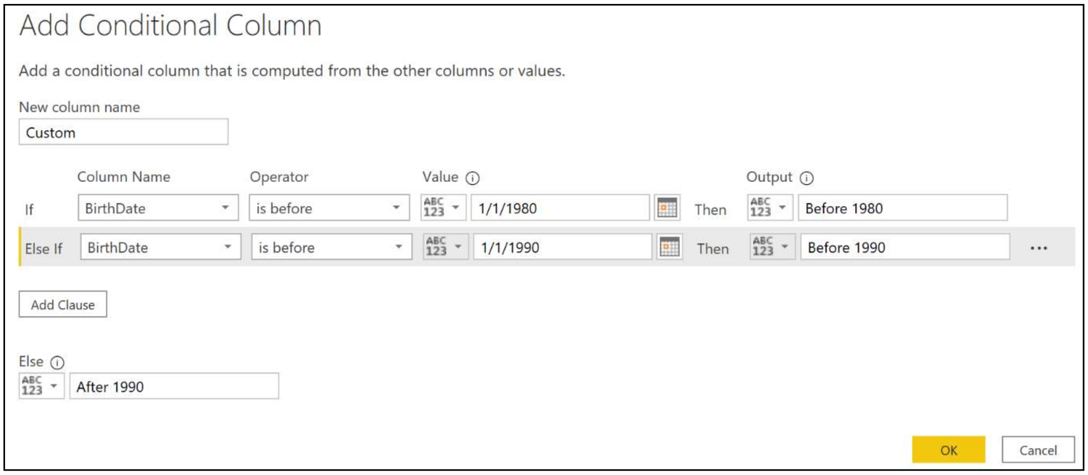


Figure 2.36: Add Conditional Column dialog

Any column from the table can be referenced, and multiple created steps can be moved up or down the order of evaluation using the ellipses (**...**). Open the **Advanced Editor** to inspect the code created.

Figure 2.37: Added conditional column M code

See also

- `Table.AddColumn`: `http://bit.ly/3vGJZ6b`
- `Table.SelectColumns`: `http://bit.ly/38Qk7Lt`
- `DateTime` functions: `http://bit.ly/3tPtKlJ`
- **Add Column From** examples: `http://bit.ly/3eWTLv6`

Combining and Merging Queries

The full power of Power BI's querying capabilities is in the integration of distinct queries representing different data sources via its merge and append transformations. Retrieval processes that consolidate files from multiple network locations or integrate data from multiple data sources can be developed efficiently and securely. Additionally, the same join types and data transformation patterns SQL and ETL developers are familiar with can be achieved with the M language. This recipe provides examples of combining sources into a single query and leveraging the table join functions of M to support common transformation scenarios.

Getting ready

To follow along with this recipe, you can use the **Merge Queries** and **Append Queries** icons on the **Home** tab of the Power Query Editor to generate the join expressions used in this recipe. However, as joining queries is fundamental to the retrieval process, it is recommended to learn how to use the `Table.Join`, `Table.NestedJoin`, and `Table.Combine` functions.

To get ready for this recipe, import the `DimCustomer` and `FactCallCenter` tables from the **AdventureWorksDW2019** database by doing the following:

1. Open Power BI Desktop and choose **Transform data** from the ribbon of the **Home** tab to open the **Power Query Editor**.
2. Create an Import mode data source query called `AdWorksDW`. This query should be similar to the following:

```
let
    Source = Sql.Database("localhost\MSSQLSERVERDEV",
"AdventureWorksDW2019")
in
    Source
```

3. Isolate this query in a query group called **Data Sources**.
4. Right-click `AdWorksDW` and choose **Reference**, select the `DimEmployee` table in the data preview area, and rename this query `DimEmployee`.
5. Repeat *step 4* but choose the **FactInternetSales** table and name this query **Sales2011**. Filter the **OrderDate** column to be between January 1, 2011 and December 31, 2011.

```
Let
    Source = AdWorksDW,
    dbo_FactInternetSales = Source{[Schema="dbo",Item="FactInternetSal
es"]}[Data],
    #"Filtered Rows" =
        Table.SelectRows(
```

```
            dbo_FactInternetSales, each
                [OrderDate] >= #datetime(2011, 1, 1, 0, 0, 0) and
                [OrderDate] <= #datetime(2011, 12, 31, 0, 0, 0))
in
    #"Filtered Rows"
```

6. Right-click the **Sales2011** query and choose **Duplicate**. Name this query **Sales2012**. Edit the `Table.SelectRows` expression to filter dates between January 1, 2012 and December 31, 2012.
7. Repeat *step 6*, naming this new query **Sales2013** and filtering for dates between January 1, 2013 and December 31, 2013.

For additional details on performing these steps, see the *Managing Queries and Data Sources* recipe in this chapter.

How to Combine Queries

The goal of this example is to produce an integrated table based on three "Sales" queries. While in this example the three queries come from the same data source, it is important to realize that the three queries could point to completely different data sources, such as three text files or even a text file, an Excel spreadsheet, and a SQL database. What is important is that the three queries have the same column names and number of columns. To implement this recipe, perform the following steps:

1. Move the **Sales2011**, **Sales2012**, and **Sales2013** queries to a new query group called **Staging Queries**.
2. Disable the load for the **Sales2011**, **Sales2012**, and **Sales2013** queries.
3. Create a new **Blank** query in the **Other Queries** group and call this query **FactInternetSales2011to2012**.
4. Open the **FactInternetSales2011to2012** query in **Advanced Editor**.
5. Use the `Table.Combine` (or **Append Queries** feature in the ribbon) function to return a single table based on the rows of the **Sales2011**, **Sales2012**, and **Sales2013** queries.

```
Let
    Source = Table.Combine( {Sales2011, Sales2012, Sales2013} )
in
    Source
```

6. Move the **DimEmployees** query to the **Staging Queries** group and disable loading.

7. Duplicate the **DimEmployees** query and call this new query **Managers**.
8. Disable loading for the **Managers** query.
9. Open the **Managers** query in the **Advanced Editor**.
10. Add a **Manager Name** column using the `Table.AddColumn` function.

```
    ManagerName =
        Table.AddColumn(
            dbo_DimEmployee,
            "Manager Name", each [FirstName] & " " & [LastName]
        )
```

11. Select only the **EmployeeKey**, **Manager Name**, and **Title** columns using the `Table.SelectColumns` function.

```
    SelectCols =
        Table.SelectColumns(
            ManagerName,
            { "EmployeeKey", "Manager Name", "Title" }
        )
```

12. Create a new **Blank** query in the **Other Queries** group and call this query **Employees**.
13. Open the **Employees** query in **Advanced Editor**.
14. Join the `Managers` query and `DimEmployee` query using the `Table.NestedJoin` function or the **Merge Queries** feature in the ribbon.

```
Let
    Source =
        Table.NestedJoin(
            DimEmployee, "ParentEmployeeKey", Managers, "EmployeeKey",
            "ManagerColumn", JoinKind.LeftOuter
        )
in
    Source
```

15. Use the `Table.ExpandTableColumn` function to add the `Manager Name` and `Manager Title` columns.

```
    ManagerColumns =
        Table.ExpandTableColumn(
            Source, "ManagerColumn",
            { "Manager Name", "Title" },
            { "Manager Name", "Manager Title" }
        )
```

16. Add an **Employee Name** column.

```
EmployeeName =
    Table.AddColumn(
        ManagerColumns,
        "Employee Name", each [FirstName] & " " & [LastName]
    )
```

17. Rename the **Title** column to **Employee Title**.

```
RenameTitle =
    Table.RenameColumns(
        EmployeeName,
        { "Title", "Employee Title" }
    )
```

18. Select the `EmployeeKey`, `Employee Name`, `Employee Title`, `Manager Name`, and `Manager Title` columns.

```
SelectCols =
    Table.SelectColumns(
        RenameTitle,
        {
            "EmployeeKey", "Employee Name", "Employee Title",
            "Manager Name", "Manager Title"
        }
    )
```

How it works

For the **FactInternetSales2011to2013** query, only a single expression is required using the `Table.Combine` function. No other expressions are necessary in this example given that the staging queries have identical column names and the same number of columns. The `Table.Combine` function performs an append operation and does not remove duplicate rows similar to a SQL UNION statement.

Any columns which are unique to one of the input tables in a `Table.Combine` function will be added to the result set with null values for the rows from the other tables. Depending on the scenario, the developer could apply the `Table.Distinct` function to avoid any duplicate rows from reaching the data model.

The **Employees** query references the **DimEmployees** query as the left table in a `Table.NestedJoin` function, and is joined to the `Managers` query via a left outer join. The left join is required to retain all employee rows in this scenario, as the `DimEmployees` table includes one employee that does not have a parent employee key, the `Chief Executive Officer`.

The join is performed on the `ParentEmployeeKey` column in the **DimEmployees** query to the `EmployeeKey` column in the **Managers** query. After this step, all of the rows from the matching **Managers** table are stored within the row as a `Table` object in the column **ManagerColumn**. When expanding the **ManagerColumn** column using the `Table.ExpandTableColumn` function, the **Manager Name** column can retain the same name, but the **Title** column is renamed to **Manager Title** in order to avoid conflicting with the **Title** column in the **DimEmployees** query.

In implementing the table joins, you can choose to use the `Table.Join` and `Table.NestedJoin` functions. All six join types—inner, left outer, right outer, full outer, left anti, and right anti—are supported by both functions. The `Table.NestedJoin` function enters the results of the join (the right or second table) into a new column of table values and will use local resources to execute the join operation, unless the `Table.ExpandTableColumn` function is used to replace this new column with columns from the right table. A left outer join type is the default if the `JoinKind` parameter is not specified. For performance reasons, `Table.NestedJoin` should not be used without a `Table.ExpandTableColumn` function removing the column of tables.

Conversely, the `Table.Join` function automatically expands the left table with the columns from the right table input (a flat join) and defaults to an inner join if the `JoinKind` parameter is not specified. The `Table.Join` function gets folded to the source without any additional functions but requires that there are no matching column names between the joined tables for a `JoinKind` other than inner join. For inner joins, the matching column names from both tables must be specified in the join key parameters. A `Table.SelectColumns` function is required to exclude any columns from the right table added with the join.

Whether implemented via `Table.NestedJoin` or `Table.Join`, developers should look to use inner joins if the source tables have referential integrity, such as with foreign key constraints and whether this meets requirements. For joins against larger tables, developers should confirm that query folding is occurring and can evaluate the different query plans generated by alternative retrieval designs in terms of performance.

Note that the two rows for Rob Walters are due to a **Slowly Changing Dimension** (**SCD**) Type 2 process applied in the source database. For more information on SCDs, refer to this Wikipedia article: `https://bit.ly/3yIQeI5`.

There's more...

Rather than creating separate lookup/join staging queries, it is possible to consolidate these expressions into a single `let…in` M expression. For example, the following single query returns the exact same results as the **Sales2011**, **Sales2012**, **Sales2013**, and **FactInternetSales2011to2013** queries:

```
let
    Source = AdWorksDW,
    Sales = Source{[Sche"a=""bo",It"m="FactInternetSa"es"]}[Data],
    Sales2011Rows =
```

```
        Table.SelectRows(
            Sales, each
                [OrderDate] >= #datetime(2011, 1, 1, 0, 0, 0) and
                [OrderDate] <= #datetime(2011, 12, 31, 0, 0, 0)
        ),
    Sales2012Rows =
        Table.SelectRows(
            Sales, each
                [OrderDate] >= #datetime(2012, 1, 1, 0, 0, 0) and
                [OrderDate] <= #datetime(2012, 12, 31, 0, 0, 0)
        ),
    Sales2013Rows =
        Table.SelectRows(
            Sales, each
                [OrderDate] >= #datetime(2013, 1, 1, 0, 0, 0) and
                [OrderDate] <= #datetime(2013, 12, 31, 0, 0, 0)
        ),
    Append = Table.Combine( {Sales2011Rows, Sales2012Rows, Sales2013Rows} )
in
    Append
```

Inline query approaches are helpful in limiting the volume of queries, but you lose the management benefits provided by group folders and the **Query Dependencies** view. The graphical support makes it easier to explain and quickly troubleshoot a data retrieval process over a single but complex M expression. Staging queries are recommended for all but the most trivial projects and retrieval processes. Staging queries should generally never be loaded to the data model, as staging tables could both confuse the user and would require the data model to use additional resources to process and store the additional data.

Similarly, merge queries can also be combined into a single query. The following table breaks down the six different join types that can be specified in both the `Table.NestedJoin` and `Table.Join` functions. Both the **Parameter** and **Parameter Value** can be used, though the recipes in this book use **Parameter** as this makes the expressions easier to follow.

Join type	Parameter	Parameter value
Inner	`JoinKind.Inner`	0
Left Outer	`JoinKind.LeftOuter`	1
Right Outer	`JoinKind.RightOuter`	2
Full Outer	`JoinKind.FullOuter`	3
Left Anti	`JoinKind.LeftAnti`	4
Right Anti	`JoinKind.RightAnti`	5

Table 2.3: Power Query (M) join types, parameters, and parameter values

One final note is that, for data source files with the same structure stored in the same network directory folder, Power BI offers the **Combine Binaries** transformation, which can be used with text, CSV, Excel, JSON, and other file formats. This feature can be used when creating a **Folder** query. The **Combine Binaries** feature automatically creates an example query and a function linked to this query, such that any required modification to the source files can be applied to all files, and the source location of the files can be easily revised.

See also

- `Table.Combine`: `http://bit.ly/3c6L2o0`
- `Table.NestedJoin`: `http://bit.ly/30ZO3jZ`
- `Table.Join`: `http://bit.ly/3lxMRh7`
- `Table.ExpandTableColumn`: `http://bit.ly/3eY6u0z`
- `Table.AddColumn`: `http://bit.ly/3vGJZ6b`
- `Table.SelectColumns`: `http://bit.ly/38Qk7Lt`
- `Table.RenameColumns`: `http://bit.ly/3rTVfd4`
- M table function reference: `http://bit.ly/2oj0k0I`
- Combining binaries in Power BI Desktop: `http://bit.ly/2oL2nM4`

Selecting Column Data Types

Setting the data types of columns in Power BI Desktop is usually the final step of data retrieval queries, and has great implications for all layers of the solution, including data refresh, data modeling, and visualization. Choosing appropriate data types reduces the risk of refresh failures, ensures consistent report results, and provides analytical flexibility to the data model and visualization layers.

This recipe demonstrates how to choose and define data types to load to Power BI Desktop. Additional details on data types and the implications of data types for Power BI development are contained in the sections following these examples.

Getting ready

In preparation for this recipe, import the `FactCallCenter` table from the **AdventureWorksDW2019** database by doing the following:

1. Open Power BI Desktop and choose **Transform data** from the ribbon of the **Home** tab to open the **Power Query Editor**.

2. Create an Import mode data source query called `AdWorksDW`. This query should be similar to the following:

```
let
    Source = Sql.Database("localhost\MSSQLSERVERDEV",
"AdventureWorksDW2019")
in
    Source
```

3. Isolate this query in a query group called **Data Sources**.
4. Right-click `AdWorksDW` and choose **Reference**, select the **FactFinance** table in the data preview area, and rename this query **FactFinance**.
5. Move the **FactFinance** query to the **Other Queries** group.

For additional details on performing these steps, see the *Managing Queries and Data Sources* recipe in this chapter.

How to Select Column Data Types

To implement this recipe, perform the following steps:

1. Use the `Table.TransformColumnTypes` function to revise the type of the numeric integer **FinanceKey** column to text. Note that the column header for the **FinanceKey** column is initially prefaced with a **123** icon and changes to an **ABC** icon. Also, note that the row values are initially left justified and italicized and after transformation to text are aligned to the right and not italicized.

```
let
    Source = AdWorksDW,
    dbo_FactFinance = Source{[Schema="dbo",Item="FactFinance"]}[Data],
    FinanceKeyText =
        Table.TransformColumnTypes(
            dbo_FactFinance, {{"FinanceKey", Text.Type}}
        )
in
    FinanceKeyText
```

2. Add a numeric column from a source column stored as text using the `Number.FromText` and `Table.AddColumn` functions.

```
    FinanceKeyNum =
        Table.AddColumn(
            FinanceKeyText, "FinanceKeyNum",
            each Number.FromText([FinanceKey]),Int64.Type
        )
```

3. Change the fixed decimal **Amount** column to currency using the `Table.TransformColumnTypes` function. Note that the column header icon changes from **1.2** initially to a dollar sign, **$**.

```
Currency =
    Table.TransformColumnTypes(
        FinanceKeyNum,{{"Amount", Currency.Type}}
    )
```

How it works

For the `FinanceKeyText` expression, the `Table.TransformColumnTypes` function takes two parameters. The first parameter is the table to operate upon; the second is a list of list pairs that include the column name to transform and then the transformation data type. Multiple pairs can be included in the form:

```
{ { "Column1", type }, { "Column2", type } }
```

Additional valid values for the type parameter include the following:

- `Currency.Type` sets the column as a **Fixed Decimal Number** to two decimal places.
- `Decimal.Type` or `type number` sets the new column as a **Decimal Number**.
- `Percentage.Type` sets the column as a **Percentage** data type. Unlike **Whole Number**, **Fixed Decimal Number**, and **Decimal Number**, this type does not have a corresponding type in the data model. When loaded to the data model, the **Percentage** data type is represented as a **Decimal Number** type.
- `Text.Type` or `type text` sets the column to a **Text** data type.
- `Date.Type` or `type date` sets the column to a **Date** data type.
- `DateTime.Type` or `type datetime` sets the column to a **Date Time** data type.
- `DateTimeZone.Type` or `type datetimezone` sets the column to a **Date/Time/Timezone** data type.
- `Time.Type` or `type time` sets the column to a **Time** data type.
- `Duration.Type` or `type duration` sets the column to a **Duration** data type.
- `Logical.Type` or `type logical` sets the column to a **True/False** data type.
- `Binary.Type` or `type binary` sets the column to a **Binary** data type.

Like all M expressions, data type declarations are case-sensitive.

For the `FinanceKeyNum` expression, the type parameter for the `Table.AddColumn` function is optional. Leaving this parameter blank results in an **Any** data type, which would be loaded into the data model as a **Text** data type. By specifying `Int64.Type` as the optional type parameter to `Table.AddColumn`, the new column stores whole numbers instead of text.

Great care should be taken when choosing data types. For example, convert **Decimal Number** to **Fixed Decimal Number** data types if consistent rounding results are required. Also, converting from **Decimal Number** to **Fixed Decimal Number** can marginally improve data compression and query performance. A **Decimal** data type is approximate and can produce inconsistent reporting results due to rounding. **Decimal Number** data types are floating-point (approximate) data types with 15 digits of precision. **Fixed Decimal Number** data types store 19 digits of precision and four significant digits after the decimal. **Whole Number** data types store up to 19 digits of precision.

Revising **Text** data types to **Numeric** data types impacts the DAX metrics that can be written. For example, if a `Calendar Year` column is stored as a **Text** data type, the following DAX metric will fail due to the type incompatibility of the number 2016:

```
Sales in 2016 and Later = CALCULATE([Internet Sales], 'Date'[Calendar Year] >= 2016)
```

Figure 2.38: DAX measure expression

Revising `Calendar Year` to a whole number type avoids the need to use `VALUE` or `FORMAT` functions in each DAX measure. Power BI Desktop provides rich analysis capabilities for columns of the **Date** data type, including drill-down hierarchies, visual calendar pickers for filters, custom date filtering logic in slicers, and calculations such as for the first and last date. Given these capabilities, as well as DAX functionality with **Date** data types, converting **Text** and **Numeric** types to **Date** data types can provide significantly more options to develop Power BI content.

There's more...

While there are many topics that can be discussed regarding data types in Power Query, two are worth exploring in greater detail: **automatic data type detection** and **date with locale**. When enabled, automatic data type detection occurs when using unstructured data sources, such as flat files and Excel workbooks. When importing such data, a **Changed Type** step is added that uses a sampling or preview of each source column to determine the appropriate type.

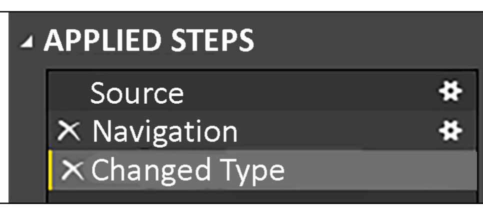


Figure 2.39: Automatic Data Type Selection Step

If the data sample does not reflect the full or future set of values for the column, the data type selected may be incorrect. Automatic type detection is not used with structured relational database systems such as SQL Server.

You can avoid automatic type detection via the **Data Load** options in the **File | Options and settings | Options** dialog.

As automatic detection is a **CURRENT FILE** option only, and since the setting is enabled by default, you currently need to disable this automatic type detection for each new file. It is recommended that you disable this for each file or manually remove the **Changed Type** step and make your own decisions regarding data type transformations.

Power Query also supports different locales or cultures. If there's any potential for **Date** data types to be sourced from a region with a different date standard than your local system, you should apply the **Locale** option to the `Table.TransformColumnTypes` function; for example, when a date column stores date values in the format `dd/mm/yyyy`, whereas the local system uses `mm/dd/yyyy`. Trying to convert this date directly on a desktop configured for US English causes an error as the first two digits are greater than 12. However, specifying the source locale in the transform expression allows for successful conversion. The Query Editor provides a simple interface for the source locale. Simply right-click on the column, expand **Change Type**, and then select **Using Locale....**

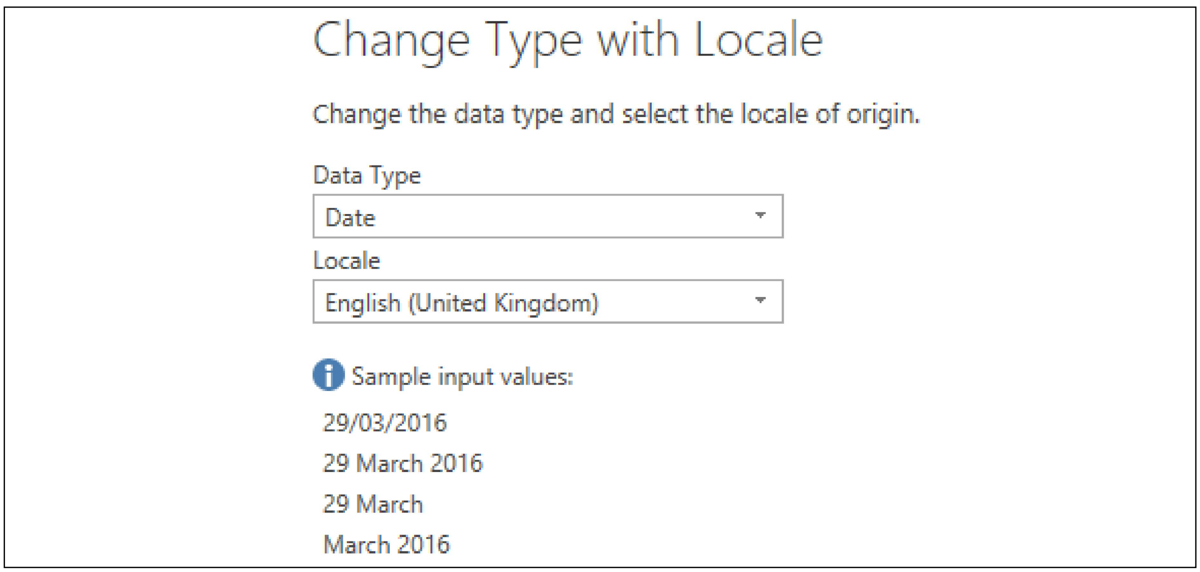


Figure 2.40: Change Type with Locale interface

Alternatively, you can add the locale to the expression itself directly:

```
DateLocale =
    Table.TransformColumnTypes(
        PreviousStep, {{ "Date", type date }}, "en-GB"
    )
```

See also

- `Table.AddColumn`: `http://bit.ly/3vGJZ6b`
- `Table.TransformColumnTypes`: `http://bit.ly/3s5AfjC`
- Data types in Power Query: `http://bit.ly/392iWIP`

- Language ID and tag reference: `http://bit.ly/3cXpPfw`
- 10 Common Mistakes You Do In #PowerBI #PowerQuery – Pitfall #2: `http://bit.ly/2otDbcU`
- Choosing Numeric Data Types in DAX: `http://bit.ly/2nOWYAm`

Visualizing the M library

To implement complex and less common data transformation requirements, it is often necessary to browse the M library to find a specific function or review the parameters of a specific function.

This short recipe provides a pre-built M query expression you can use to retrieve the M library into a table for analysis in Power BI Desktop. Additionally, an example is provided of visualizing and cross-filtering this table of functions on the Power BI report canvas.

Getting ready

To get ready for this recipe, do the following:

1. Open Power BI Desktop.
2. Click the **Transform data** icon in the ribbon of the **Home** tab.
3. Create a new **Blank Query** and call this query **MLibrary**.

How to Visualize M library

To implement this recipe, perform the following steps:

1. Enter the following M code in the **Advanced Editor**:

```
let
    Source = Record.ToTable(#shared),
    Rename = Table.RenameColumns(Source, {{"Name", "Function"}}),
    Sort = Table.Sort(Rename, {{"Function", Order.Ascending}}),
    Dupe = Table.DuplicateColumn(Sort, "Function", "Function2"),
    Split =
```

```
            Table.SplitColumn(
                Dupe, "Function2",
                Splitter.SplitTextByDelimiter(".", QuoteStyle.Csv),
                {"Group", "Detail"}
            ),
        MLibraryTable =
            Table.TransformColumnTypes(
                Split, {{"Group", Text.Type}, {"Detail", Text.Type}}
            )
in
    MLibraryTable
```

2. Click the **OK** button to close the **Advanced Editor**. The preview area should now look similar to that shown in *Figure 2.41*.

	Function	Value	Group	Detail
1	AI.ExecuteInProc	Function	AI	ExecuteInProc
2	AI.ExecuteInternal	Function	AI	ExecuteInternal
3	AI.ExternalSort	Function	AI	ExternalSort
4	AI.GetAutoMLEntity	Function	AI	GetAutoMLEntity
5	AI.SampleStratifiedWithHoldout	Function	AI	SampleStratifiedWithHoldout
6	AI.TestConnection	Function	AI	TestConnection
7	AIFunctions.Capacities	Function	AIFunctions	Capacities
8	AIFunctions.Contents	Function	AIFunctions	Contents
9	AIFunctions.ExecuteInternal	Function	AIFunctions	ExecuteInternal
10	AIFunctions.GetAutoMLEntity	Function	AIFunctions	GetAutoMLEntity
11	AIFunctions.PostProcess	Function	AIFunctions	PostProcess
12	AIInsights.Contents	Function	AIInsights	Contents
13	AIInsights.ContentsGenerator	Function	AIInsights	ContentsGenerator
14	AML.Execute	Function	AML	Execute
15	AML.ExecuteBatch	Function	AML	ExecuteBatch
16	Access.Database	Function	Access	Database

Figure 2.41: Query Editor view of library table function

3. Click on **Close and Apply** from the Query Editor.
4. The 1,000+ rows from the M library are now loaded to the **Data** mode.

5. Create a **visualization** that uses the `Function Groups` column for filtering.

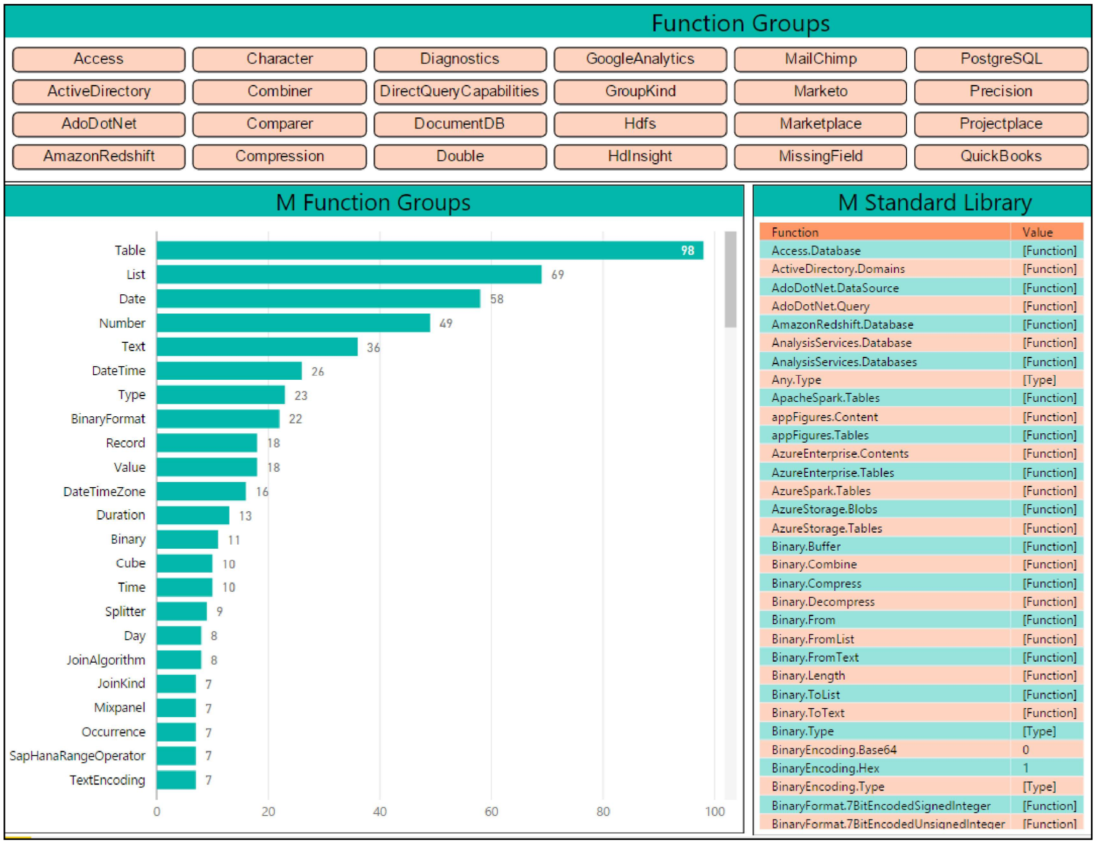


Figure 2.42: Report page of M standard library

How it works

The M expression leverages the `#shared` variable, which returns a record of the names and values currently in scope. The record is converted to a table value and then the `Function` column, originally `Name` in the context of the library, is split based on the period delimiter to allow for the `Group` column.

There's more...

M library details for every function are made available by entering the function without any parameters.

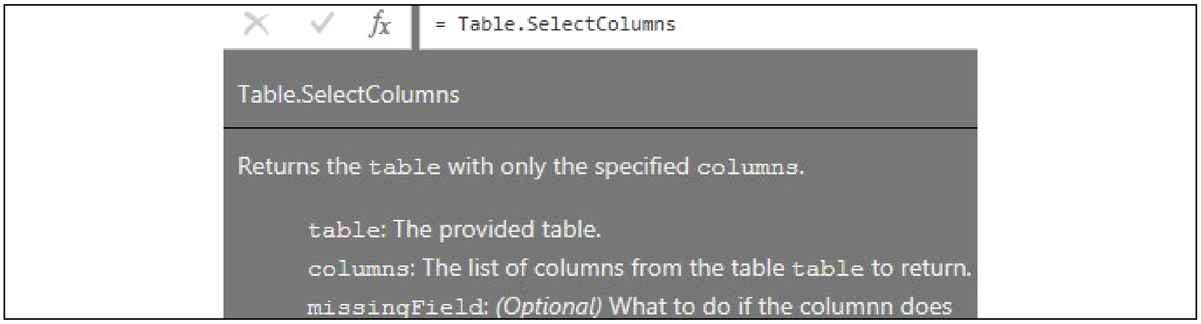


Figure 2.43: Library Function Details

See also

- Power Query function reference: `http://bit.ly/3bLKJ1M`

Profiling Source Data

The topic of data quality deals with the overall utility of datasets, and the ability to easily process and use the data for certain purposes, including analytics and reporting. Data quality is an essential component of data governance, ensuring that business data is accurate, complete, consistent, and valid. Good data quality is an essential element of any data analytics and reporting endeavor. Poor data quality can lead to incorrect analysis and decisions by the business—hence the phrase "garbage in, garbage out". Luckily, the Power Query Editor provides powerful data profiling tools to assist in quickly determining the quality of the data with which you are working. This recipe demonstrates how to unlock the powerful tools within the Power Query Editor for profiling columns and gaining a sense of the quality of the data being worked upon.

Getting ready

To get ready for this recipe, import the `FactCallCenter` table from the **AdventureWorksDW2019** database by doing the following:

1. Open Power BI Desktop and choose **Transform data** from the ribbon of the **Home** tab to open the **Power Query Editor**.
2. Create an **Import** mode data source query called `AdWorksDW`. This query should be similar to the following:

```
let
    Source = Sql.Database("localhost\MSSQLSERVERDEV",
"AdventureWorksDW2019")
in
    Source
```

3. Isolate this query in a query group called **Data Sources**.
4. Right-click `AdWorksDW` and choose **Reference**, select the **FactFinance** table in the data preview area, and rename this query **FactFinance**.
5. Move the **FactFinance** query to the **Other Queries** group.

For additional details on performing these steps, see the *Managing Queries and Data Sources* recipe in this chapter.

How to Profile Source Data

To implement this recipe, perform the following steps:

1. Select the **FactFinance** query.
2. In the **View** tab, check the box for **Column profile** in the **Data Preview** area of the ribbon.
3. Select a column to view the column statistics similar to those in *Figure 2.44*:

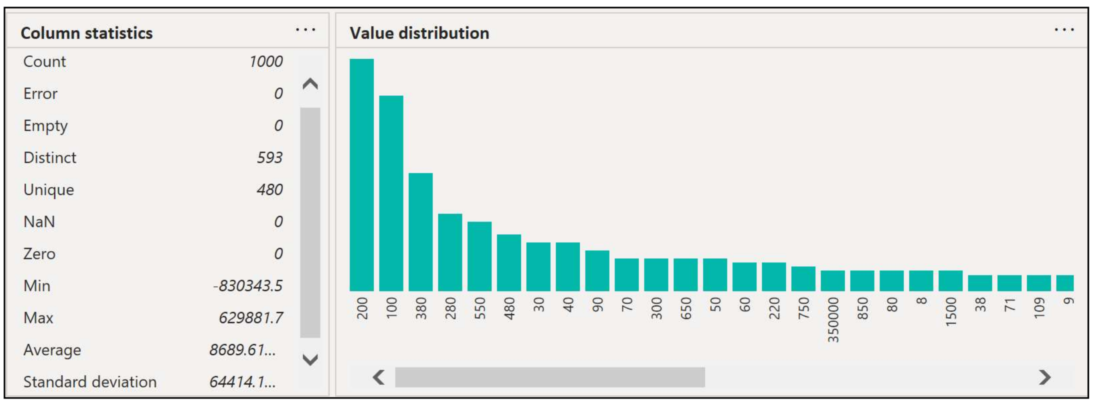


Figure 2.44: Column profile information

How it works

By default, the M query engine pulls the first 1,000 rows of data from the specified data source. This is the data used in the data preview area. The default of using only the first 1,000 rows of data can be changed by clicking on **Column profiling based on top 1000 rows** in the status bar in the bottom right and choosing **Column profiling based on the entire data set.** Statistics are collected on each column in the data source. When the **Column profile** feature is enabled, selecting a column causes column statistics and value distribution to display in the bottom half of the data preview area, including alongside this error counts, the number of distinct and unique values, minimum values, maximum values, and additional information that depends upon the data type of the column, as shown in *Figure 2.44*.

There's more...

Additional data quality dialogs are available in the Power Query Editor. From the **View** tab, check the box next to **Column quality** and **Column distribution**. Small visuals appear under the column headings. Hovering your mouse over this area provides a pop-up dialog that provides suggested actions as well as common data cleansing activities via the ellipsis menu (...).

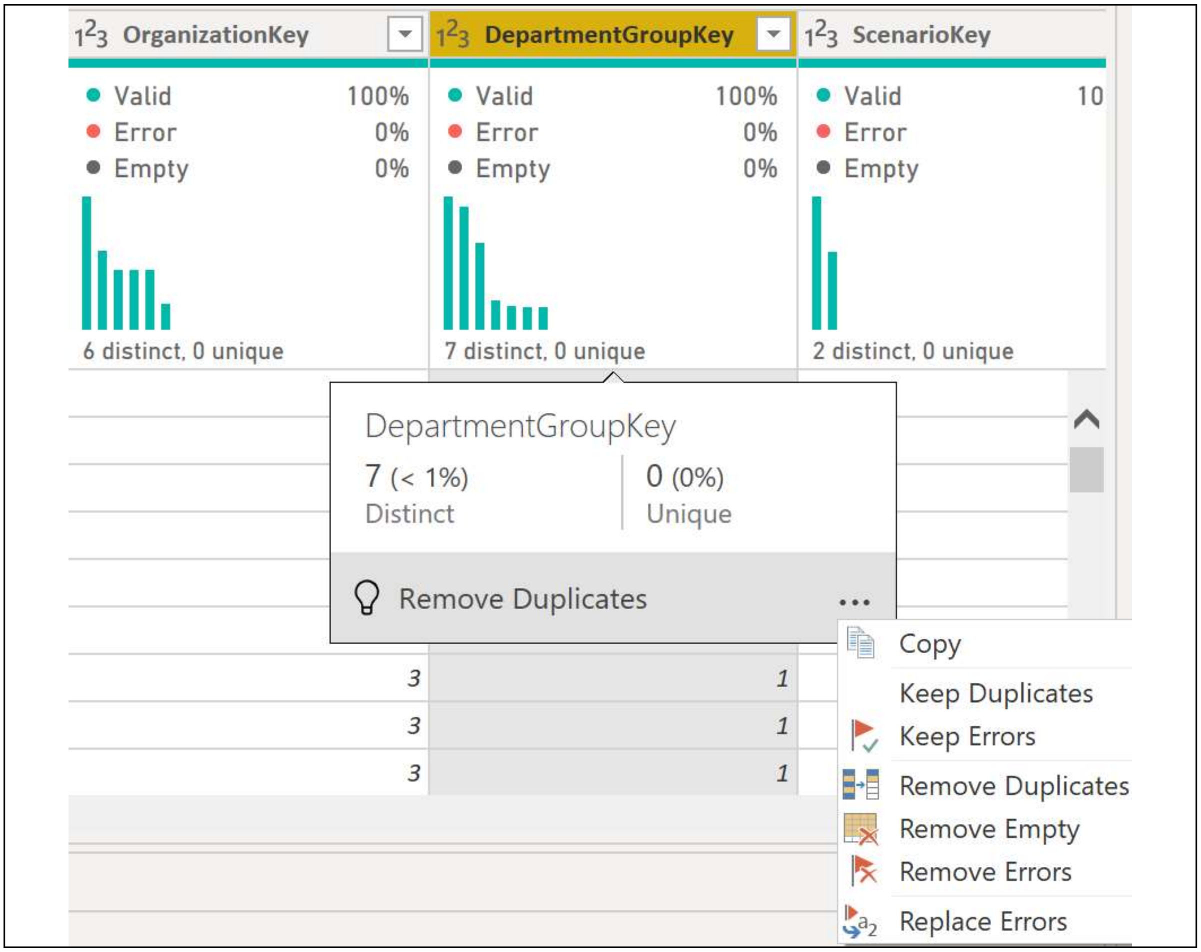


Figure 2.45: Column quality and Column distribution visuals

See Also

- *Using the data profiling tools*: `http://bit.ly/3c46s5g`

Diagnosing Queries

The Power Query M engine is an extremely powerful and fast data transformation and data preparation engine used across an array of products, including:

- Excel for Windows
- Excel for Mac
- Power BI
- Power Apps
- Power Automate
- Azure Data Factory
- SQL Server Integration Services
- SQL Server Analysis Services
- Dynamics 365 Customer Insights

While both fast and powerful, there are times when you may find that a particular query is not as performant as desired. In these instances, Query Diagnostics can help you pinpoint problematic expressions and better understand what Power Query is doing in order to identify areas for query optimization. This recipe demonstrates how the user can use Query Diagnostics to troubleshoot a query and identify how the query might be optimized to be more performant.

Getting ready

To get ready, import the `FactCallCenter` table from the **AdventureWorksDW2019** database by doing the following:

1. Open Power BI Desktop and choose **Transform data** from the ribbon of the **Home** tab to open the **Power Query Editor**.
2. Create an Import mode data source query called `AdWorksDW`. This query should be similar to the following:

```
let
    Source = Sql.Database("localhost\MSSQLSERVERDEV",
"AdventureWorksDW2019")
in
    Source
```

3. Isolate this query in a query group called **Data Sources**.

4. Right-click `AdWorksDW` and choose **Reference**; select the **FactCurrencyRate** table in the data preview area, and rename the AdWorksDW query to **FactCurrencyRate**.
5. Move the **FactCurrencyRate** query to the **Other Queries** group.
6. In the **Power Query Editor**, select the **Tools** tab and then **Diagnostic Options**.
7. Ensure that the radio button for **Enable in Query Editor (does not require running as admin)** is selected and check all the boxes under the **Diagnostics Level** and **Additional Diagnostics** sub-headings.

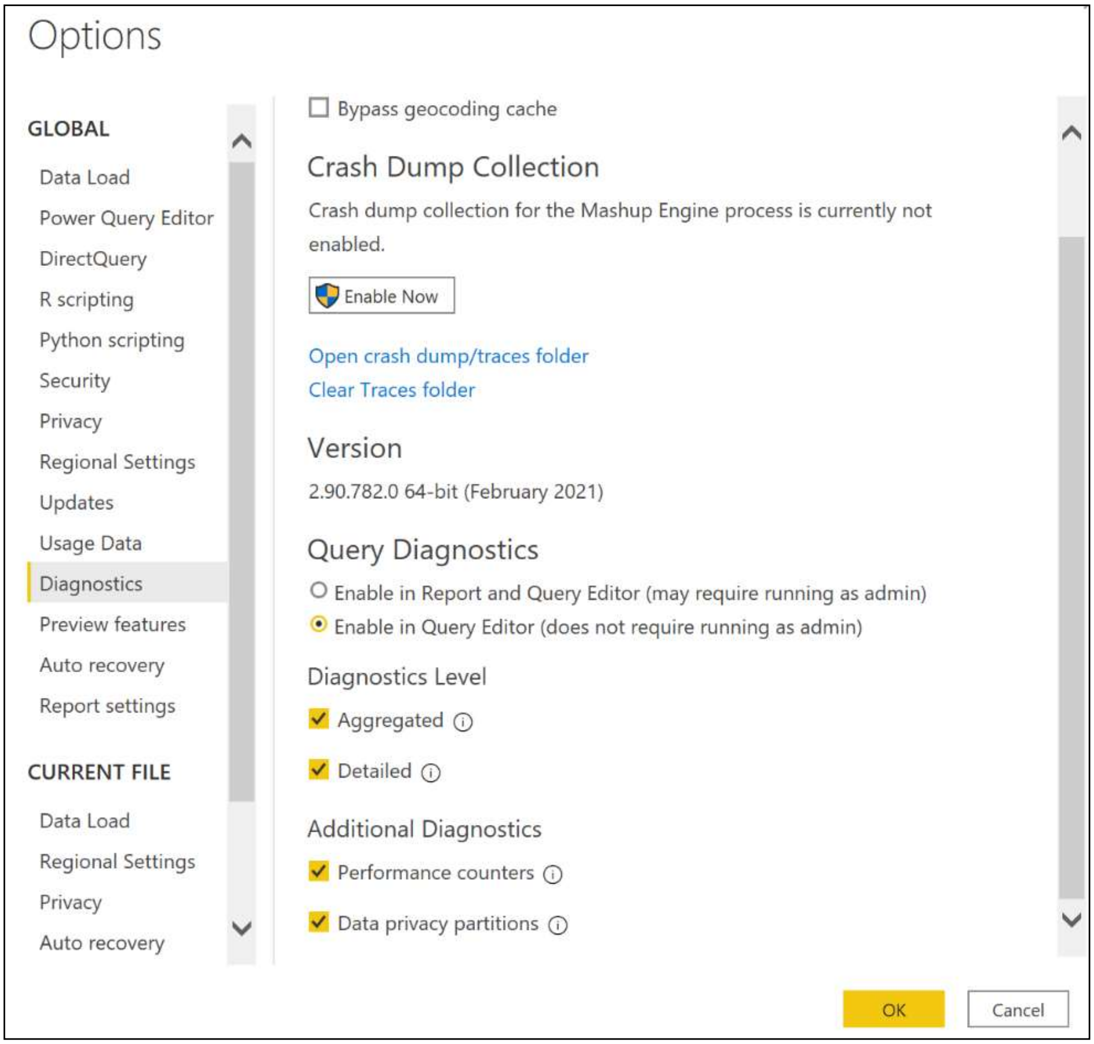


Figure 2.46: Query Diagnostic options

For additional details on performing these steps, see the *Managing Queries and Data Sources* recipe in this chapter.

How to Diagnose Queries

To implement this recipe, perform the following steps:

1. Select the **FactCurrencyRate** query, open **Advanced Editor**, and modify the query to calculate the daily change in currency rates.

```
let
    Source = AdWorksDW,
    dbo_FactCurrencyRate = Source{[Schema="dbo",Item="FactCurrencyRa
te"]}[Data],
    Sort =
        Table.Sort(
            dbo_FactCurrencyRate,
            {{"CurrencyKey", Order.Ascending}, {"DateKey", Order.
Ascending}}
        ),
    Index =
        Table.TransformColumnTypes(
            Table.AddIndexColumn(Sort, "Row Index", 1, 1),
            {{ "Row Index", Int64.Type }}
        ),
    PrevIndex =
        Table.TransformColumnTypes(
            Table.AddIndexColumn(Index, "Prev Index", 0, 1),
            {{ "Prev Index", Int64.Type }}
        ),
    SelfJoin =
        Table.NestedJoin(
            PrevIndex, {"Prev Index"}, PrevIndex, {"Row Index"},
            "NewColumn", JoinKind.LeftOuter
        ),
    PrevColumns =
        Table.ExpandTableColumn(
            SelfJoin, "NewColumn",
            {"EndOfDayRate", "CurrencyKey"}, {"PrevRate", "PrevKey"}
        ),
    AddChange =
        Table.AddColumn(
            PrevColumns, "Daily Change", each
            if [CurrencyKey] = [PrevKey] then [EndOfDayRate] -
[PrevRate]
```

```
            else null, type decimal
        ),
    SelectColumns =
        Table.SelectColumns(
            AddChange,
            {"CurrencyKey", "EndOfDayRate", "Date", "Daily Change"}
        )
in
    SelectColumns
```

2. You may have to wait several minutes for the preview data to display. To investigate what is going on, click on the **Tools** tab and then **Start Diagnostics**.
3. Click back on the **Home** tab and click **Refresh Preview**.
4. Wait for the preview data to refresh and then click back on the **Tools** tab and **Stop Diagnostics**.

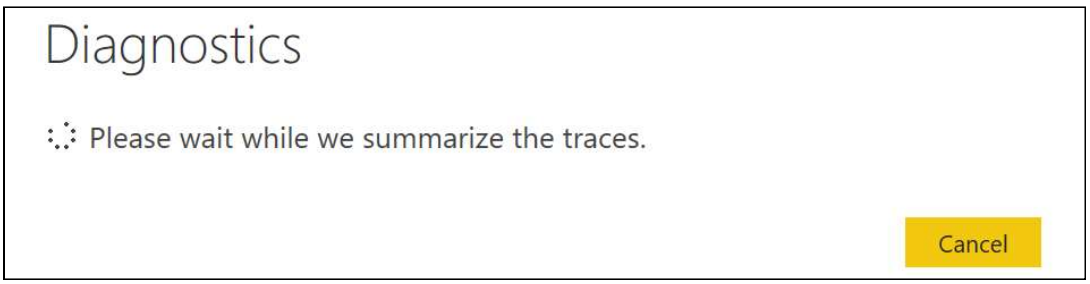


Figure 2.47: Diagnostics processing display

5. When the **Diagnostics** processing completes, you will have a new query group called **Diagnostics** containing four queries for **Diagnostics_Counters**, **Diagnostic_Detailed**, **Diagnostic_Aggregated**, and **Diagnostic_Partitions**. Each of these queries is suffixed with a date and time stamp of when the diagnostics were run, and each has loading disabled.

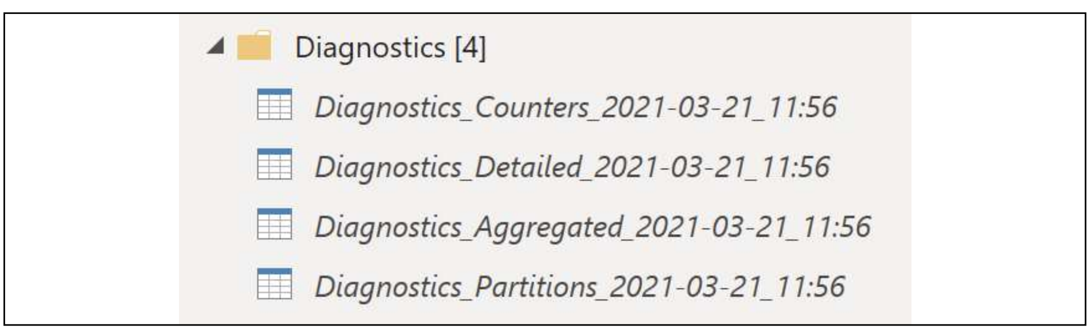
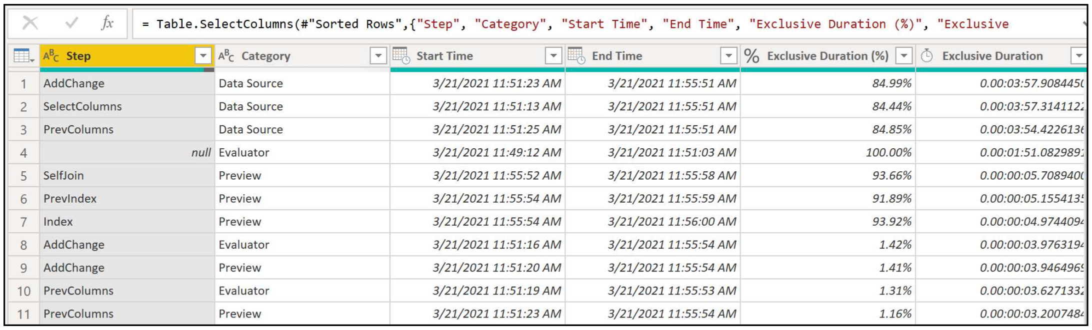


Figure 2.48: Diagnostics queries

6. Click on the **Diagnostics_Aggregated** query. Select the **Step**, **Category**, **Start Time**, **End Time**, **Exclusive Duration (%)**, and **Exclusive Duration** columns and remove the other columns.

7. Sort the **Exclusive Duration** column in descending order.



```
= Table.SelectColumns(#"Sorted Rows",{"Step", "Category", "Start Time", "End Time", "Exclusive Duration (%)", "Exclusive
```

	Step	Category	Start Time	End Time	Exclusive Duration (%)	Exclusive Duration
1	AddChange	Data Source	3/21/2021 11:51:23 AM	3/21/2021 11:55:51 AM	84.99%	0.00:03:57.908445
2	SelectColumns	Data Source	3/21/2021 11:51:13 AM	3/21/2021 11:55:51 AM	84.44%	0.00:03:57.314112
3	PrevColumns	Data Source	3/21/2021 11:51:25 AM	3/21/2021 11:55:51 AM	84.85%	0.00:03:54.422613
4	null	Evaluator	3/21/2021 11:49:12 AM	3/21/2021 11:51:03 AM	100.00%	0.00:01:51.082989
5	SelfJoin	Preview	3/21/2021 11:55:52 AM	3/21/2021 11:55:58 AM	93.66%	0.00:00:05.708940
6	PrevIndex	Preview	3/21/2021 11:55:54 AM	3/21/2021 11:55:59 AM	91.89%	0.00:00:05.155413
7	Index	Preview	3/21/2021 11:55:54 AM	3/21/2021 11:56:00 AM	93.92%	0.00:00:04.974409
8	AddChange	Evaluator	3/21/2021 11:51:16 AM	3/21/2021 11:55:54 AM	1.42%	0.00:00:03.976319
9	AddChange	Preview	3/21/2021 11:51:20 AM	3/21/2021 11:55:54 AM	1.41%	0.00:00:03.946496
10	PrevColumns	Evaluator	3/21/2021 11:51:19 AM	3/21/2021 11:55:53 AM	1.31%	0.00:00:03.627133
11	PrevColumns	Preview	3/21/2021 11:51:23 AM	3/21/2021 11:55:54 AM	1.16%	0.00:00:03.200748

Figure 49: Diagnostic results

8. Look for large jumps in the **Exclusive Duration** column; we see two such jumps between lines 3 and 4, and 4 and 5, with the larger jump being between lines 3 and 4. Also, note the high **Exclusive Duration (%)** value for row 3.
9. Look at the **Start Time** and **End Time** columns for row 3 and note that this operation took 4 minutes and 26 seconds to complete. The **Step** column shows that the query step for row 3 is the **PrevColumns** step.
10. Having zeroed in on the **PrevColumns** step of the query, click on the **Diagnostics_Detailed** query and filter the **Step** column to just show **PrevColumns**. If the **PrevColumns** value does not appear in the filtering dialog, use the **Load More** link or edit the query in **Advanced Editor** to add the **Table.SelectRows** expression manually: `Table.SelectRows(#"Changed Type", each [Step] = "PrevColumns").`
11. Sort the query by the **Exclusive Duration (%)** column in **Descending** order.
12. Note that the **Operation** column for the top row is **DbDataReader**.

At this point, it should be evident that this query would likely be better done in the source database system as a view or stored procedure.

How it works

The **FactCurrencyRate** query joins the base table with itself in order to compare subsequent rows of data. The goal is to compare the values of one row with the previous row in order to compute a value for a change in currency rate between days. This is done by sorting the table by first the currency and then the date using the `Table.Sort` function. Next, the `Table.AddIndexColumn` function is used twice, once to add an index column starting from 1 (**Row Index** column) and a second time to add an index column starting from 0 (**Prev Inde**x column). These two index columns are then used in a `Table.NestedJoin` function to join the table to itself. The `Table.ExpandTableColumn` function is used to expose the previous row's **CurrencyKey** and **EndOfDayRate** columns of the previous row. This information can then be used to create the **Daily Change** column using the `Table.AddColumns` function, and finally, only the essential columns are selected using the `Table.SelectColumns` function.

When you start Query Diagnostics, query diagnostic information is logged to JSON and CSV files stored in the application's directory. These files can be located by looking at the **Source** step for aggregated, detailed, and partition diagnostic queries and the **CsvFiles** step of the **Counters** diagnostic query. For the Power BI Desktop Store App, the path should be similar to the following:

```
C:\Users\[user]\Microsoft\Power BI Desktop Store App\Traces\Diagnostics
```

These files record diagnostic information performed by the query engine during processes such as refreshing the preview data. Stopping Query Diagnostics ends logging of the diagnostic data and generates queries for each enabled Query Diagnostics feature: **Aggregated**, **Detailed**, **Performance counters**, and **Data privacy partitions**. As diagnostic logging is costly in terms of performance and system resources, it is recommended to only use Query Diagnostics when troubleshooting a query's performance. In addition, only enable the minimal amount of diagnostic logging required to identify the problem—for example, often just starting with the **Aggregated** diagnostic data is enough to identify the problematic step(s).

There's more...

There is also a **Diagnose Step** feature available for Query Diagnostics. To see how **Diagnose Step** can be used, follow these steps:

1. Open the **Diagnostic Options** from the ribbon of the Tools tab and uncheck the **Performance counters** and **Data privacy** partitions.
2. In the **Query Settings** pane, select the **SelfJoin** step. You can now either right-click the **SelfJoin** step and select **Diagnose** or select **Diagnose Step** in the ribbon of the **Tools** tab.
3. Once complete, two additional queries are added to the Diagnostics query group, **FactCurrencyRate_SelfJoin_Detailed** and **FactCurrencyRate_SelfJoin_Aggregated**, each suffixed with a date and time stamp.
4. Click on the **FactCurrencyRate_SelfJoin_Aggregated** query.
5. Add an **Index** column.
6. Sort the **Exclusive Duration** column in descending order.
7. Here we can see that the most expensive operation occurs early on in the process, at index 15 out of 3,000+ rows, and appears to be the initial selection of columns with the Data Source Query being the following:

```
select [_].[CurrencyKey],
    [_].[DateKey],
    [_].[AverageRate],
    [_].[EndOfDayRate],
    [_].[Date]
```

```
from [dbo].[FactCurrencyRate] as [_]
order by [_].[CurrencyKey],
        [_].[DateKey]
```

It should be evident that diagnosing a single step of a query is faster and consumes fewer system resources than analyzing the entire query. Thus, it is recommended that you run only **Aggregated** diagnostics over an entire query to identify problematic steps, and then run **Detailed** diagnostics on those steps individually. If you look at the **FactCurrencyRate_SelfJoin_Detailed**, the most expensive operation is on line **60**, and it is the **DbDataReader** operation. The SQL statement identified is actually on line **59** with the operation **Execute Query**. Thus, we can conclude that the most expensive operation performed was not in executing the query, but rather reading the data generated by the query.

See Also

- *Recording Query Diagnostics in Power BI*: `http://bit.ly/2ND2yqF`
- *Query Diagnostics*: `http://bit.ly/3lFz8ET`
- Reading query diagnostics: `http://bit.ly/3s8IFXA`

Conclusion

In this chapter, we dove into Power BI Desktop's Get Data experience and walked through the process of establishing and managing data source connections and queries. The ability to ingest and access data is crucial to every BI project. In Power BI, this data ingest and access is driven by a powerful functional language and query engine, M. The Power Query M language provides a robust, scalable, and flexible engine for data retrieval, cleansing, and transformation.