

Calculation Basics

Advanced Calculations

- Introduction to DAX
- Essential DAX functions
- Calculated columns
- Measures
- Aggregators
- Time intelligence
- DAX function roadmap
- CALCULATE & FILTER functions
- How DAX Processes & Calculates Results
- Dependent measures
- Evolution of a measure
- Modifying Row & Filter context
- When to use iterators
- DAX Studio

Design Phases

Get Data

Connect
Import
Refresh
Stream



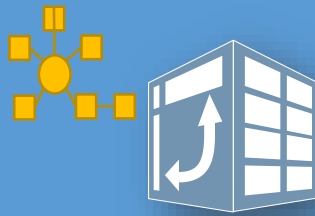
Transform

Shape
Cleanse
Rename
Merge
Filter



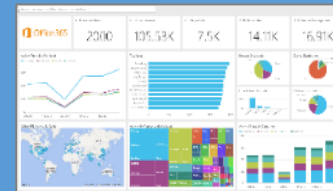
Model

Relate
Calculate
Hide
Format



Visualize & Analyze

Filter
Slice
Interact
Drill



Publish & Share

Pin
Configure
Collaborate
Embed



DAX

What is DAX and Where Did it Come From?

1. Expression language, used to perform calculations in:
 - Power Pivot
 - Power BI
 - SQL Server Analysis Service (SSAS) Tabular
2. Query language
3. Language elements derived from:

**Excel
functions**

SQL

MDX



DAX

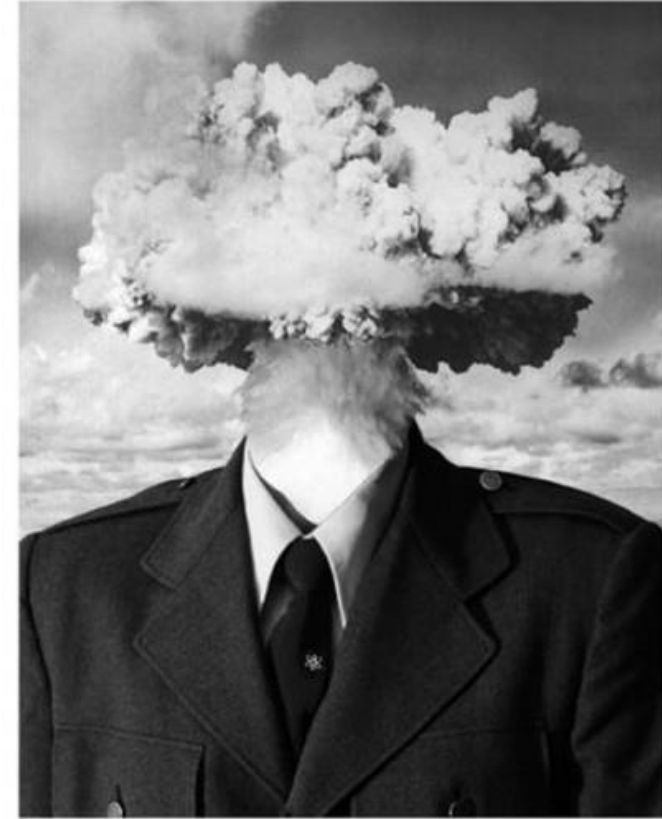
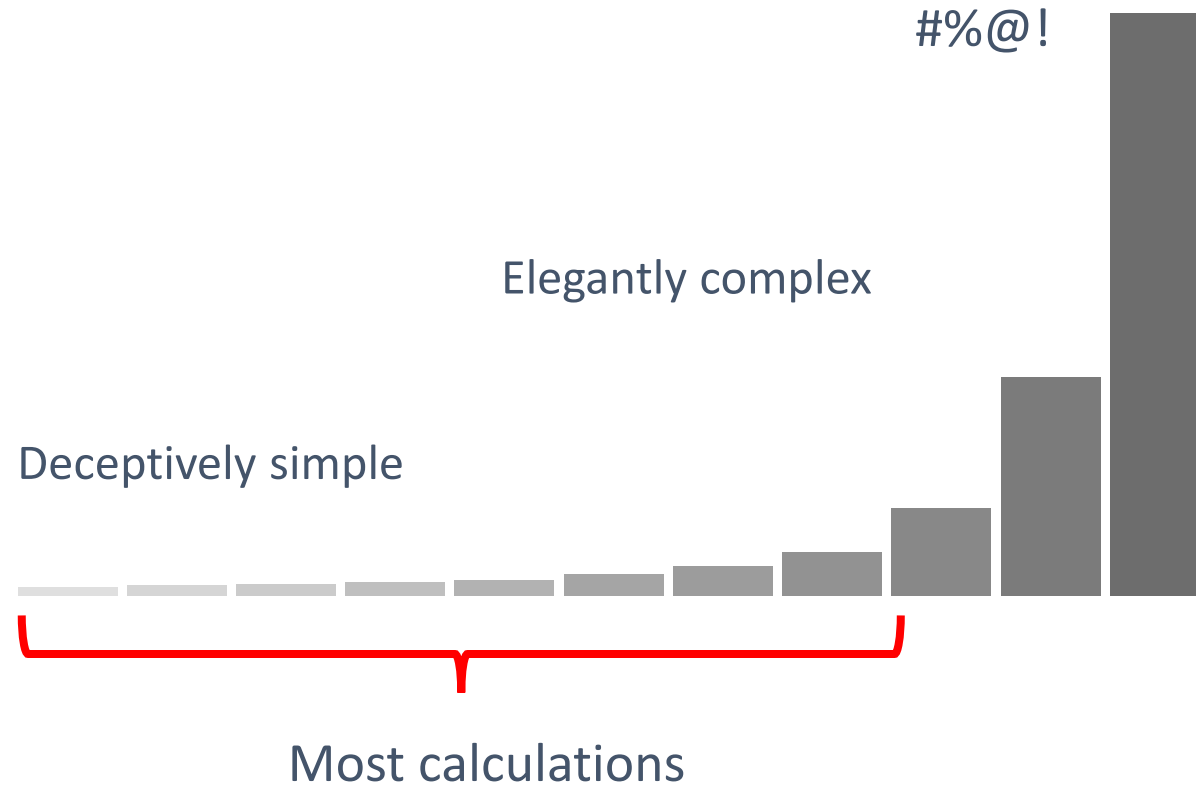
Learning DAX



- Understanding essential concepts is more important than memorizing functions
- You can always lookup function syntax
- Keeping a library of working examples may be more valuable than a web search

ABS	DATESMTD	LEFT	REPT
ACOS	DATESQTD	LEN	RIGHT
ACOSH	DATESYTD	LN	ROLLUP
ACOT	DATEVALUE	LOG	ROLLUPADDISSUBTOTAL
ACOTH	DAY	LOG10	ROLLUPGROUP
ADDCOLUMNS	DEGREES	LOOKUPVALUE	ROLLUPISSUBTOTAL
ADDMISSINGITEMS	DISTINCT	LOWER	ROUND
ALL	DISTINCTCOUNT	MAX	ROUNDDOWN
ALLEXCEPT	DIVIDE	MAXA	ROUNDUP
ALLNOBLANKROW	EARLIER	MAXX	ROW
ALLSELECTED	EARLIEST	MEDIAN	SAMEPERIODLASTYEAR
AND	EDATE	MEDIANX	SAMPLE
ASIN	ENDOFMONTH	MID	SEARCH
ASINH	ENDOFQUARTER	MIN	SECOND
ATAN	ENDOFYEAR	MINA	SELECTCOLUMNS
ATANH	EOMONTH	MINUTE	SIGN
AVERAGE	EVEN	MINX	SIN
AVERAGEA	EXACT	MOD	SINH
AVERAGEX	EXCEPT	MONTH	SQRT
BETA.DIST	EXP	MROUND	SQRTPI
BETA.INV	EXPON.DIST	NATURALINNERJOIN	STARTOFMONTH
BLANK	FACT	NATURALLEFTOUTERJOIN	STARTOFQUARTER
CALCULATE	FILTER	NEXTDAY	STARTOFYEAR
CALCULATETABLE	FILTERS	NEXTMONTH	STDEV.P
CALENDAR	FIND	NEXTQUARTER	STDEV.S
CALENDARAUTO	FIRSTDATE	NEXTYEAR	STDEVX.P
CEILING	FIRSTNONBLANK	NOT	STDEVX.S
CHISQ.DIST	FIXED	NOW	SUBSTITUTE
CHISQ.DIST.RT	FLOOR	ODD	SUBSTITUTEWITHINDEX
CHISQ.INV	FORMAT	OPENINGBALANCEMONTH	SUM
CHISQ.INV.RT	GCD	OPENINGBALANCEQUARTER	SUMMARIZE
CLOSINGBALANCEMONTH	GENERATE	OPENINGBALANCEYEAR	SUMMARIZECOLUMNS
CLOSINGBALANCEQUARTER	GENERATEALL	OR	SUMX
CLOSINGBALANCEYEAR	GEOMEAN	PARALLELPERIOD	SWITCH
COMBIN	GEOMEANX	PATH	TAN
COMBINA	GROUPBY	PATHCONTAINS	TANH
CONCATENATE	HASONEFILTER	PATHITEM	TIME
CONCATENATEX	HASONEVALUE	PATHITEMREVERSE	TIMEVALUE
CONFIDENCE.NORM	hour	PATHLENGTH	TODAY
CONFIDENCE.T	IF	PERCENTILE.EXC	TOPN
CONTAINS	IFERROR	PERCENTILE.INC	TOTALMTD
COS	IGNORE	PERCENTILEX.EXC	TOTALQTD
COSH	INT	PERCENTILEX.INC	TOTALYTD
COT	INTERSECT	PERMUT	TRIM
COTH	ISBLANK	PI	TRUNC
COUNT	ISCROSSFILTERED	POISSON.DIST	UNICODE
COUNTA	ISEMPTY	POWER	UNION
COUNTAX	ISERROR	PREVIOUSDAY	UPPER
COUNTBLANK	ISEVEN	PREVIOUSMONTH	USERELATIONSHIP
COUNTROWS	ISFILTERED	PREVIOUSQUARTER	USERNAME
COUNTX	ISLOGICAL	PREVIOUSYEAR	VALUE
CROSSFILTER	ISNONTEXT	PRODUCT	VALUES
CROSSJOIN	ISNUMBER	PRODUCTX	VAR.P
CURRENCY	ISO.CEILING	QUOTIENT	VAR.S
CURRENTGROUP	ISODD	RADIANS	VARX.P
CUSTOMDATA	ISONORAFTER	RAND	VARX.S
DATATABLE	ISSUBTOTAL	RANDBETWEEN	WEEKDAY
DATE	ISTEXT	RANK.EQ	WEEKNUM
DATEADD	KEEPFILTERS	RANKX	XIRR
DATEDIFF	LASTDATE	RELATED	XNPV
DATESBETWEEN	LASTNONBLANK	RELATEDTABLE	YEAR
DATESINPERIOD	LCM	REPLACE	YEARFRAC

DAX Learning Curve



What to Learn

Examples of some important DAX functions & concepts

Beyond the basics, specific functions are useful in different business scenarios

There are more than 250 DAX functions and more added with each major release

PERCENTILE() ISERROR() RANKX() RELATEDTABLE()
CALCULATETABLE() **IF()** **SUM()** **ALL()** EARLIER()
CONTAINS() **SWITCH()** **SUMX()** **ALLSELECTED()**
EVALUATE ISBLANK() DATEDIFF()
ROW() **MEASURES** DATE() TIME() VALUES()
EOMONTH() CALCULATED COLUMNS NOW() DATESINPERIOD()
CALCULATE() HASONEVALUE()
DIVIDE() **FILTER()** PERVIOUSMONTH() **TODAY()**
FIRSTNONBLANK() SUMMARIZE() **TOTALMTD()**
SAMEPERIODLASTYEAR() DATESMTD()

Important Concepts

- Row context
 - Filter context
 - Filter propagation
 - Aggregators
 - Iterators
- Calculated columns
 - Measures

Context

Webster:

"The interrelated conditions in which something exists or occurs"

Turley:

*"Where the heck am I?"...
..."and how did I get here?"*

Row Context:

"What row am I on?"

Filter Context:

"What filters are applied?"
- 1st Class, Bus. Class or Economy
- Window, isle or middle seat



Implicit & Explicit Measures

No one right answer

Two schools of thought:

1. Power BI should behave like Excel

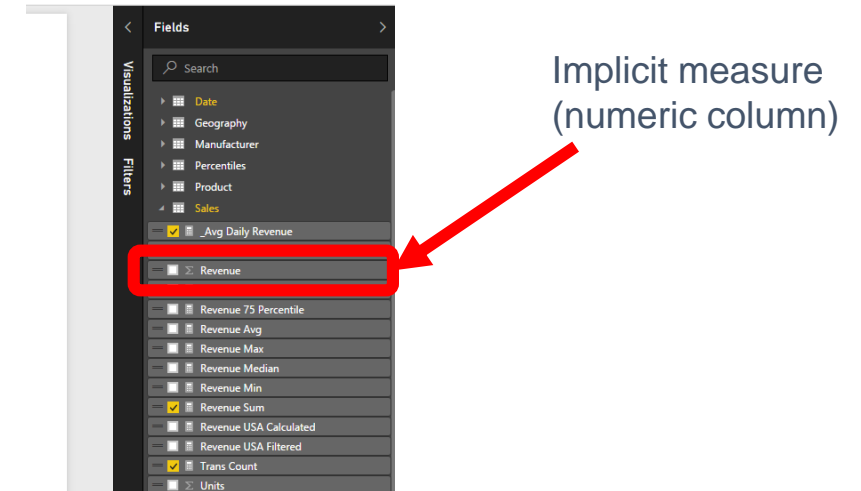
- Excel uses implicit measures with workbook data
- PivotTables & charts:
 - SUM numbers by default
 - COUNT text by default
- Power BI Desktop: numeric columns have Summarize By property

2. All measures should be explicitly defined

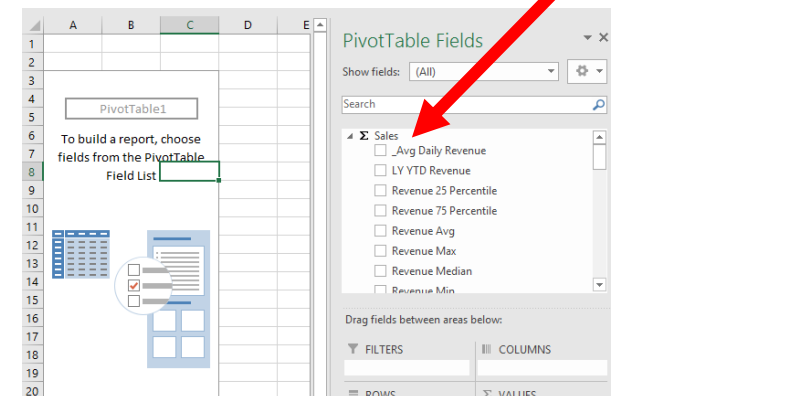
- Model designer maintains control
- Default behavior may not always be right

Excel doesn't support Power BI Implicit measures

Power BI Report



Excel Pivot Table



Recommended DAX Tools

Power BI Desktop /Excel 2013+

- Power BI Desktop
- Excel
- DAX Studio

SSAS Tabular

- SSDT for Visual Studio 2015+
- SSMS
- Excel
- DAX Studio

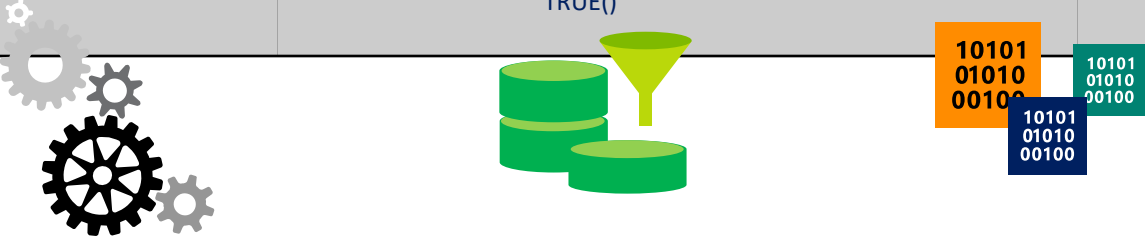
Excel 2010/SSAS 2012, 2014

- NotePad++
- DAX Studio
- DAXFormatter.com

DAX Function Roadmap

Some examples

Date & Time	Time Intelligence	Filter	Information	Logical	Math	Statistical
DATE() TIME() TODAY() NOW() DATEDIFF() EOMONTH()	DATESMTD() TOTALMTD() PERVIOUSMONTH() SAMEPERIODLASTYEAR() DATESINPERIOD()	FILTER() VALUES() ALL() CALCULATE()	ISBLANK() ISERROR() CONTAINS() HASONEVALUE()	IF() AND, &&, AND() OR, , OR() SWITCH() TRUE()	SUM() AVERAGE() DIVIDE()	SUMX() AVERAGEX() RANKX() PERCENTILE()



Important concepts

DAX query engine flow:

- Get report filter context
- Apply CALCULATE() filters
- Apply dimension table filter context
- Filter fact table using relationships
- Perform math & calculations

Context:

- Evaluation...
- Filter...
- Row...
- Context transition

Measures:

- Majority of all calculations
- Can have implicit or explicit filter context
- Can override natural filter behavior

Calculated Columns:

- Good for banding
- Built-in row context
- Using measures in calc. columns will ignore row context

Calculated Columns

- Typically used in the context of a single row
- May be used as intermediate calculations to support measures

Arrival Date Time =

IF([ArrTime] < [DepTime],
 [FlightDate] + 1,
 [FlightDate]
) + [ArrTime]

This calculated column combines the flight **date** and arrival **time** values needed by measure calculations. It adds one day if the arrival time is earlier than the departure time because the flight landed the next day (after midnight)

Airline	FlightNum	FlightDate	DepTime ▼	ArrTime	Arrival Date Time
Spirit Air Lines	970	1/3/2015	11:59:00 PM	5:46:00 AM	1/4/2015 5:46:00 AM
Southwest Airlines Co.	910	1/3/2015	11:58:00 PM	1:04:00 AM	1/4/2015 1:04:00 AM
JetBlue Airways	98	1/3/2015	11:54:00 PM	5:19:00 AM	1/4/2015 5:19:00 AM
Southwest Airlines Co.	2160	1/3/2015	10:53:00 PM	1:58:00 AM	1/4/2015 1:58:00 AM
United Air Lines Inc.	1693	1/3/2015	10:48:00 PM	1:17:00 AM	1/4/2015 1:17:00 AM
Frontier Airlines Inc.	242	1/3/2015	10:42:00 PM	1:50:00 AM	1/4/2015 1:50:00 AM
American Airlines Inc.	1491	1/3/2015	10:34:00 PM	1:45:00 AM	1/4/2015 1:45:00 AM

Measure Calculations

- Understanding context
 - Row context
 - Filter context
 - Context switching
- The CALCULATE function revisited
- How DAX processes & calculates results
- Maintaining a development, testing and learning environment

CALCULATE function

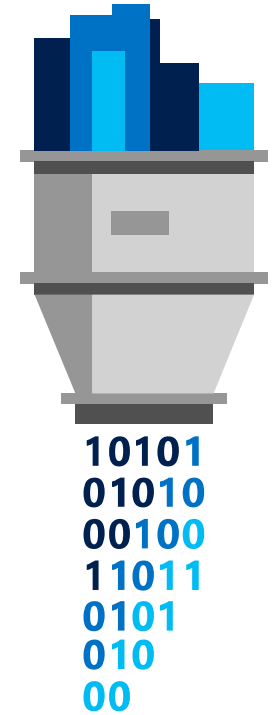
revisited

CALCULATE(<expression>, <filter1>, <filter2>)

Means: "Go apply filters"

Similar in concept to **Where** in TSQL

```
Avg Weath Delay for bad weather days =  
CALCULATE(  
    AVERAGE( [Weather Delay] ),  
    'Airline Performance'[WeatherDelay] > 0  
)
```



This measure calculates the average Weather Delay only for those flights where there was a delay (over 0 minutes)

How DAX Processes & Calculates Results

1. Get Row & Filter Context from report visual (or Pivot Table here)
2. Adjust the Filter Context based on

CALCULATE() parameters

(if CALCULATE is part of the function)



3. Filter the related lookup tables



4. Pass those filters along to the Fact table

5. Output a subset of rows

6. Do the math

Excel example:

...based on filters, slicers, rows& columns

Sales Amount Row Labels	Column Labels			
	CY 2007	CY 2008	CY 2009	Grand Total
Azure	\$4,863.10	\$4,480.80	\$2,728.00	\$12,071.90
A. Datum	\$4,863.10	\$4,480.80	\$2,728.00	\$12,071.90
Black	\$282,020.06	\$245,539.76	\$264,175.99	\$791,735.81
A. Datum	\$13,691.00	\$681.90	\$10,455.00	\$24,827.90
Adventure Works	\$45,584.87	\$29,849.86	\$29,736.17	\$105,170.90
Contoso	\$37,330.92	\$26,921.86	\$55,237.03	\$119,489.81
Fabrikam	\$22,642.87	\$49,585.00	\$44,397.04	\$116,624.91
Litware	\$12,742.44	\$9,642.05	\$25,524.23	\$47,908.72
Northwind Traders			\$99.99	\$99.99
Proseware	\$46,793.84	\$22,221.50	\$13,912.41	\$82,927.75
Southridge Video	\$64,377.31	\$17,329.31	\$16,475.62	\$98,182.24
Tailspin Toys	\$831.31	\$1,752.50	\$4,168.63	\$6,752.44
The Phone Company	\$13,050.00	\$21,493.00	\$21,043.00	\$55,586.00
Wide World Importers	\$24,975.50	\$66,062.78	\$43,126.87	\$134,165.15

Time Intelligence

DAX functions

- NOW, DATE, TIME
- DATEADD
- DATEDIFF
- DATESMTD
- DATESBETWEEN
- TOTALMTD
- NEXTMONTH
- PARALLELPERIOD

...QTD, YTD

...DAY, QUARTER, YEAR

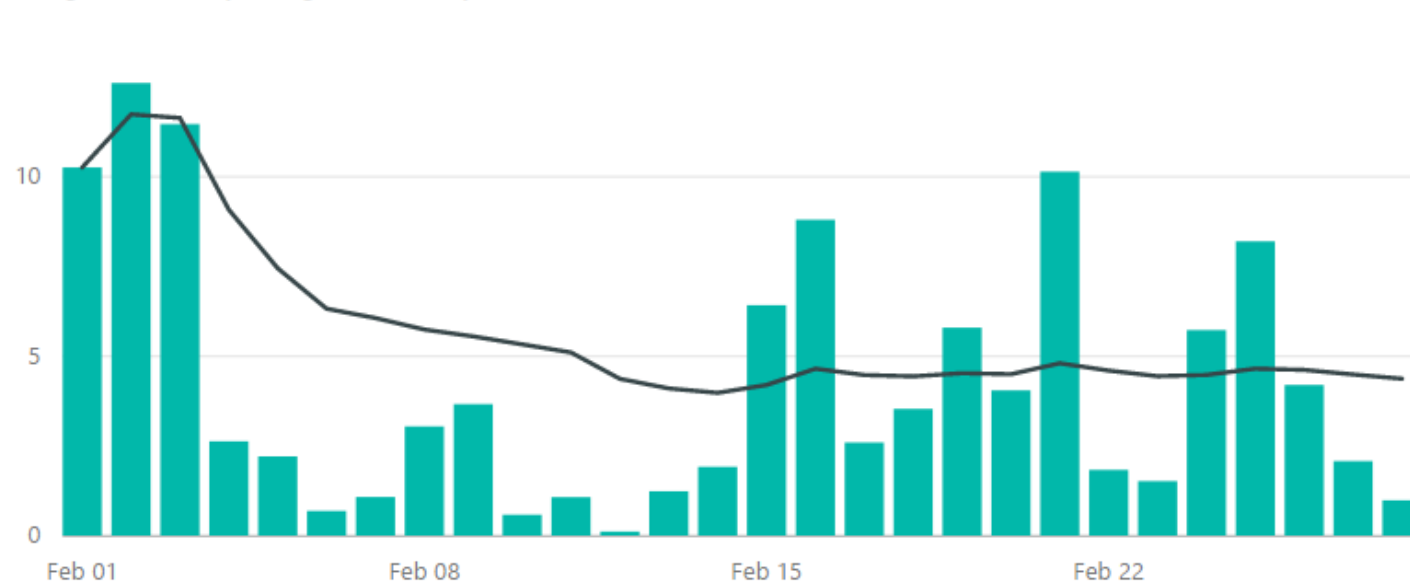
Time Intelligence Example

Month-To-Date Average

Avg Weather Delay MTD = **CALCULATE**([Avg Weather Delay],
DATESMTD('Flight Date'[Flight Date]))

Avg Weather Delay and Avg Weather Delay MTD by Flight Date

● Avg Weather Delay ● Avg Weather Delay MTD



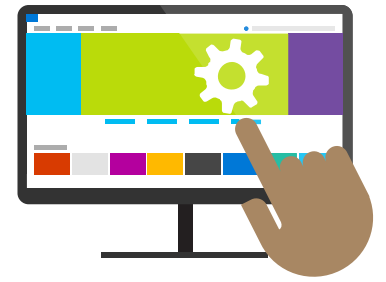
Airline

- ☐ (Blank)
- ☐ Alaska Airlines Inc.
- ☐ American Airlines Inc.
- ☐ Delta Air Lines Inc.
- ☐ ExpressJet Airlines Inc.
- ☐ Frontier Airlines Inc.
- ☐ Hawaiian Airlines Inc.
- ☐ JetBlue Airways
- ☐ SkyWest Airlines Inc.
- ☐ Southwest Airlines Co.
- ☐ Spirit Air Lines
- ☒ United Air Lines Inc.
- ☐ Virgin America

Month

- ☐ January
- ☒ February
- ☐ March
- ☐ April
- ☐ May
- ☐ June
- ☐ July
- ☐ August
- ☐ September
- ☐ October
- ☐ November
- ☐ December

Iterator functions



Mixed totals: Operates on one row at a time, accumulating the result of the prior iteration

- SUMX
- AVERAGEX
- MINX
- MAXX
- COUNTX
- COUNTAX
- PRODUCTX
- CONCATENATEX

Category	Month	Revenue per Unit	Revenue per Unit Accum	Month List
Mix	Jan	\$380.80	\$380.80	Jan
	Feb	\$380.85	\$380.85	Feb
	Mar	\$364.12	\$364.12	Mar
	Apr	\$363.05	\$363.05	Apr
	May	\$362.93	\$362.93	May
	Jun	\$365.12	\$365.12	Jun
	Jul	\$364.19	\$364.19	Jul
	Aug	\$367.87	\$367.87	Aug
	Sep	\$372.46	\$372.46	Sep
	Oct	\$393.20	\$393.20	Oct
	Nov	\$391.08	\$391.08	Nov
	Dec	\$392.53	\$392.53	Dec
Total		\$371.15	\$4,498.11	Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec
Rural	Jan	\$206.66	\$206.66	Jan
	Feb	\$209.07	\$209.07	Feb
	Mar	\$203.84	\$203.84	Mar
	Apr	\$194.38	\$194.38	Apr
	May	\$185.97	\$185.97	May
	Jun	\$180.53	\$180.53	Jun
	Jul	\$172.96	\$172.96	Jul
	Aug	\$185.09	\$185.09	Aug
	Sep	\$198.83	\$198.83	Sep
	Oct	\$204.80	\$204.80	Oct
	Nov	\$184.68	\$184.68	Nov
	Dec	\$148.92	\$148.92	Dec
Total		\$185.89	\$2,275.73	Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec

Using Iterators

These two different calculation techniques achieve the same result using different formula mechanics:

```
Avg Weather Delay =  
AVERAGEX (  
    FILTER ( 'Airline Performance', 'Airline Performance'[WeatherDelay] > 0 ),  
    'Airline Performance'[WeatherDelay] )
```

For every row in the 'Airline Performance' table, the FILTER is applied and qualifying values are added to the Average calculation. Although less efficient than the following example, complex operations can be performed within each iteration.

```
Avg Weather Delay =  
CALCULATE(  
    [Avg Weather Delay],  
    'Airline Performance'[WeatherDelay] > 0 )
```

Dependent Measures

- Measures may be used in other measure calculations
- Measure names must be unique within the model
- Measures contained in any table can be used in any calculation

```
Flights = COUNTROWS( 'Airline Performance' )
```

```
All Flights = CALCULATE( [Flights],  
                          ALL( 'Airline Performance' ) )
```

```
% of Total Flights = DIVIDE( [Flights], [All Flights] )
```

CALCULATE() with FILTER()

- Use FILTER() function for rich filtering

Flights Over 15 min = CALCULATE([Flights],
FILTER('Airline Performance', [Avg Weather Delay] > 15)
)

Comparison options:

Table[Column] = [Measure]

Table[Column] = Table[Column]

[Measure1] > [Measure2]

<true/false expr1> && <true/false expr2>

<true/false expr1> || <true/false expr2>

Any expression that evaluates to true/false

Function-based comparisons:

=AND(<true/false expr1>, <true/false expr2>)

=OR (<true/false expr1>, <true/false expr2>)

Financial Calculations

common scenario

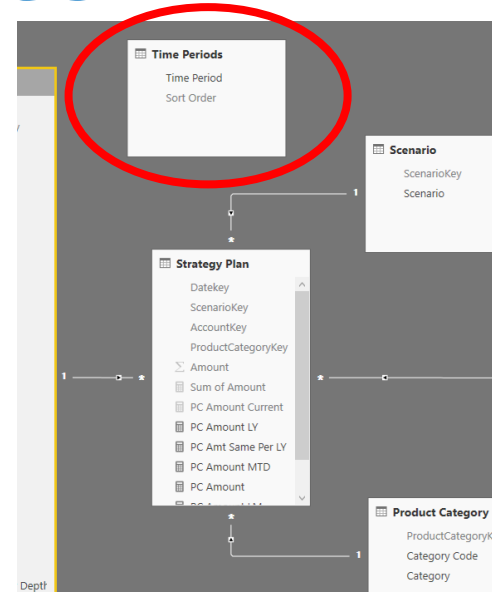
- Chart of Account dimension
- Level Rollups
- Parent-child source table
- Unary Operators

Level 1	PC Amount
Profit and Loss after tax	\$3,378,795,723.2516
Profit and Loss before tax	\$5,404,707,805.2889
Expense	(\$16,021,006,428.087299)
Cost of Goods Sold	\$9,354,804,873.4778
Selling, General & Administrative Expenses	\$6,666,201,554.6095
Administration Expense	\$624,495,173.3963
Human Capital	\$1,169,650,123.0862
IT Cost	\$584,664,479.2223
Light, Heat, Communication Cost	\$583,611,720.423
Marketing Cost	\$2,515,889,395.0696
Back-to-School Ad Cost	\$464,825,139.0068
Business Ad Cost	\$90,085,597.9358
Holiday Ad Cost	\$1,748,510,477.2632
Internet	\$577,008,457.791
Other	\$87,425,522.3202
Print	\$839,285,031.5274
Radio & TV	\$244,791,465.6246
Spring Ad Cost	\$170,888,263.6368
Tax Time / Summer Ad Cost	\$41,579,917.227
Other Expenses	\$82,621,148.3998
Property Costs	\$1,105,269,515.0123
Income	\$21,425,714,233.3762
Sale Revenue	\$21,425,714,233.3762
Taxation	(\$2,025,912,082.0373001)
Total	

Using Disconnected Tables

May be used to:

- Pass “parameters” to a measure without filtering other model elements
- Implement conditional measure behavior
- Dynamically slice specialized measure calculations

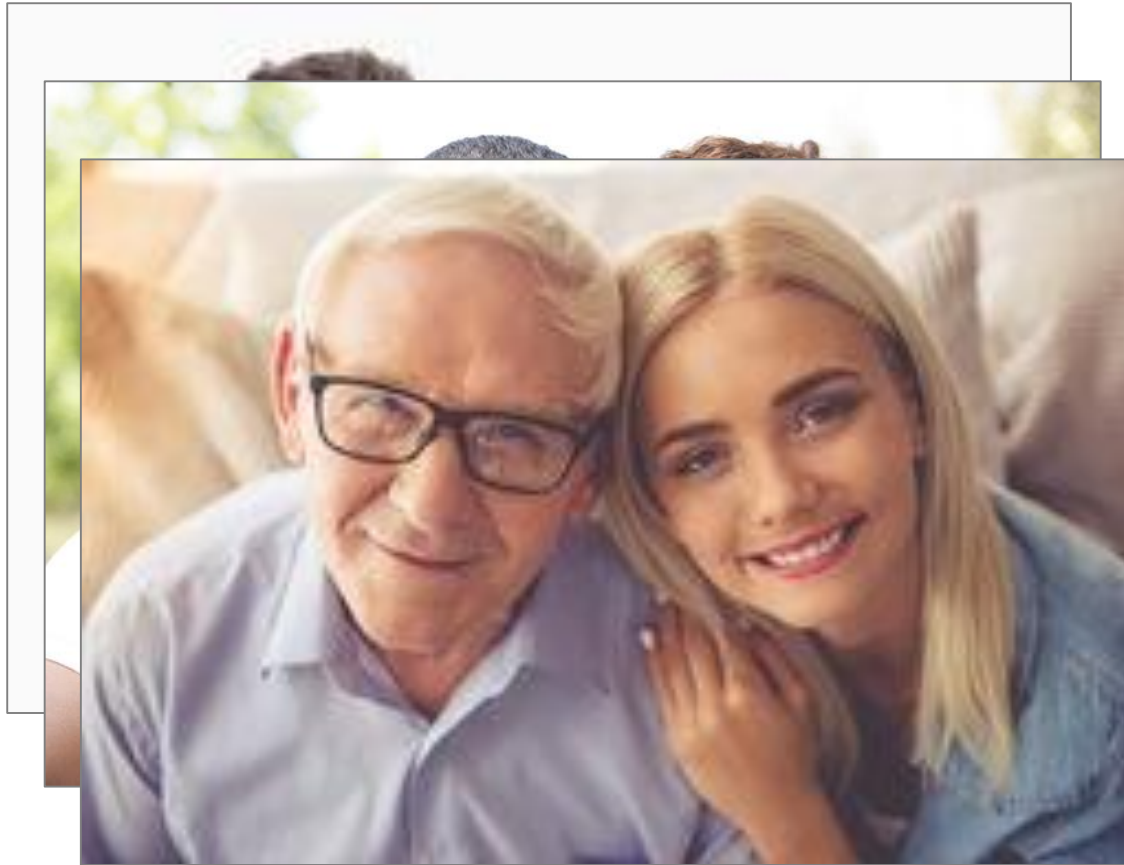


Time Period	Sort Order
Current Period	1
LM	2
LY	3
MTD	5
YTD	6
Same Period LY	4

Time Period		<div> <div>Current Per...</div> <div>LM</div> <div>LY</div> <div>Same Peri...</div> <div>MTD</div> <div>YTD</div> </div>					
Calendar Year	CY 2008						
PC Amount	Column Labels						
Row Labels	January						
	Current Period	LM	Same Period LY	YTD	February	Current Period	LM
Profit and Loss after tax	(\$88,880,614.5978)	\$237,036,287.8008	(\$88,220,075.017)	(\$88,880,614.5978)	(\$124,533,046.8404)	(\$88,886,614.5978)	
Profit and Loss before tax	(\$47,150,382.893)	\$335,044,232.4921	(\$42,227,477.015)	(\$47,150,382.893)	(\$82,832,939.3062)	(\$47,150,382.893)	
Expense	(\$486,824,152.2409)	(\$474,059,566.6742)	(\$533,885,009.2371)	(\$486,824,152.2409)	(\$534,115,508.1189)	(\$486,824,152.2409)	
Cost of Goods Sold	\$195,012,873.3882	\$352,469,465.8203	\$215,322,626.2394	\$195,012,873.3882	\$199,686,125.5531	\$195,012,873.3882	
Selling, General & Administrative Expenses	\$291,811,278.8527	\$121,590,100.8539	\$318,562,382.9977	\$291,811,278.8527	\$334,429,382.5658	\$291,811,278.8527	
Administration Expense	\$12,272,787.7223	\$16,944,572.2919	\$10,515,731.0649	\$12,272,787.7223	\$12,404,101.3668	\$12,272,787.7223	
Human Capital	\$22,146,309.5051	\$33,954,335.6782	\$20,316,360.6162	\$22,146,309.5051	\$23,816,805.2585	\$22,146,309.5051	
IT Cost	\$11,593,924.7507	\$17,127,159.6558	\$10,462,540.4388	\$11,593,924.7507	\$11,458,695.1407	\$11,593,924.7507	
Light, Heat, Communication Cost	\$11,209,839.5921	\$16,884,887.3541	\$10,087,544.9132	\$11,209,839.5921	\$11,738,839.5244	\$11,209,839.5921	
Marketing Cost	\$211,773,293.0258		\$245,101,795.9936	\$211,773,293.0258	\$251,006,420.6406	\$211,773,293.0258	
Back-to-School Ad Cost	\$12,229,657.0432		\$14,629,049.9888	\$12,229,657.0432	\$22,157,261.1406	\$12,229,657.0432	
Business Ad Cost	\$3,261,241.723		\$3,919,745.3984	\$3,261,241.723	\$12,997,930.2528	\$3,261,241.723	
Holiday Ad Cost	\$192,205,841.9256		\$221,653,318.9936	\$192,205,841.9256	\$192,205,841.9256	\$192,205,841.9256	
Internet	\$63,427,927.9986		\$73,145,595.1408	\$63,427,927.9986	\$63,427,927.9986	\$63,427,927.9986	
Other	\$9,610,291.8326		\$11,082,666.0048	\$9,610,291.8326	\$9,610,291.8326	\$9,610,291.8326	
Print	\$92,258,804.3822		\$106,393,593.28	\$92,258,804.3822	\$92,258,804.3822	\$92,258,804.3822	

Power BI and Excel

How is their relationship?



Use DAX Studio to Get Power BI Connection

- DAX Studio exposes the random port number Power BI Desktop uses to connect to the local SSAS server (msmdsrv.exe)
- Use the connection string localhost:XXXXX to connect with Excel, SQL Server Profiler, SSMS or any other OLAP client.

The image illustrates the process of connecting DAX Studio to a Power BI instance. The top-left screenshot shows the 'Connect' dialog in DAX Studio 2.6.0, where the 'PBI / SSDT Model' is selected and the data source is 'Lab02-Get Data Basics (Finished)'. The bottom-left screenshot shows the 'Airline' table in the 'Model' pane of DAX Studio, with the connection string 'localhost:63631' highlighted in a red box. The right screenshot shows the 'PivotTable Fields' task pane in Excel, displaying a pivot table with 'Flights' as the row labels and 'Year' as the column labels. A red arrow points from the highlighted connection string in the bottom-left screenshot to the 'PivotTable Fields' task pane in the right screenshot.

Recommended Practices

- Learn DAX concepts before function syntax
- Learn DAX essential functions... Learn these first:
SUM, AVERAGE, MIN, MAX, COUNT, COUNTROWS, CALCULATE, FILTER, IF
- Name measure so users can find them
- Don't try to memorize complex DAX
- Build a library of useful examples, books & articles
- Work in iterations
- Understand measure categories:
aggregates, time & ratios, business-specific, KPI parts

