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2021 EMEA **Db2** Tech Conference

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Developer Best Practices for Db2 Performance

Tony Andrews, Themis Inc.

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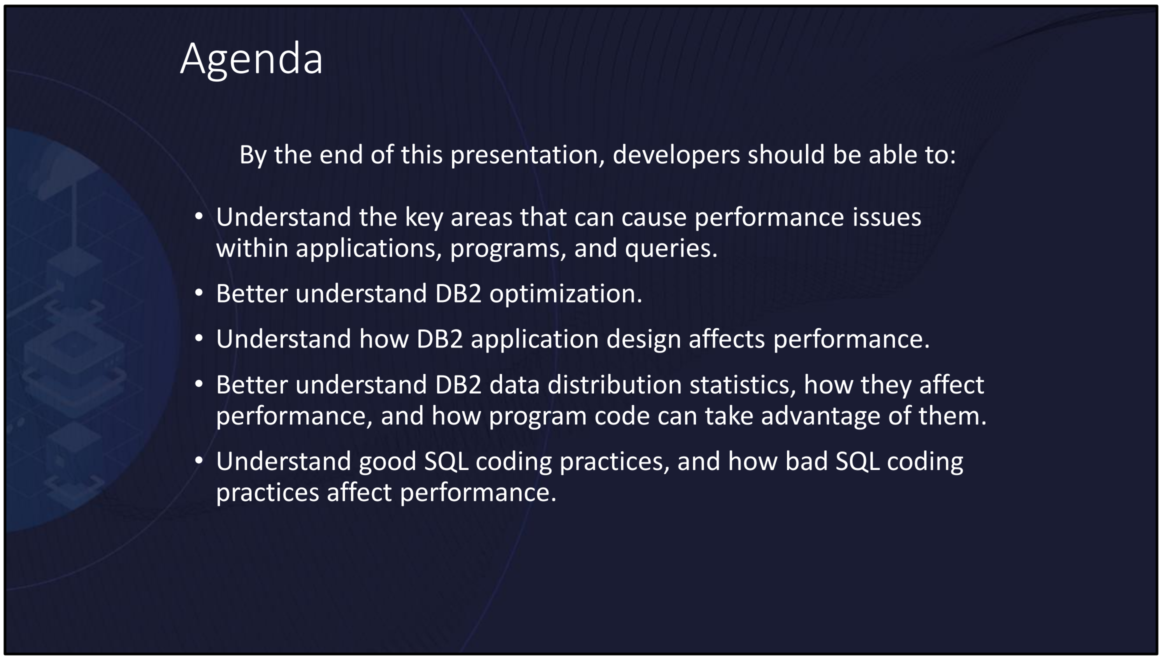
#IDUGDb2

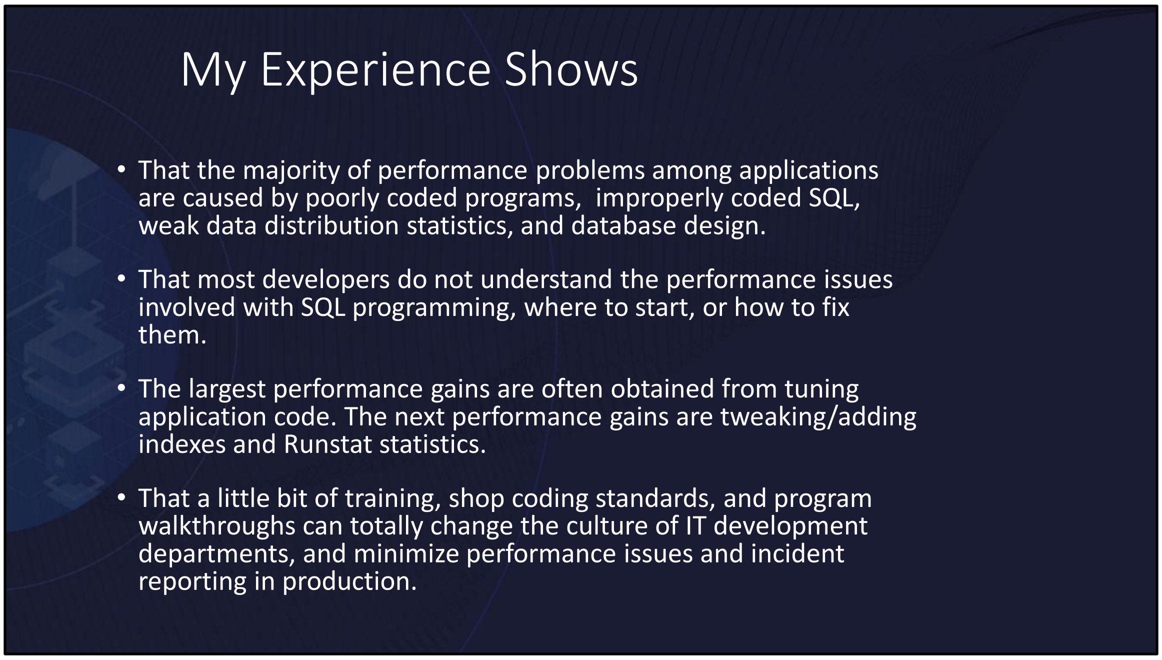
Cross-Platform



Agenda

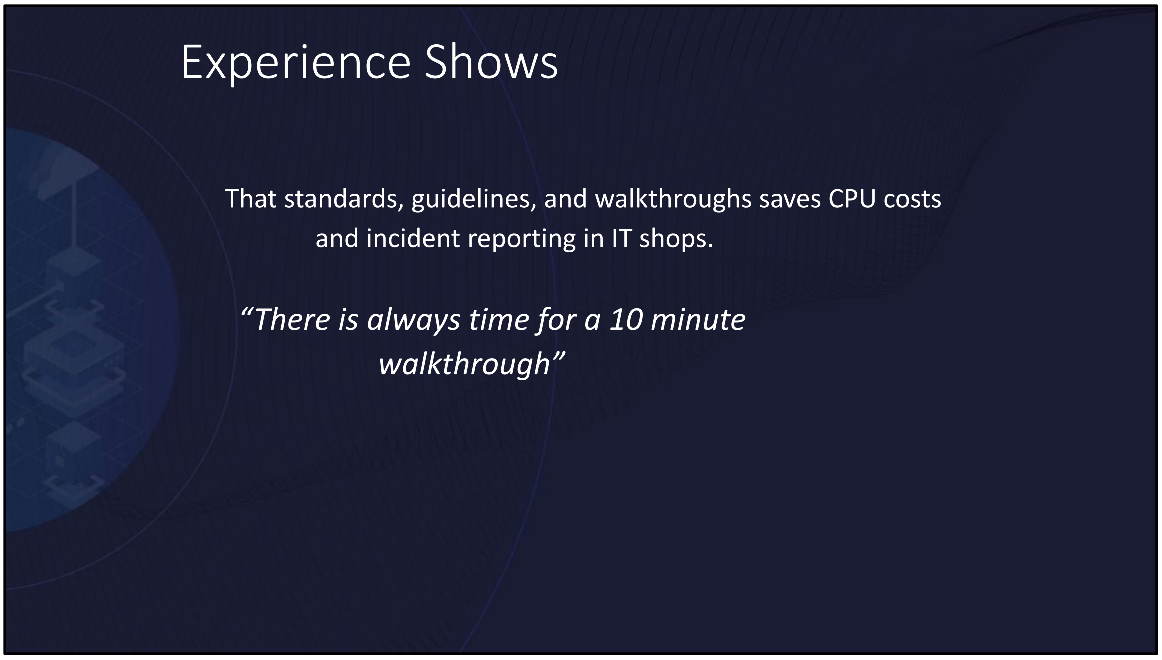
By the end of this presentation, developers should be able to:

- Understand the key areas that can cause performance issues within applications, programs, and queries.
- Better understand DB2 optimization.
- Understand how DB2 application design affects performance.
- Better understand DB2 data distribution statistics, how they affect performance, and how program code can take advantage of them.
- Understand good SQL coding practices, and how bad SQL coding practices affect performance.



My Experience Shows

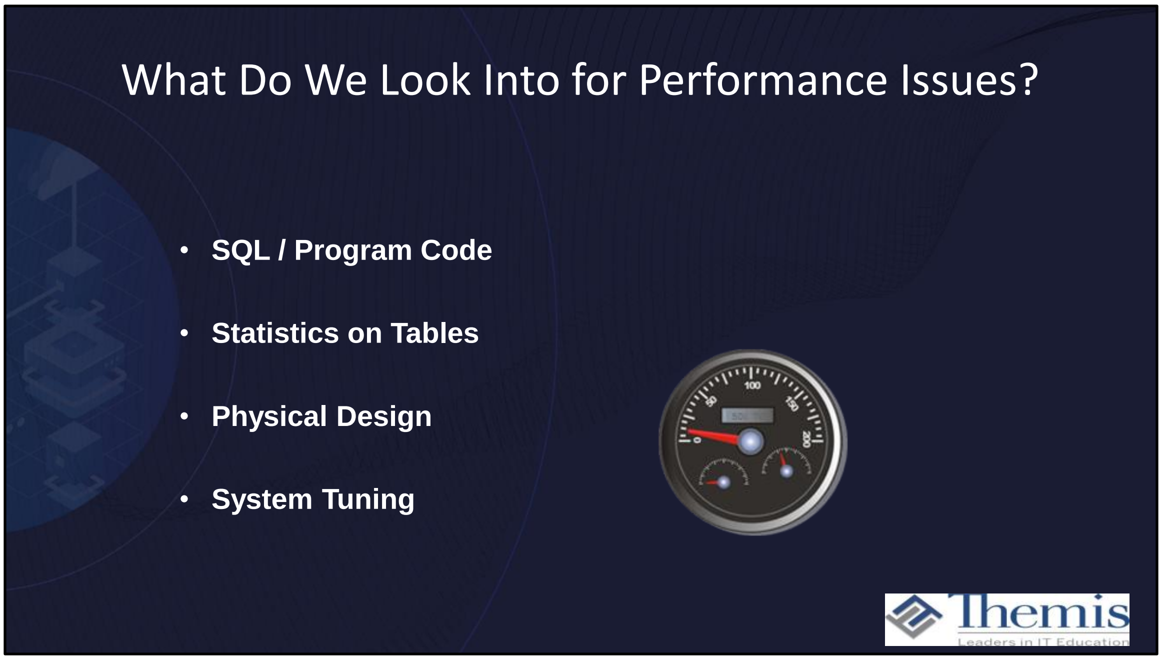
- That the majority of performance problems among applications are caused by poorly coded programs, improperly coded SQL, weak data distribution statistics, and database design.
- That most developers do not understand the performance issues involved with SQL programming, where to start, or how to fix them.
- The largest performance gains are often obtained from tuning application code. The next performance gains are tweaking/adding indexes and Runstat statistics.
- That a little bit of training, shop coding standards, and program walkthroughs can totally change the culture of IT development departments, and minimize performance issues and incident reporting in production.



Experience Shows

That standards, guidelines, and walkthroughs saves CPU costs and incident reporting in IT shops.

"There is always time for a 10 minute walkthrough"



What Do We Look Into for Performance Issues?

- **SQL / Program Code**
- **Statistics on Tables**
- **Physical Design**
- **System Tuning**

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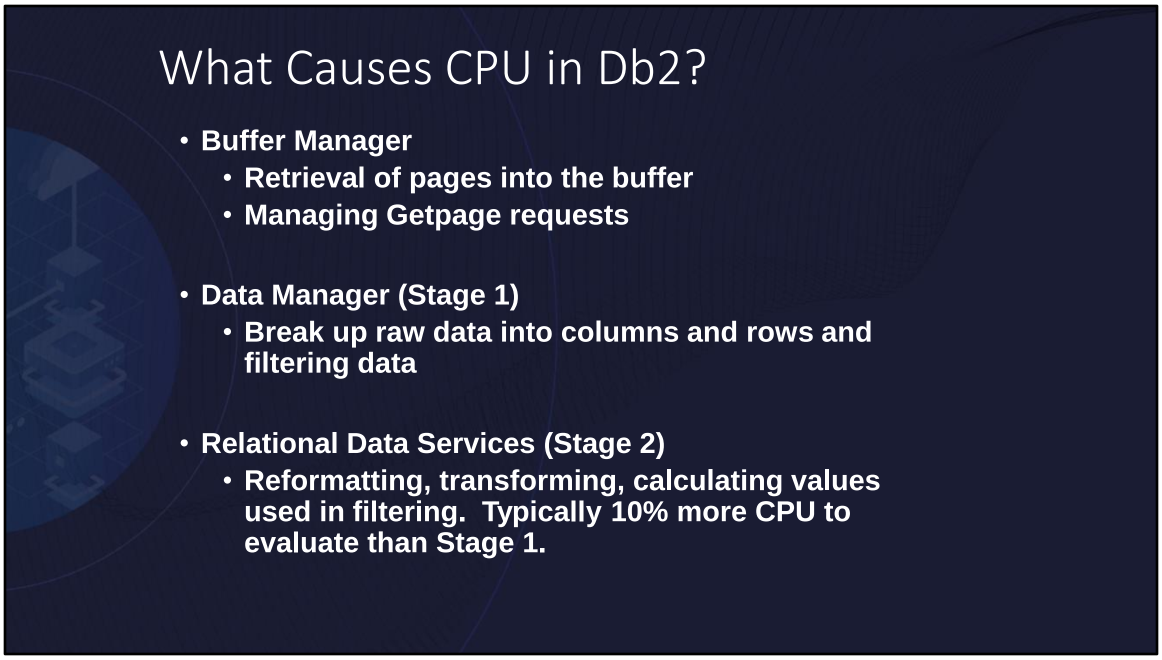
Improving SQL performance can be done in one of at least 4 ways. System tuning may be done to adjust the parameters under which the Db2 subsystem operates to effectively match the workload. Altering system parameters, tuning temporary space, and adjusting bufferpool sizes and thresholds are all examples of this type of tuning. An appropriately tuned system can affect an improvement in performance. Most of the time, however, other factors dominate a tuning scenario. The SQL itself must be written in a way that may be processed efficiently by the database. An appropriate level of statistics about the data must be gathered to tell the optimizer about the nature of the data being accessed. Lastly, the way the physical objects are defined must be aligned with the types of queries that are to be performed.



What Causes CPU in Db2?

- **Buffer Manager**
  - **Retrieval of pages into the buffer**
  - **Managing Getpage requests**
- **Data Manager (Stage 1)**
  - **Break up raw data into columns and rows and filtering data**
- **Relational Data Services (Stage 2)**
  - **Reformatting, transforming, calculating values used in filtering. Typically 10% more CPU to evaluate than Stage 1.**

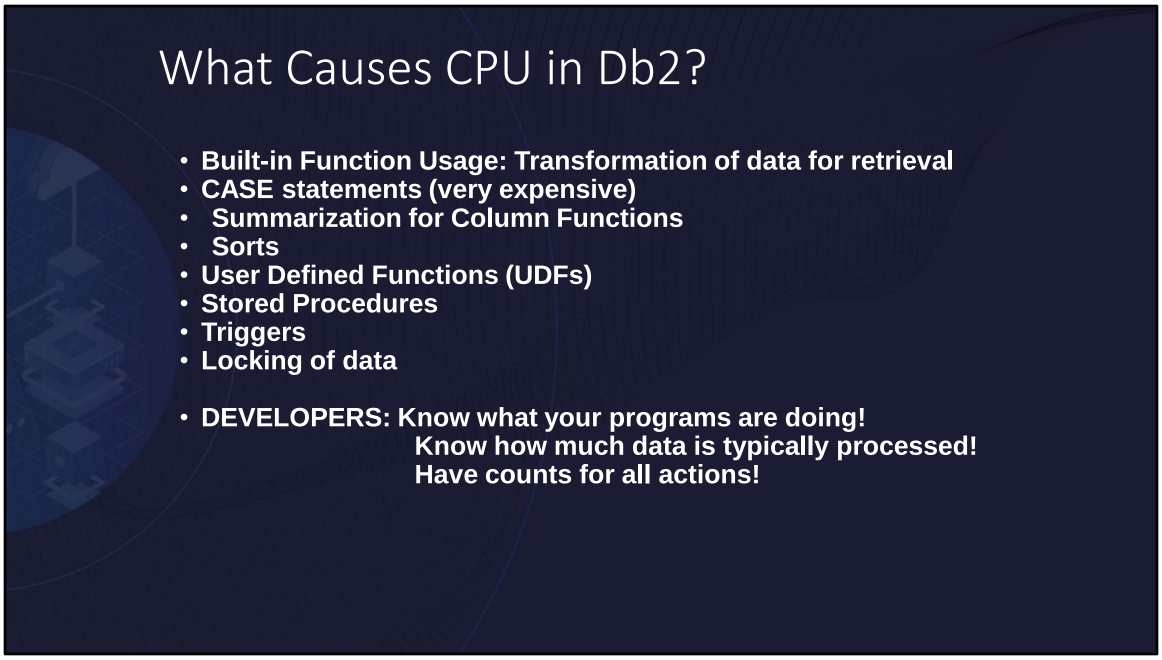
CPU is consumed my many layers of software within Db2. The code responsible for storing, retrieving and filtering data for queries consumes the bulk of CPU related to application performance.

The Buffer Manager is responsible for managing the pages of data for various tablespaces and indexes inside Db2s bufferpools. It determines if the requested pages are already in the bufferpool and if not issues appropriate requests to retrieve the data from the underlying linear VSAM files that store data. Buffer Manager is not aware of columns and rows of data, only the pages and page numbers. The more getpage requests that are necessary to run an SQL statement, the more CPU will be consumed by Buffer Manager.

Data Manager (sometimes called "Stage 1") is responsible for translating the raw data stored on pages into columns and rows for a given query. As it is doing this, it can throw away some data that does not meet the criteria of the WHERE clause. Predicates that are written in a fairly straightforward way can usually be evaluated by Data Manager with relatively little expense.

Relational Data Services (RDS) is also referred to as "Stage 2". Complex predicates that require data transformation or computations will be evaluated by RDS rather than Data Manager. These "Stage 2" predicates are much more expensive to resolve than "Stage 1" predicates. Additionally, RDS cannot make effective use of indexes, so there is a risk of retaining data much longer that does not qualify for the query. It is obviously desirable to write queries in a way that may be evaluated at Stage 1 rather than by RDS.

These layers of code will be discussed in detail in a later chapter.



What Causes CPU in Db2?

- Built-in Function Usage: Transformation of data for retrieval
- CASE statements (very expensive)
- Summarization for Column Functions
- Sorts
- User Defined Functions (UDFs)
- Stored Procedures
- Triggers
- Locking of data

- DEVELOPERS: Know what your programs are doing!
  Know how much data is typically processed!
  Have counts for all actions!

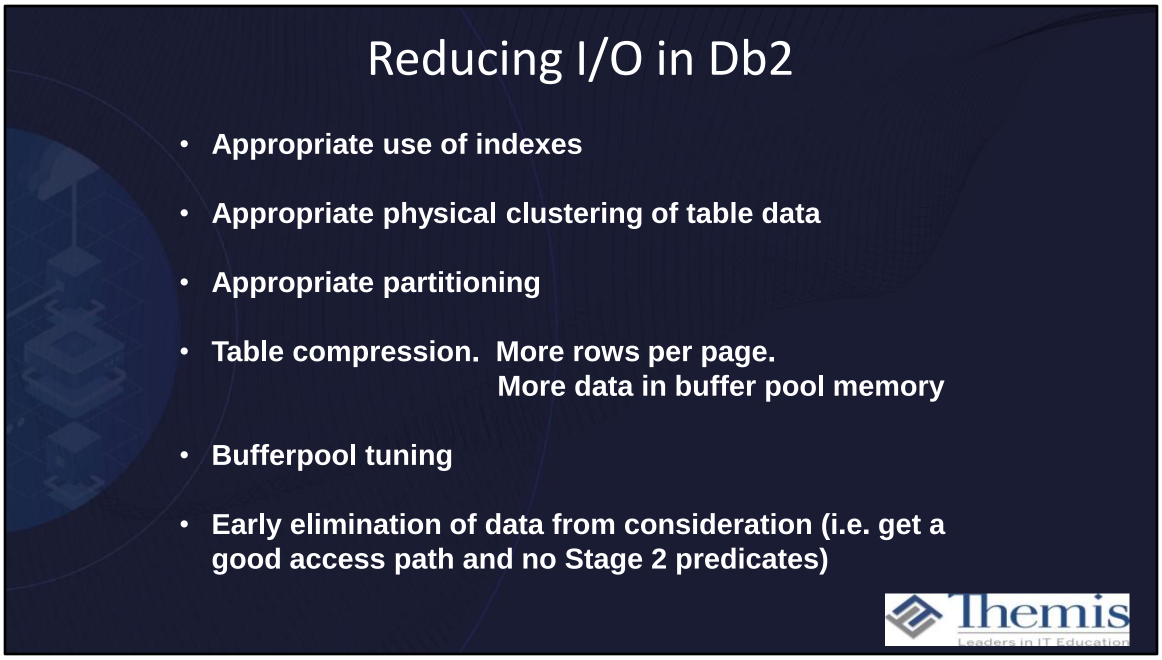
Use of Built-in functions (BIFs) in a query may also involve substantial CPU to reformat or summarize data. In the case where BIFs are used in the WHERE clause, this will almost always result in Stage 2 processing for that predicate. Among the most powerful BIFs is the CASE statement which allows conditional logic to be done inside an SQL statement. The CASE statement may also be one of the most CPU intensive functions used in SQL. Care should be taken when using CASE to be sure that it is being used appropriately.

User Defined Functions (UDFs) are custom functions written by programmers to accomplish reformatting or summarization of data that cannot be done with Db2's BIFs. UDFs run in Workload Manager (WLM) address spaces and may involve significant overhead to call and manage. Stored procedures can incur similar overhead.

Any sorts use CPU. Stored procedures called during processing will use a percentage of the overall CPU.

Are there any triggers being executed on table processing?

How much locking I taking place? Can it be minimized? Can the program execute optimistic locking?



Reducing I/O in Db2

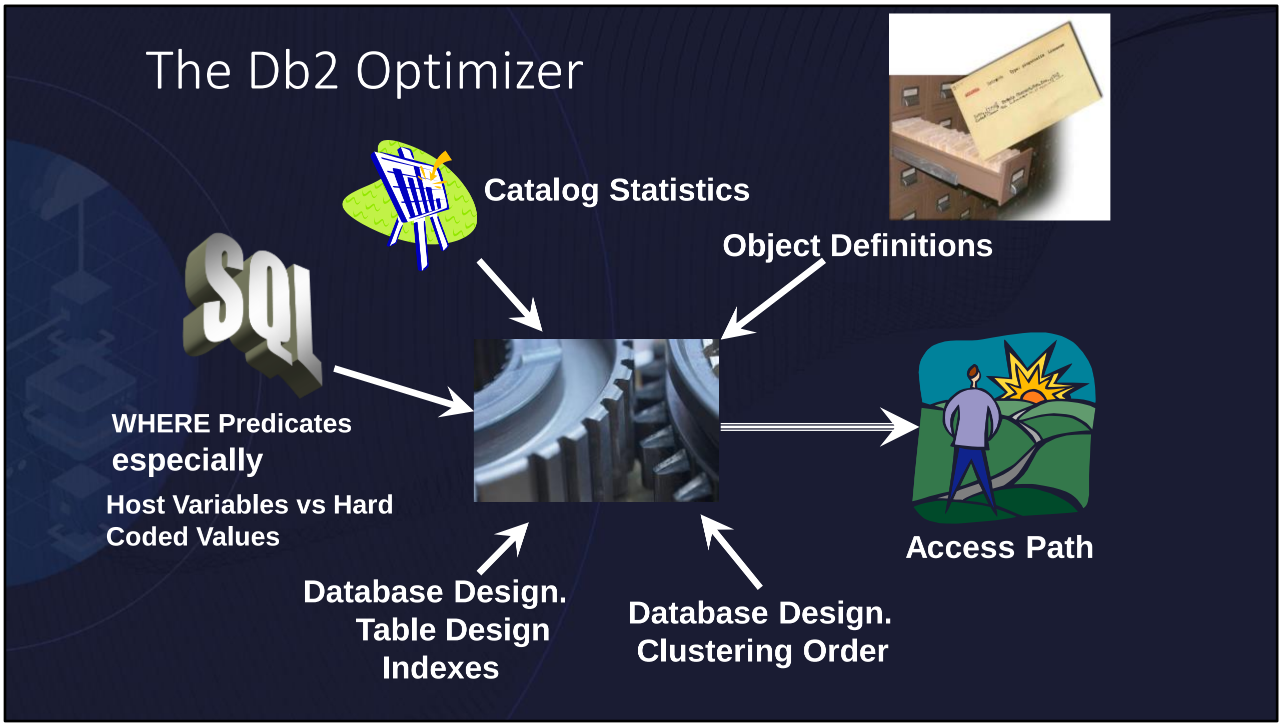
- Appropriate use of indexes
- Appropriate physical clustering of table data
- Appropriate partitioning
- Table compression. More rows per page.
  More data in buffer pool memory
- Bufferpool tuning
- Early elimination of data from consideration (i.e. get a good access path and no Stage 2 predicates)

Reducing I/O within Db2 is one of the easiest ways to improve the performance of SQL within an application.

Creating appropriate indexes on columns or groups of columns that are commonly used to identify needed data can significantly reduce the I/O and CPU needed to retrieve a result.

It is also important that they Db2 system itself be configured optimally for the workload that must be supported. One important component of system tuning is the bufferpools. Bufferpools exist to reduce the amount of I/O needed by applications. Bufferpools should be configured to allow for as much reuse of cached data as possible. Objects may be grouped by sequential and random access patterns and the settings of the pools adjusted accordingly. In some cases a system tuning effort can reap significant rewards.

No amount of system tuning, however, can recover the resources wasted by a poor database design or poor access paths generated by the Db2 optimizer. This presentation focuses on optimization and tuning at the SQL level. In general, we want the optimizer to generate an access path that eliminates as much data from consideration as early as possible in the process.



The Db2 Optimizer

Catalog Statistics
Object Definitions
WHERE Predicates
especially
Host Variables vs Hard Coded Values
Access Path
Database Design. Table Design Indexes
Database Design. Clustering Order

Through the Data Manipulation Language (DML) the user of a Db2 database supplies the "WHAT"; that is, the data that is needed from the database to satisfy the business requirements. Db2 then uses the information in the Db2 Catalog to resolve "WHERE" the data resides. The Db2 Optimizer is then responsible for determining the all important "HOW" to access the data most efficiently.

Ideally, the user of a relational database is not concerned with how the system accesses data. This is probably true for an end user of Db2, who writes SQL queries quickly for one-time or occasional use. It is less true for developers who write application pro-grams and transactions, some of which will be executed thou-sands of times a day. For these cases, some attention to Db2 access methods can significantly improve performance. Db2's access paths can be influenced in four ways:

♦ By rewriting a query in a more efficient form.
♦ By creating, altering, or dropping indexes.
♦ By updating the catalog statistics that Db2 uses to estimate access costs.
♦ By utilizing Optimizer Hints.

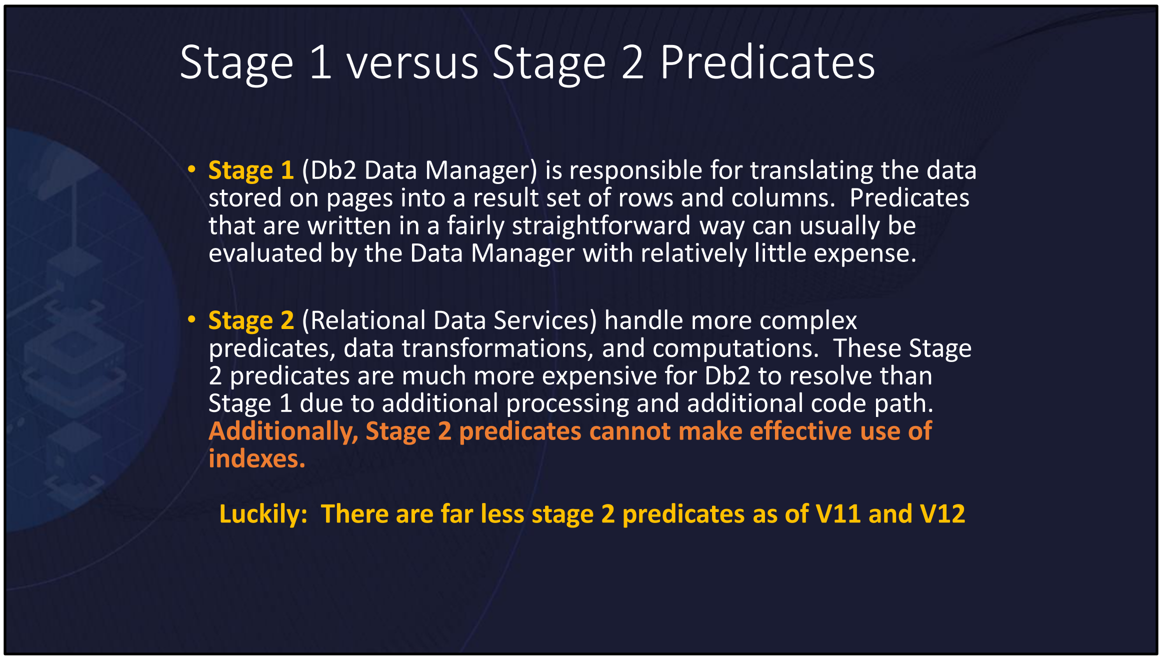
Watch out for different RID pool sizing from production and test environments. The row id (RID) pool is used for the RID sorts that accompany optimizer access path techniques such as list pre-fetch, hybrid join, and multi-index access. These pool sizes may vary from production environments to test environments with typically more RID pool sort area in production. This can at times cause the access path to be different in different environments

Other items affecting optimization: ♦ Buffer Pools, ♦ Rid Pools.

You can improve access path testing by updating the catalog statistics on your test system to be the same as your production system.
There are various ways to accomplish this.
You can improve the accuracy of test access path by modeling the configuration and settings of your production subsystem in your test subsystem. The test system uses values that you specify in profile tables for:

- processor configuration
- RID pool, Sort pool

- Buffer pool settings.



Stage 1 versus Stage 2 Predicates

- **Stage 1** (Db2 Data Manager) is responsible for translating the data stored on pages into a result set of rows and columns. Predicates that are written in a fairly straightforward way can usually be evaluated by the Data Manager with relatively little expense.

- **Stage 2** (Relational Data Services) handle more complex predicates, data transformations, and computations. These Stage 2 predicates are much more expensive for Db2 to resolve than Stage 1 due to additional processing and additional code path. **Additionally, Stage 2 predicates cannot make effective use of indexes.**

Luckily: There are far less stage 2 predicates as of V11 and V12

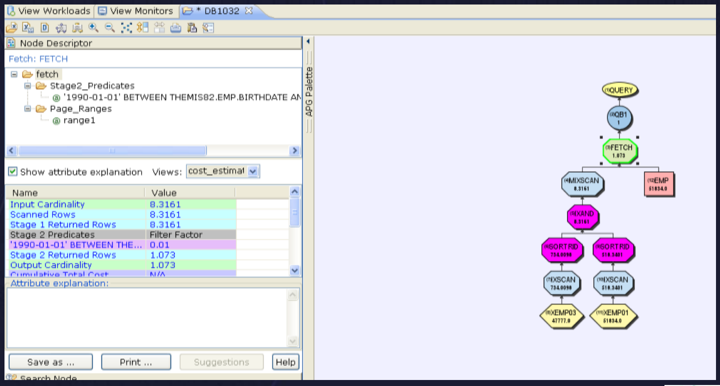
Stage 1 = Sargeable

Stage 2 = Non Sargeable. Predicate processing by this RDS are of Db2 is much more expensive than the RDS Stage 1 area. Additional processing, additional code path, much more expensive then stage 1.

Indexable predicates evaluated first, Stage 1 predicates, next, and Stage 2 predicates last.

Stage 2 Predicates

Use the Visual Explain in IBM Data Studio or query directly the DSN_PREDICAT_TABLE to see any stage 2 predicates. Note the filter factor information also.



Fetch: FETCH

```
fetch
  Stage2_Predicates
    '1990-01-01' BETWEEN THEMIS82.EMP.BIRTHDATE AN
  Page_Ranges
    range1
```

Show attribute explanation [✓]   Views: cost_estimat

Name	Value
Input Cardinality	8.3161
Scanned Rows	8.3161
Stage 1 Returned Rows	8.3161
Stage 2 Predicates	Filter Factor
'1990-01-01' BETWEEN THE...	0.01
Stage 2 Returned Rows	1.073
Output Cardinality	1.073
Cumulative Total Cost	N/A

Attribute explanation:

1) Click on the FETCH box to see any/all predicates not associated with the index chosen
2) Click on the IXSCAN boxes to see matching index and screening index predicate information

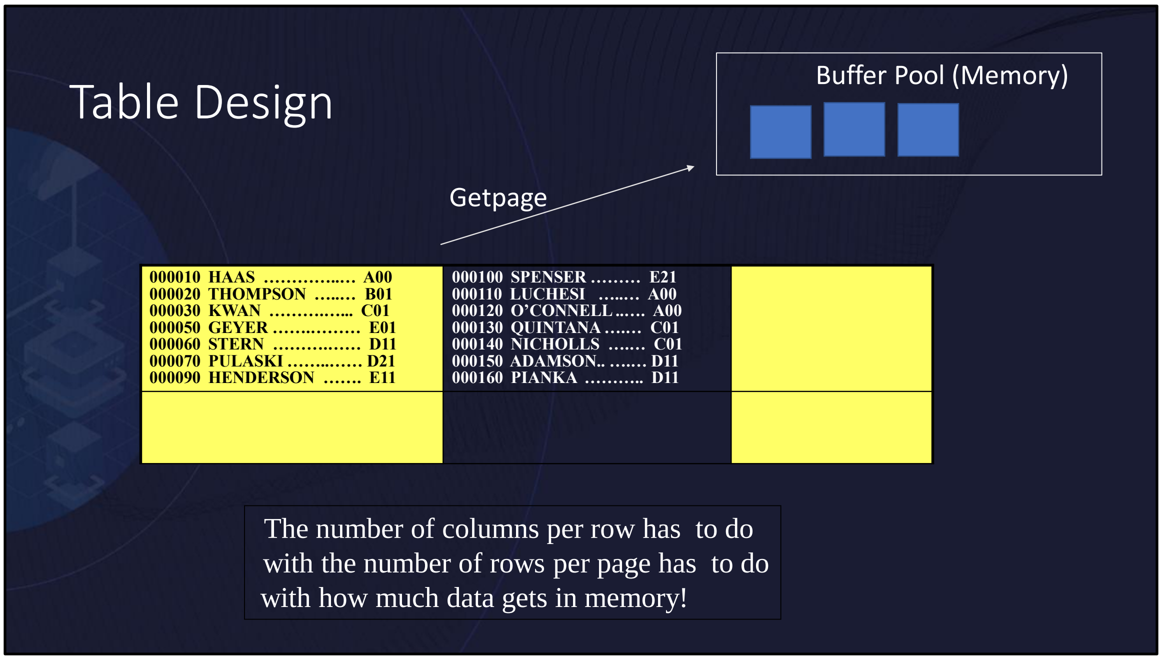
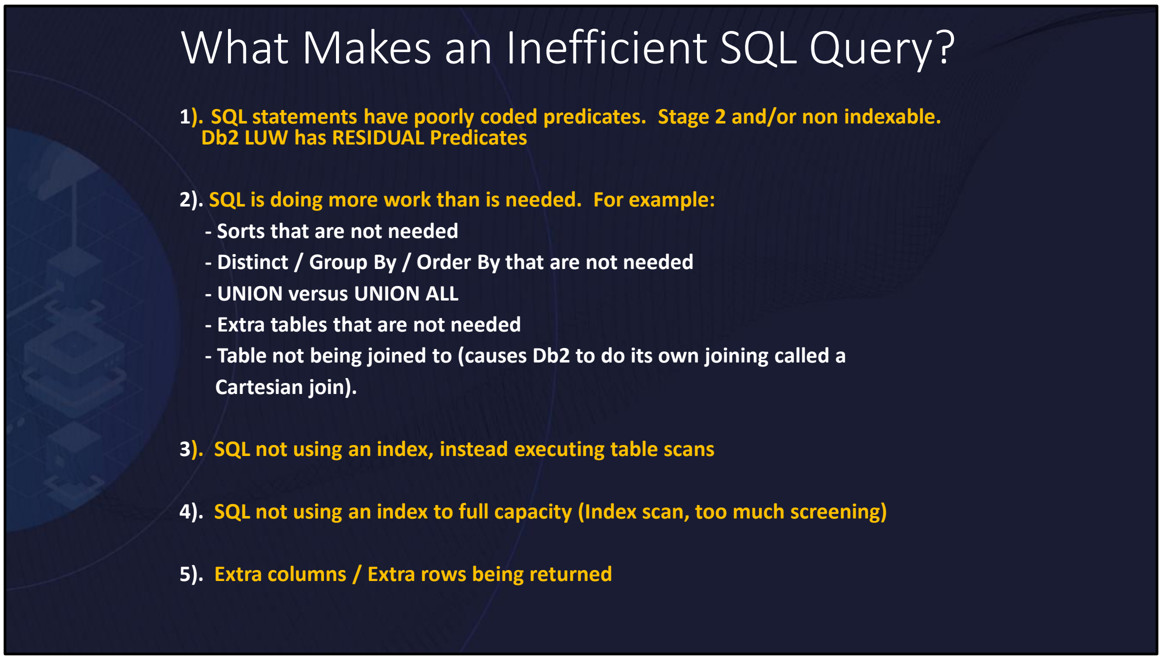


Table Design

000010 HAAS A00	000100 SPENSER E21
000020 THOMPSON B01	000110 LUCHESI A00
000030 KWAN C01	000120 O'CONNELL...... A00
000050 GEYER E01	000130 QUINTANA C01
000060 STERN D11	000140 NICHOLLS C01
000070 PULASKI D21	000150 ADAMSON.. .... D11
000090 HENDERSON E11	000160 PIANKA D11

The number of columns per row has to do with the number of rows per page has to do with how much data gets in memory!

This is an example of the EMP table being in EMPNO primary key order.


What Makes an Inefficient SQL Query?

1). SQL statements have poorly coded predicates. Stage 2 and/or non indexable.
Db2 LUW has RESIDUAL Predicates

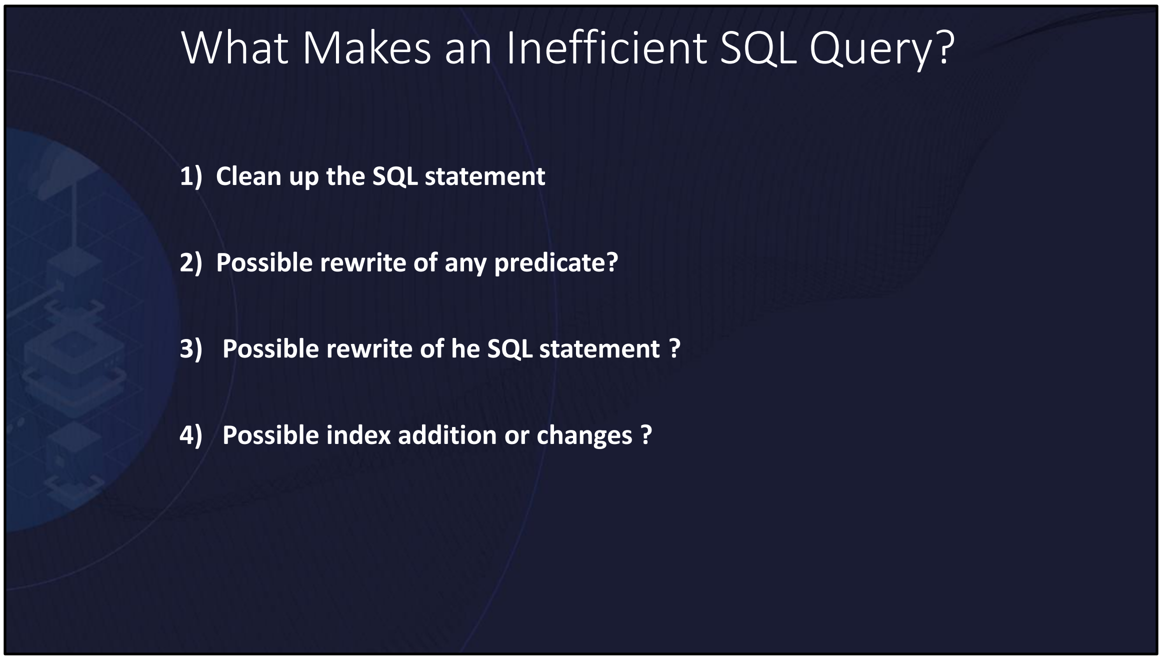
2). SQL is doing more work than is needed. For example:
- Sorts that are not needed
- Distinct / Group By / Order By that are not needed
- UNION versus UNION ALL
- Extra tables that are not needed
- Table not being joined to (causes Db2 to do its own joining called a Cartesian join).

3). SQL not using an index, instead executing table scans

4). SQL not using an index to full capacity (Index scan, too much screening)

5). Extra columns / Extra rows being returned

Developers should review their own SQL code and make sure it is:
- Not doing more work than needed
- Not bring back more data (columns and/or rows) needed
- Not doing unneeded sorts



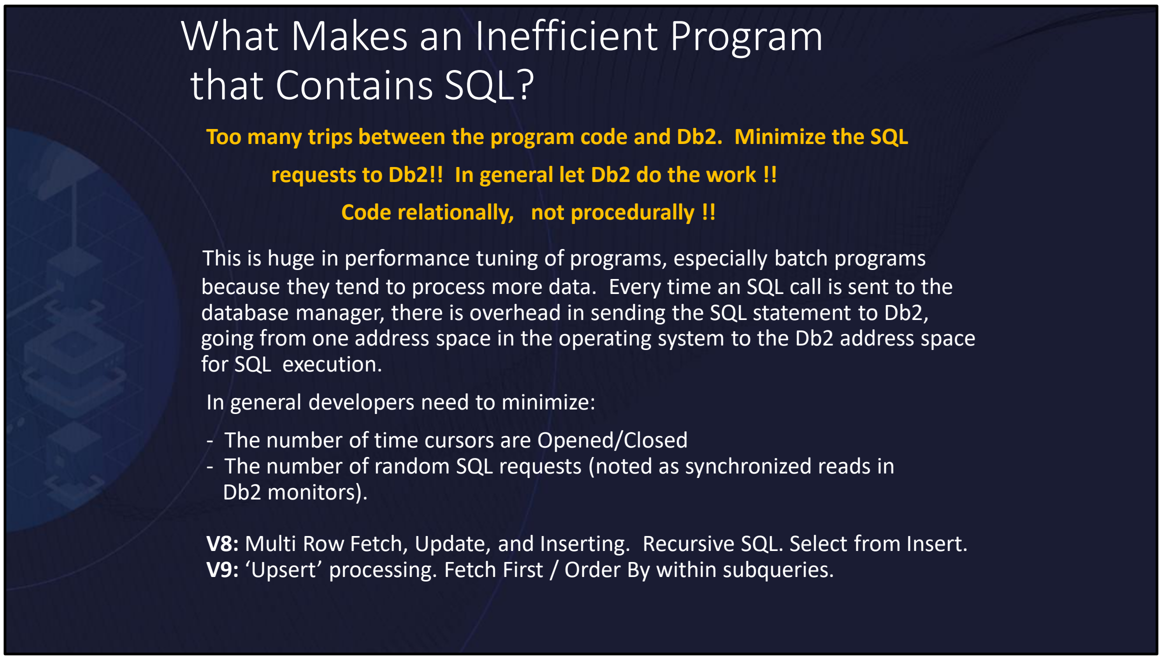
What Makes an Inefficient SQL Query?

1) **Clean up the SQL statement**
2) **Possible rewrite of any predicate?**
3) **Possible rewrite of he SQL statement ?**
4) **Possible index addition or changes ?**

Take out anything not needed is a start.   Oftern time predicates can be rewritten differently yet maintaining the same logic. This can have the optimizer come up with a different filter factor for the predicate, and possibly change the optimization path chosen

Often times there might be 3,4,5 different ways to write queries for the same result set. And often times each may take a different optimization path than the others. If a different optimization is chosen, then for sure a different runtime will occur. Could be better maybe! It depends…

See the presentation and article from past conferences titles ‘ The Power of the SQL Rewrite’.



What Makes an Inefficient Program that Contains SQL?

Too many trips between the program code and Db2. Minimize the SQL requests to Db2!! In general let Db2 do the work !!

Code relationally, not procedurally !!

This is huge in performance tuning of programs, especially batch programs because they tend to process more data. Every time an SQL call is sent to the database manager, there is overhead in sending the SQL statement to Db2, going from one address space in the operating system to the Db2 address space for SQL execution.

In general developers need to minimize:

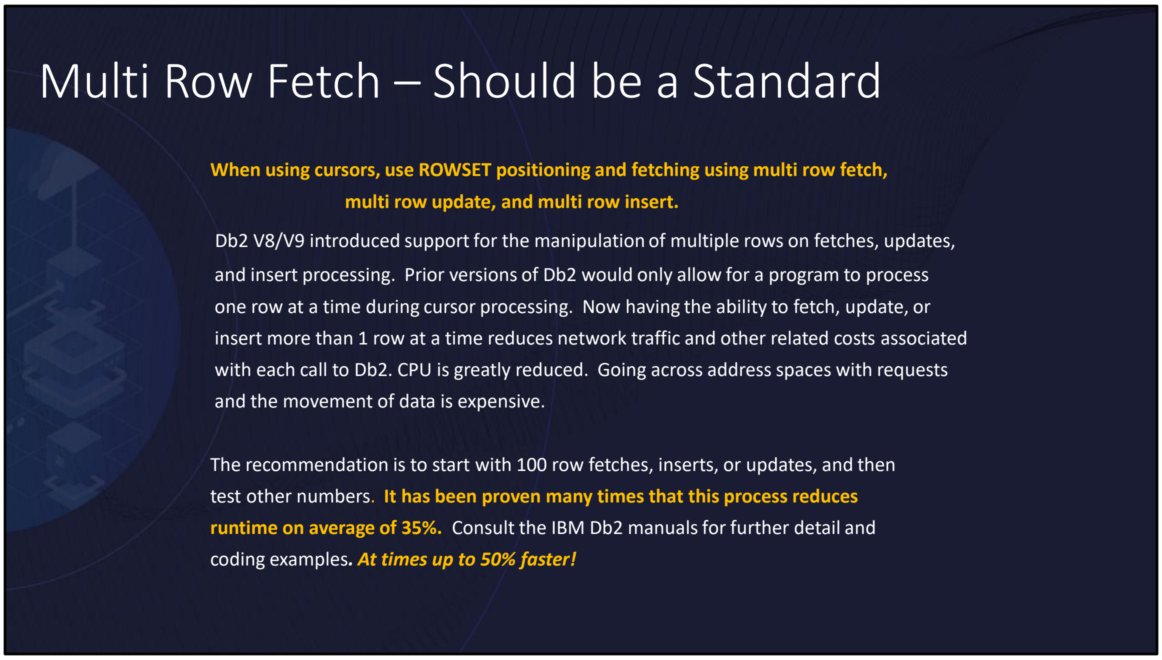
- The number of time cursors are Opened/Closed
- The number of random SQL requests (noted as synchronized reads in Db2 monitors).

V8: Multi Row Fetch, Update, and Inserting. Recursive SQL. Select from Insert.
V9: 'Upsert' processing. Fetch First / Order By within subqueries.

1) Minimize programming API (Application Programming Interface) to Db2. There is overhead involved in API calls, no matter how efficient the call may be.

2) Minimize the number of fetches by using multi row fetch. Take advantage of multi row deletes/inserts also.

3) Distributed Apps: Once in compatibility mode in V8 the blocks used for block fetching are built using the multi-row capability without any code change. This results in automatic savings for example distributed SQLJ applications.



Multi Row Fetch – Should be a Standard

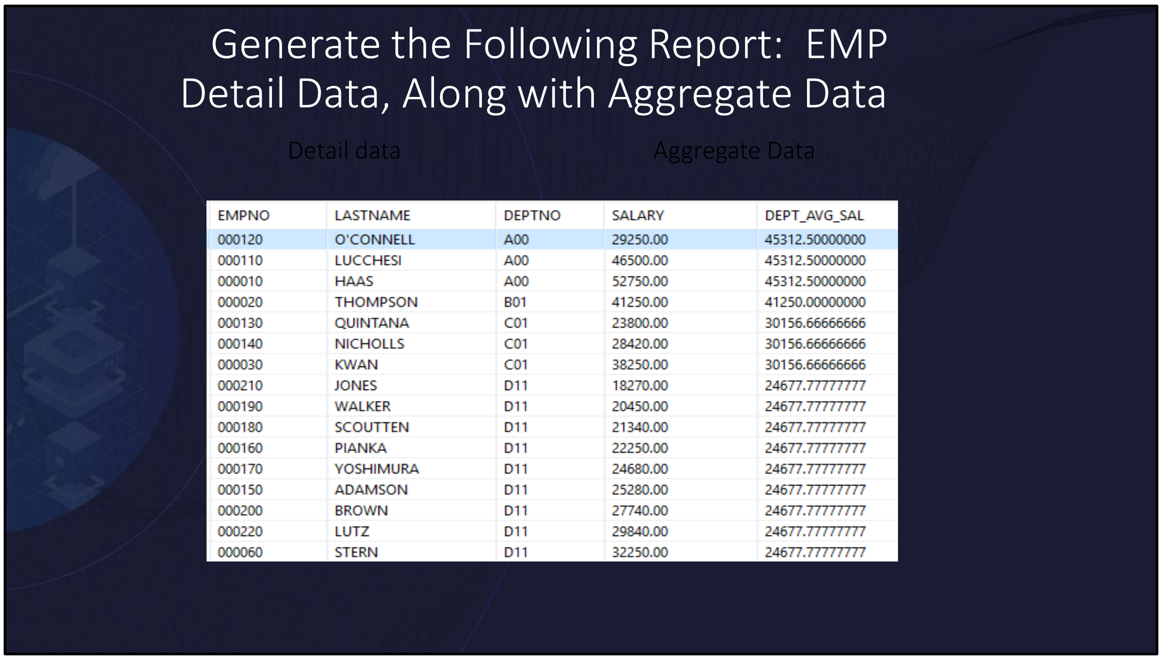
When using cursors, use ROWSET positioning and fetching using multi row fetch, multi row update, and multi row insert.

Db2 V8/V9 introduced support for the manipulation of multiple rows on fetches, updates, and insert processing. Prior versions of Db2 would only allow for a program to process one row at a time during cursor processing. Now having the ability to fetch, update, or insert more than 1 row at a time reduces network traffic and other related costs associated with each call to Db2. CPU is greatly reduced. Going across address spaces with requests and the movement of data is expensive.

The recommendation is to start with 100 row fetches, inserts, or updates, and then test other numbers. **It has been proven many times that this process reduces runtime on average of 35%.** Consult the IBM Db2 manuals for further detail and coding examples. ***At times up to 50% faster!***

1) Check ‘Get Diagnostics’ only after receiving a SQLCODE <> 0
2) For multi-row fetch you get a +354 SQLCODE which says "one or more errors may have occurred.“
3) For a non atomic multi-row insert you get a -253 if some of the rows fail, -254 if all fail
4) For an atomic multi-row insert you get the real SQLCODE of the first failure (since atomic means any failure backs out the entire insert), but you still need the diagnostics to determine which row actually tripped the error.
5) If you get multiple errors, they will be returned in reverse order. e.g. when inserting 5 rows, row no. 2 and row no. 4 had errors. GET DIAGNOSTICS shows three errors (not two!) - first is the generic, 2nd is error for row #4 and third is error for row #2.
6) If you perform a multi-row operation and receive an SQLCODE of 0 then you generally have no need for GET DIAGNOSTICS, which is VERY expensive. So, check SQLCODE first and only go to the DIAGNOSTICS when errors are encountered.
7) Multi Row for even a small number of rows returned can be beneficial. When searching for a "break-even" (runtime), don't forget to take into consideration the length of the data rows being fetched. Multi-row fetch will be especially beneficial (even for just a few rows) if the rows are short in length.

8) Seen best results with large amounts of data being returned from a cursor. Fetches of 100 rows each.



Generate the Following Report: EMP Detail Data, Along with Aggregate Data

Detail data Aggregate Data

EMPNO	LASTNAME	DEPTNO	SALARY	DEPT_AVG_SAL
000120	O'CONNELL	A00	29250.00	45312.50000000
000110	LUCCHESI	A00	46500.00	45312.50000000
000010	HAAS	A00	52750.00	45312.50000000
000020	THOMPSON	B01	41250.00	41250.00000000
000130	QUINTANA	C01	23800.00	30156.66666666
000140	NICHOLLS	C01	28420.00	30156.66666666
000030	KWAN	C01	38250.00	30156.66666666
000210	JONES	D11	18270.00	24677.77777777
000190	WALKER	D11	20450.00	24677.77777777
000180	SCOUTTEN	D11	21340.00	24677.77777777
000160	PIANKA	D11	22250.00	24677.77777777
000170	YOSHIMURA	D11	24680.00	24677.77777777
000150	ADAMSON	D11	25280.00	24677.77777777
000200	BROWN	D11	27740.00	24677.77777777
000220	LUTZ	D11	29840.00	24677.77777777
000060	STERN	D11	32250.00	24677.77777777

Not stating that this is the best option, but at times it may be. But it gives developers another way to code for certain results.

Other Options:

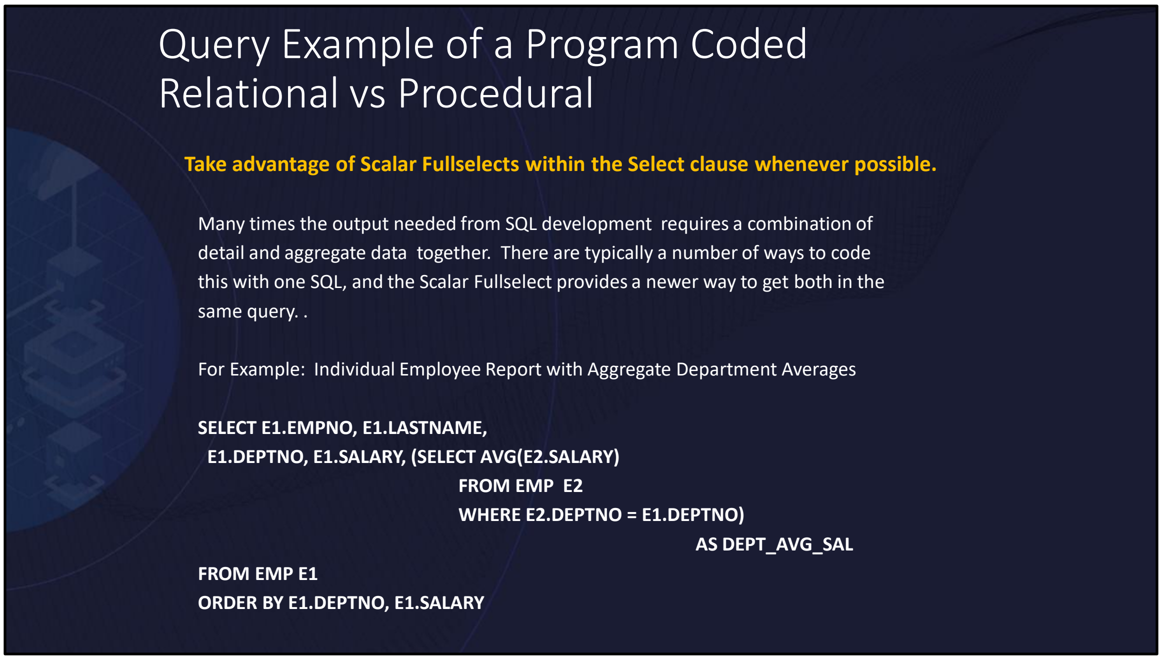
```
1)  SELECT E1.EMPNO, E1.LASTNAME, E1.WORKDEPT, E1.SALARY, X.DEPT_AVG_SAL
    FROM EMPLOYEE E1  INNER JOIN
          (SELECT E2.DEPTNO, DEC(ROUND(AVG(E2.SALARY),2),9,2)
                                                   AS DEPT_AVG_SAL
           FROM EMP E2
           GROUP BY E2.WORKDEPT) AS X  ON E1.DEPTNO  = X.DEPTNO
    ORDER BY E1.WORKDEPT, E1.SALARY

2)  WITH X AS
    (SELECT E2.WORKDEPT, DEC(ROUND(AVG(E2.SALARY),2),9,2)
                                         AS DEPT_AVG_SAL
     FROM EMPLOYEE E2
     GROUP BY E2.WORKDEPT)

   SELECT E1.EMPNO, E1.LASTNAME, E1.WORKDEPT, E1.SALARY, X.DEPT_AVG_SAL
   FROM EMP E1  INNER JOIN
           X     ON E1.DEPTNO  = X.DEPTNO
   ORDER BY E1.WORKDEPT, E1.SALARY

3) SELECT E1.EMPNO, E1.LASTNAME, E1.WORKDEPT, E1.SALARY,  AVG(E2.SALARY)  AS
```

```
DEPT_AVG_SAL
   FROM EMP E1  INNER JOIN
           EMP E2  ON E1.DEPTNO  = E2.DEPTNO
   GROUP BY E1.EMPNO, E1.LASTNAME, E1.WORKDEPT, E1.SALARY
   ORDER BY E1.WORKDEPT, E1.SALARY
```



Query Example of a Program Coded Relational vs Procedural

Take advantage of Scalar Fullselects within the Select clause whenever possible.

Many times the output needed from SQL development requires a combination of detail and aggregate data together. There are typically a number of ways to code this with one SQL, and the Scalar Fullselect provides a newer way to get both in the same query. .

For Example: Individual Employee Report with Aggregate Department Averages

```
SELECT E1.EMPNO, E1.LASTNAME,
  E1.DEPTNO, E1.SALARY, (SELECT AVG(E2.SALARY)
                         FROM EMP  E2
                         WHERE E2.DEPTNO = E1.DEPTNO)
                                          AS DEPT_AVG_SAL
FROM EMP E1
ORDER BY E1.DEPTNO, E1.SALARY
```

Not stating that this is the best option, but at times it may be. But it gives developers another way to code for certain results.

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     ORDER BY E1.WORKDEPT, E1.SALARY

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                                       AS DEPT_AVG_SAL
      FROM EMPLOYEE E2
      GROUP BY E2.WORKDEPT)

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    ORDER BY E1.WORKDEPT, E1.SALARY

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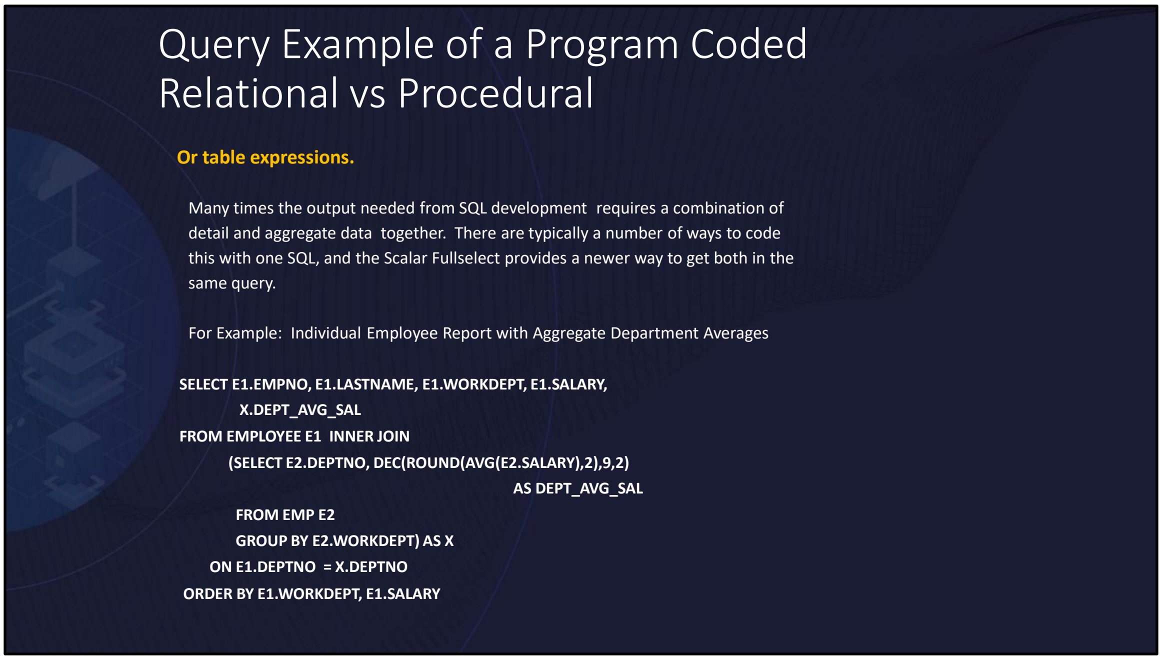
   ORDER BY E1.WORKDEPT, E1.SALARY
```



Query Example of a Program Coded Relational vs Procedural

Or table expressions.

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           GROUP BY E2.WORKDEPT) AS X
      ON E1.DEPTNO  = X.DEPTNO
 ORDER BY E1.WORKDEPT, E1.SALARY
```

Not stating that this is the best option, but at times it may be. But it gives developers another way to code for certain results.

Other Options:

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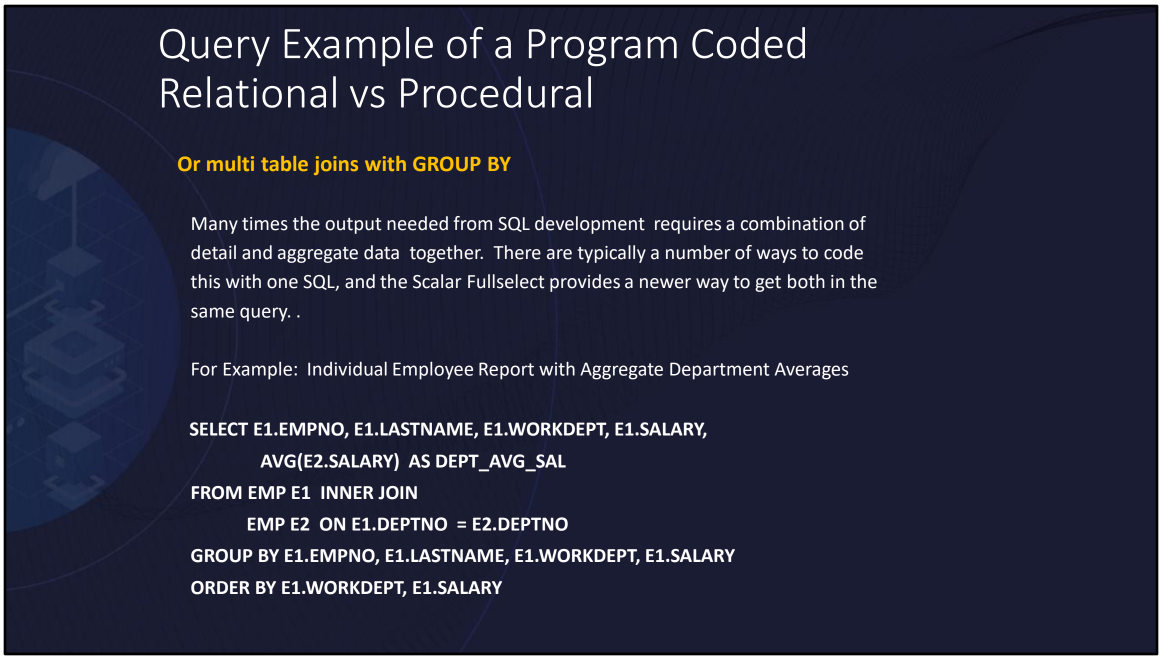
             GROUP BY E2.WORKDEPT) AS X  ON E1.DEPTNO  = X.DEPTNO
      ORDER BY E1.WORKDEPT, E1.SALARY

2)   WITH X AS
      (SELECT E2.WORKDEPT, DEC(ROUND(AVG(E2.SALARY),2),9,2)
                                                  AS DEPT_AVG_SAL
       FROM EMPLOYEE E2
       GROUP BY E2.WORKDEPT)

    SELECT E1.EMPNO, E1.LASTNAME, E1.WORKDEPT, E1.SALARY, X.DEPT_AVG_SAL
    FROM EMP E1  INNER JOIN
             X     ON E1.DEPTNO  = X.DEPTNO
    ORDER BY E1.WORKDEPT, E1.SALARY

3) SELECT E1.EMPNO, E1.LASTNAME, E1.WORKDEPT, E1.SALARY,  AVG(E2.SALARY)  AS
```

```
DEPT_AVG_SAL
   FROM EMP E1  INNER JOIN
           EMP E2  ON E1.DEPTNO  = E2.DEPTNO
   GROUP BY E1.EMPNO, E1.LASTNAME, E1.WORKDEPT, E1.SALARY
   ORDER BY E1.WORKDEPT, E1.SALARY
```



Query Example of a Program Coded Relational vs Procedural

Or multi table joins with GROUP BY

Many times the output needed from SQL development requires a combination of detail and aggregate data together. There are typically a number of ways to code this with one SQL, and the Scalar Fullselect provides a newer way to get both in the same query. .

For Example: Individual Employee Report with Aggregate Department Averages

```
SELECT E1.EMPNO, E1.LASTNAME, E1.WORKDEPT, E1.SALARY,
           AVG(E2.SALARY)  AS DEPT_AVG_SAL
FROM EMP E1  INNER JOIN
         EMP E2  ON E1.DEPTNO  = E2.DEPTNO
GROUP BY E1.EMPNO, E1.LASTNAME, E1.WORKDEPT, E1.SALARY
ORDER BY E1.WORKDEPT, E1.SALARY
```

Not stating that this is the best option, but at times it may be. But it gives developers another way to code for certain results.

Other Options:

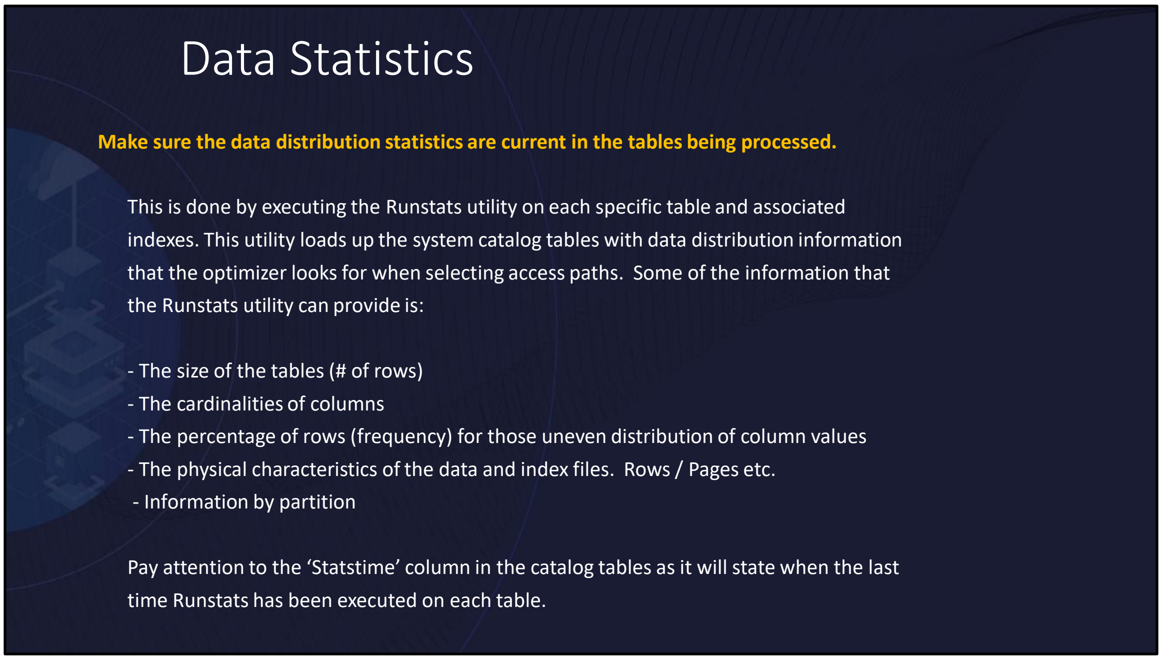
```
1)   SELECT E1.EMPNO, E1.LASTNAME, E1.WORKDEPT, E1.SALARY, X.DEPT_AVG_SAL
     FROM EMPLOYEE E1  INNER JOIN
          (SELECT E2.DEPTNO, DEC(ROUND(AVG(E2.SALARY),2),9,2)
                                                        AS DEPT_AVG_SAL
           FROM EMP E2
           GROUP BY E2.WORKDEPT) AS X  ON E1.DEPTNO  = X.DEPTNO
     ORDER BY E1.WORKDEPT, E1.SALARY

2)   WITH X AS
     (SELECT E2.WORKDEPT, DEC(ROUND(AVG(E2.SALARY),2),9,2)
                                                  AS DEPT_AVG_SAL
      FROM EMPLOYEE E2
      GROUP BY E2.WORKDEPT)

    SELECT E1.EMPNO, E1.LASTNAME, E1.WORKDEPT, E1.SALARY, X.DEPT_AVG_SAL
    FROM EMP E1  INNER JOIN
             X     ON E1.DEPTNO  = X.DEPTNO
    ORDER BY E1.WORKDEPT, E1.SALARY

3) SELECT E1.EMPNO, E1.LASTNAME, E1.WORKDEPT, E1.SALARY,  AVG(E2.SALARY)  AS
```

```
DEPT_AVG_SAL
   FROM EMP E1  INNER JOIN
           EMP E2  ON E1.DEPTNO  = E2.DEPTNO
   GROUP BY E1.EMPNO, E1.LASTNAME, E1.WORKDEPT, E1.SALARY
   ORDER BY E1.WORKDEPT, E1.SALARY
```



Data Statistics

Make sure the data distribution statistics are current in the tables being processed.

This is done by executing the Runstats utility on each specific table and associated indexes. This utility loads up the system catalog tables with data distribution information that the optimizer looks for when selecting access paths. Some of the information that the Runstats utility can provide is:

- The size of the tables (# of rows)
- The cardinalities of columns
- The percentage of rows (frequency) for those uneven distribution of column values
- The physical characteristics of the data and index files. Rows / Pages etc.
- Information by partition

Pay attention to the 'Statstime' column in the catalog tables as it will state when the last time Runstats has been executed on each table.

1) FREQVAL Statistics are important for any columns containing uneven distribution of data values. For example some tables may contain a status code column containing multiple values. If any of the values contains a high or low percentage of rows In the table, then it should have FREQVAL statistics run on that column.

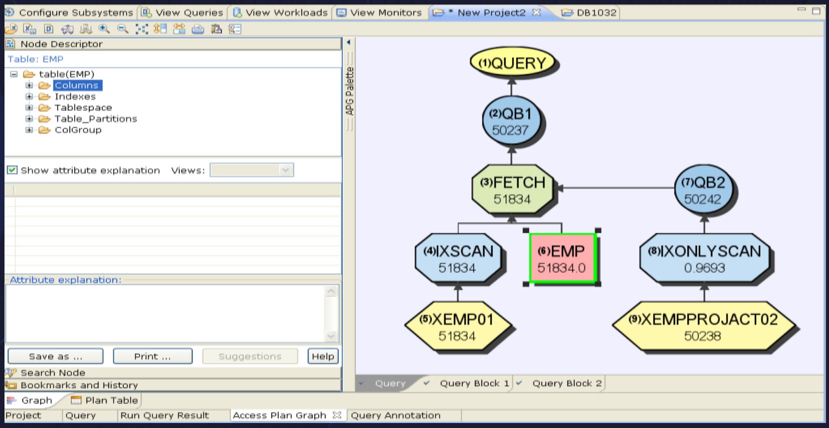
2) Statistics are typically up to date in production, but many time are behind or even reset in test environments.

3) Volatile tables are always an issue. Statistics only reflect a point in time.
By declaring the table volatile, the optimizer will consider using index scan rather than table scan. The access plans that use declared volatile tables will not depend on the existing statistics for that table.

4) By creating a Global Temporary Table, manual statistics can then be added to the catalog tables for the average number of rows, average cardinalities, etc…

Data Statistics

Make sure the data distribution statistics are current in the tables being processed.



1) FREQVAL Statistics are important for any columns containing uneven distribution of data values. For example some tables may contain a status code column containing multiple values. If any of the values contains a high or low percentage of rows In the table, then it should have FREQVAL statistics run on that column.

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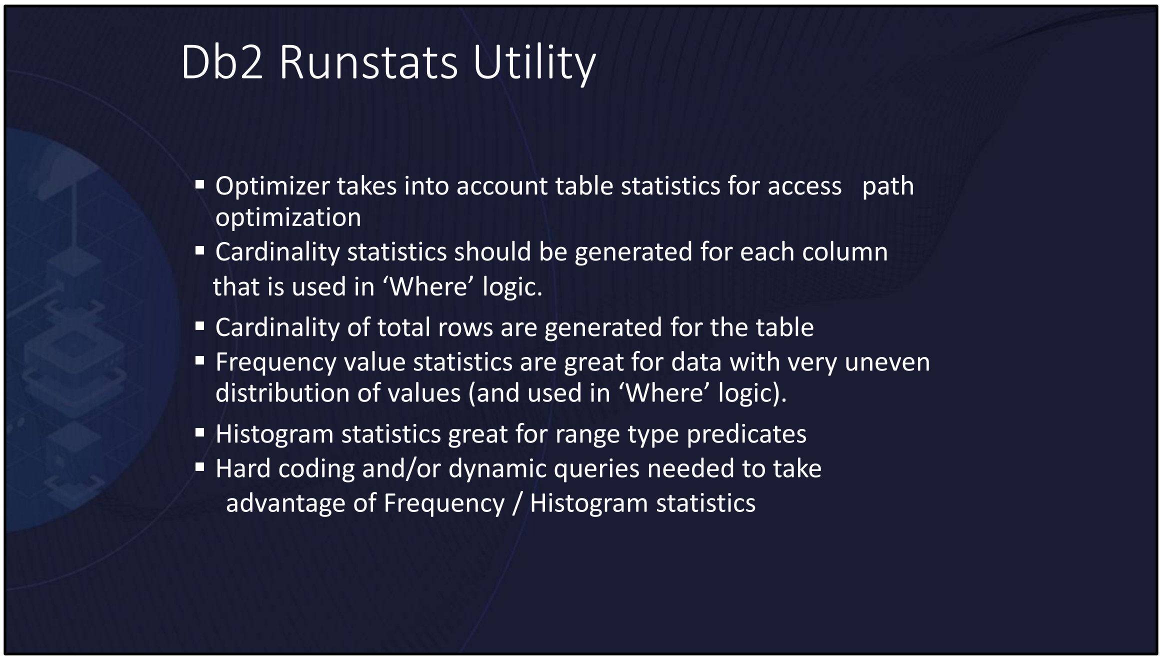
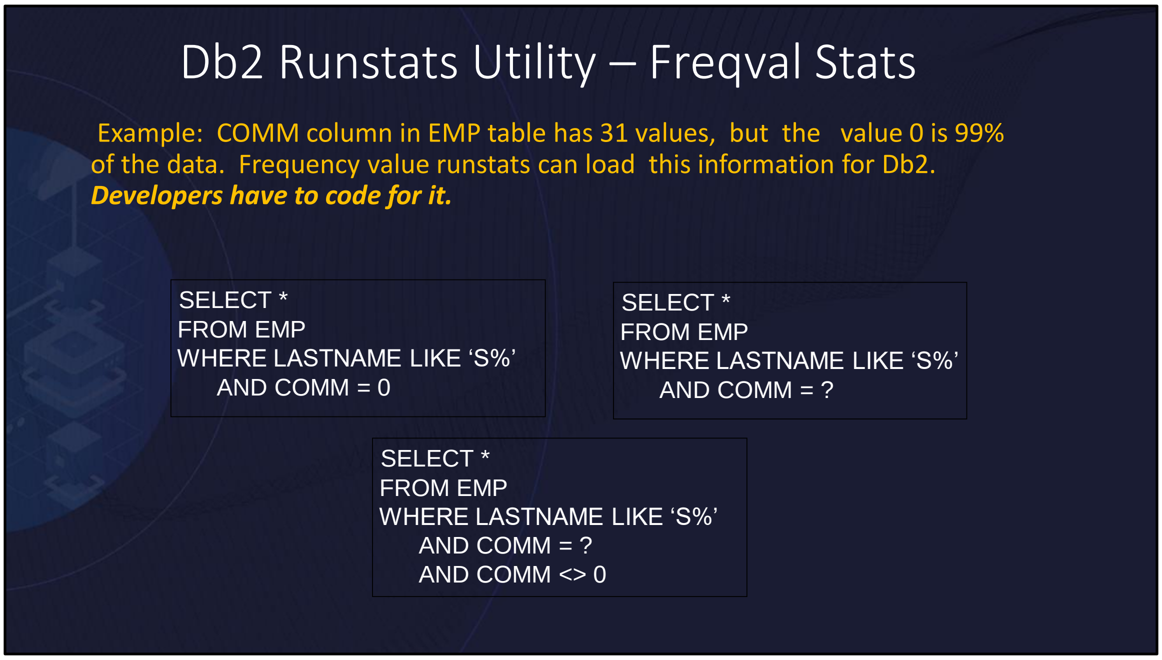


Db2 Runstats Utility

- Optimizer takes into account table statistics for access path optimization
- Cardinality statistics should be generated for each column that is used in 'Where' logic.
- Cardinality of total rows are generated for the table
- Frequency value statistics are great for data with very uneven distribution of values (and used in 'Where' logic).
- Histogram statistics great for range type predicates
- Hard coding and/or dynamic queries needed to take advantage of Frequency / Histogram statistics

The optimizer assumes that the data is uniformly distributed. Therefore, frequency distribution statistics are needed on columns where there is a skew in the data values that may cause poor decisions by the optimizer. Histogram helps data estimation when certain data ranges have a lot of data and others are sparse (hot spots in data across many values).

The best statistics do not help if the queries are optimized with host variables. At times, queries need to have some hard coded values or have the query executed dynamically.



Db2 Runstats Utility – Freqval Stats

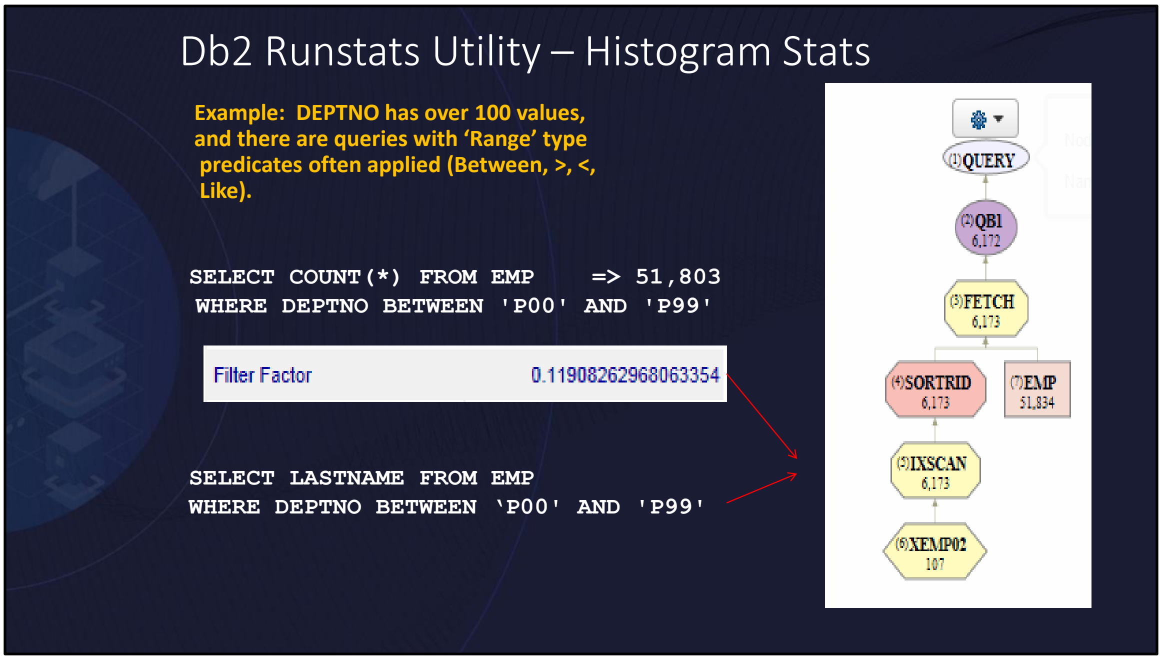
Example: COMM column in EMP table has 31 values, but the value 0 is 99% of the data. Frequency value runstats can load this information for Db2. ***Developers have to code for it.***

```
SELECT *
FROM EMP
WHERE LASTNAME LIKE 'S%'
      AND COMM = 0
```

```
SELECT *
FROM EMP
WHERE LASTNAME LIKE 'S%'
      AND COMM = ?
```

```
SELECT *
FROM EMP
WHERE LASTNAME LIKE 'S%'
      AND COMM = ?
      AND COMM <> 0
```

The optimizer assumes that the data is uniformly distributed. Therefore, frequency distribution statistics are needed on columns where there is a skew in the data values that may cause poor decisions by the optimizer. Histogram helps data estimation when certain data ranges have a lot of data and others are sparse (hot spots in data across many values).



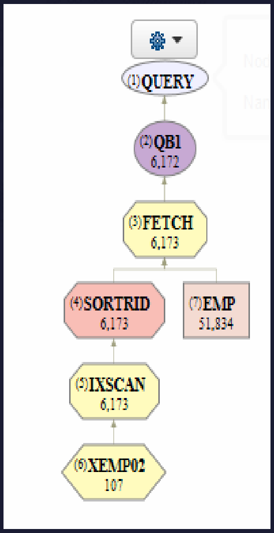
Db2 Runstats Utility – Histogram Stats

Example: DEPTNO has over 100 values, and there are queries with ‘Range’ type predicates often applied (Between, >, <, Like).

```
SELECT COUNT(*) FROM EMP     => 51,803
 WHERE DEPTNO BETWEEN 'P00' AND 'P99'
```

Filter Factor 0.11908262968063354

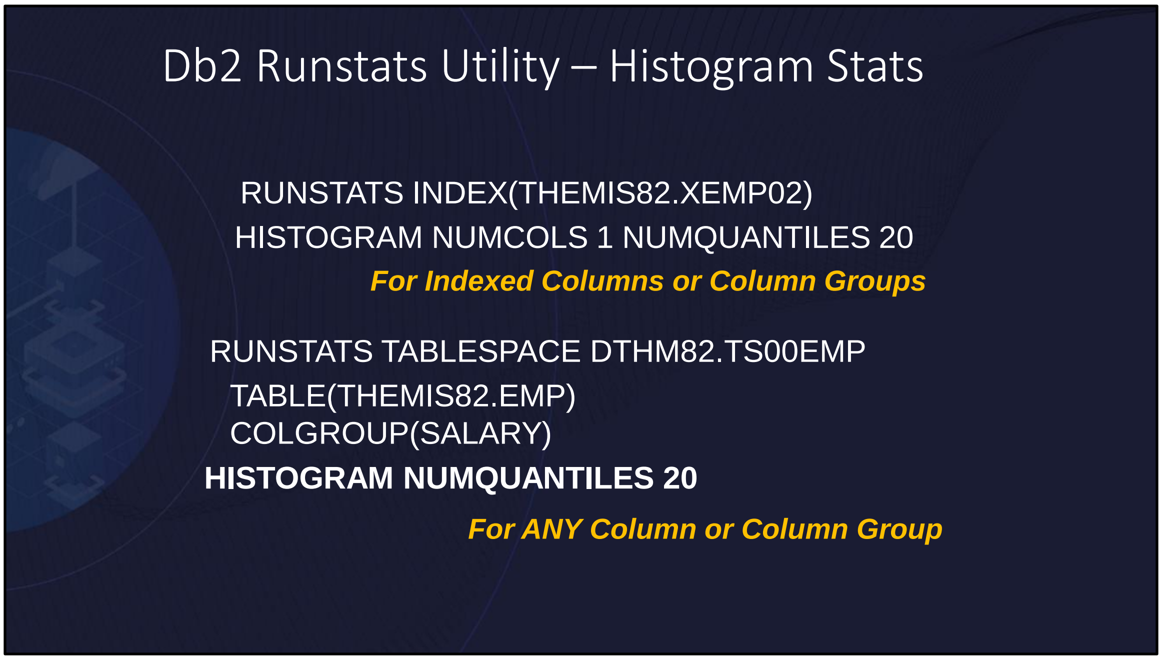
```
SELECT LASTNAME FROM EMP
WHERE DEPTNO BETWEEN ‘P00' AND 'P99'
```



The optimizer assumes that the data is uniformly distributed. Therefore, frequency distribution statistics are needed on columns where there is a skew in the data values that may cause poor decisions by the optimizer. Histogram helps data estimation when certain data ranges have a lot of data and others are sparse (hot spots in data across many values). And especially when there are range predicates against the column.

Histogram statistics are only good if the queries sent to the optimizer have hard coded values or are dynamic, or are being REPOPT’d at runtime. ***Histogram statistics will not help queries with host variables.***

If no NUMQUANTILES is specified, Db2 will choose based on the cardinality of the columns and number of rows up to 100 max. If you
know the application and the typical ranges that get executed, set the number accordingly. For example, if many of the ranges get 5% or
less, then specify a higher number of quantiles. But if the range predicates are always on a larger range, less quantiles is needed.



Db2 Runstats Utility – Histogram Stats

```
RUNSTATS INDEX(THEMIS82.XEMP02)
HISTOGRAM NUMCOLS 1 NUMQUANTILES 20
```

For Indexed Columns or Column Groups

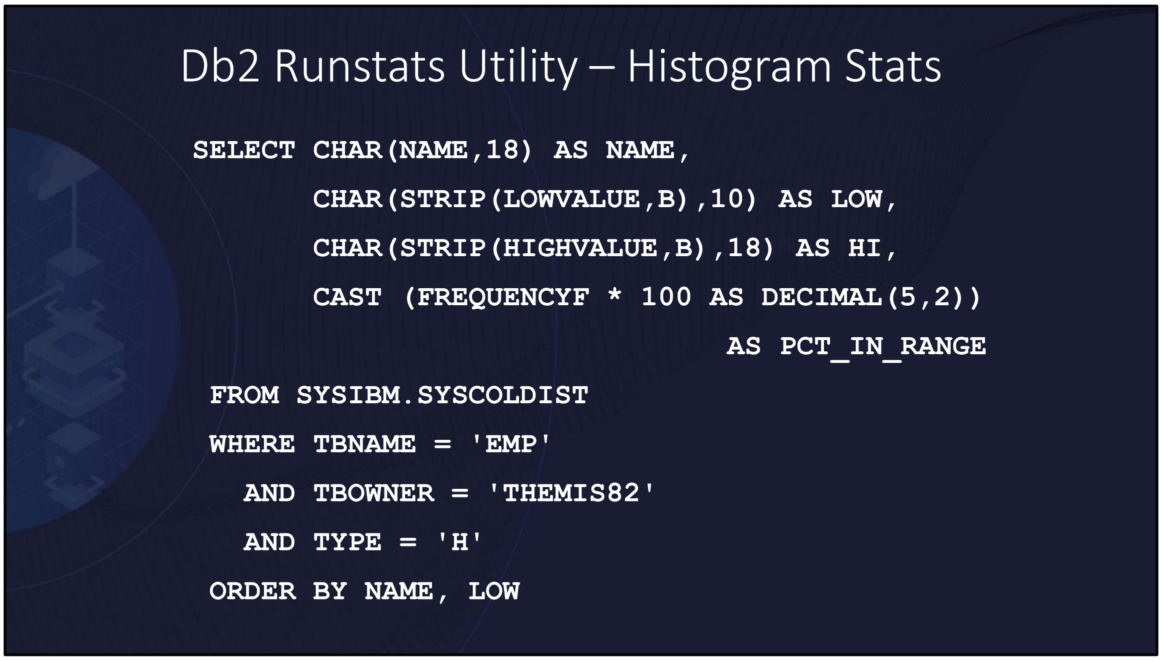
```
RUNSTATS TABLESPACE DTHM82.TS00EMP
  TABLE(THEMIS82.EMP)
  COLGROUP(SALARY)
HISTOGRAM NUMQUANTILES 20
```

For ANY Column or Column Group

These two control cards gather the new histogram statistics. The first example gathers the statistics on the leading column of the XEMP02 index (the DEPTNO column). Histogram statistics break the data into ranges of values with an estimate of the percentage of rows that fall into each range. The NUMQUANTILES option specifies how many ranges should be used (or how much granularity will be present in the statistics). This number is only an estimate, and it may be necessary for the utility to use a few more or less quantiles than requested.

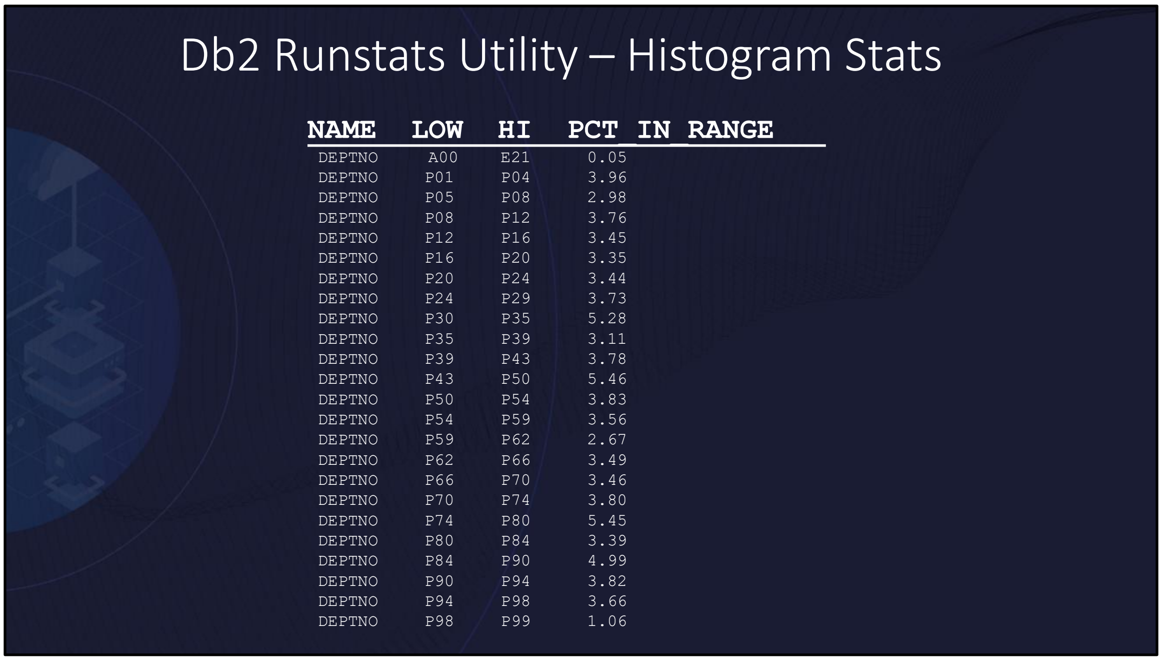
The second example gathers the histogram statistics on a non-indexed column. This invocation of the utility requires a sort of the data to determine the appropriate groupings making this collection rather expensive. Although this syntax may be used for indexed columns, the syntax used in the first example should be used whenever possible to avoid sorting.

It is possible to gather these statistics infrequently even if RUNSTATS is run regularly without the HISTOGRAM option. When the HISTOGRAM option is not used, these statistics are not overlaid in the catalog.


Db2 Runstats Utility – Histogram Stats

```
SELECT CHAR(NAME,18) AS NAME,
       CHAR(STRIP(LOWVALUE,B),10) AS LOW,
       CHAR(STRIP(HIGHVALUE,B),18) AS HI,
       CAST (FREQUENCYF * 100 AS DECIMAL(5,2))
                               AS PCT_IN_RANGE
 FROM SYSIBM.SYSCOLDIST
 WHERE TBNAME = 'EMP'
   AND TBOWNER = 'THEMIS82'
   AND TYPE = 'H'
 ORDER BY NAME, LOW
```

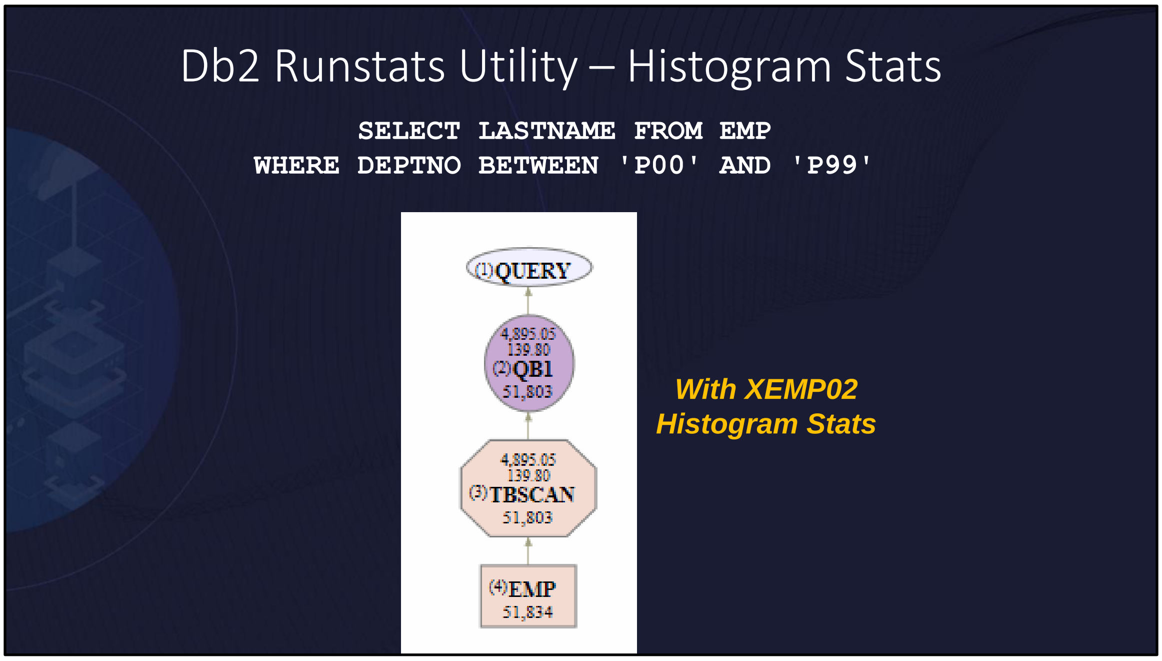
Histogram statistics are stored in SYSIBM.SYSCOLDIST with a TYPE code of “H”. This query may be used to view and analyze histogram statistics for a particular column. The frequency values are stored as floating point decimals, so this query converts them to decimals for ease of viewing.



Db2 Runstats Utility – Histogram Stats

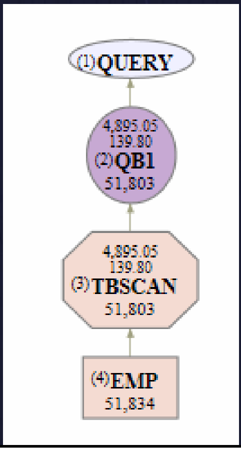
NAME	LOW	HI	PCT_IN_RANGE
DEPTNO	A00	E21	0.05
DEPTNO	P01	P04	3.96
DEPTNO	P05	P08	2.98
DEPTNO	P08	P12	3.76
DEPTNO	P12	P16	3.45
DEPTNO	P16	P20	3.35
DEPTNO	P20	P24	3.44
DEPTNO	P24	P29	3.73
DEPTNO	P30	P35	5.28
DEPTNO	P35	P39	3.11
DEPTNO	P39	P43	3.78
DEPTNO	P43	P50	5.46
DEPTNO	P50	P54	3.83
DEPTNO	P54	P59	3.56
DEPTNO	P59	P62	2.67
DEPTNO	P62	P66	3.49
DEPTNO	P66	P70	3.46
DEPTNO	P70	P74	3.80
DEPTNO	P74	P80	5.45
DEPTNO	P80	P84	3.39
DEPTNO	P84	P90	4.99
DEPTNO	P90	P94	3.82
DEPTNO	P94	P98	3.66
DEPTNO	P98	P99	1.06

Here are the results of the SYSCOLDIST query. Note that the data is not evenly distributed across the potential values.



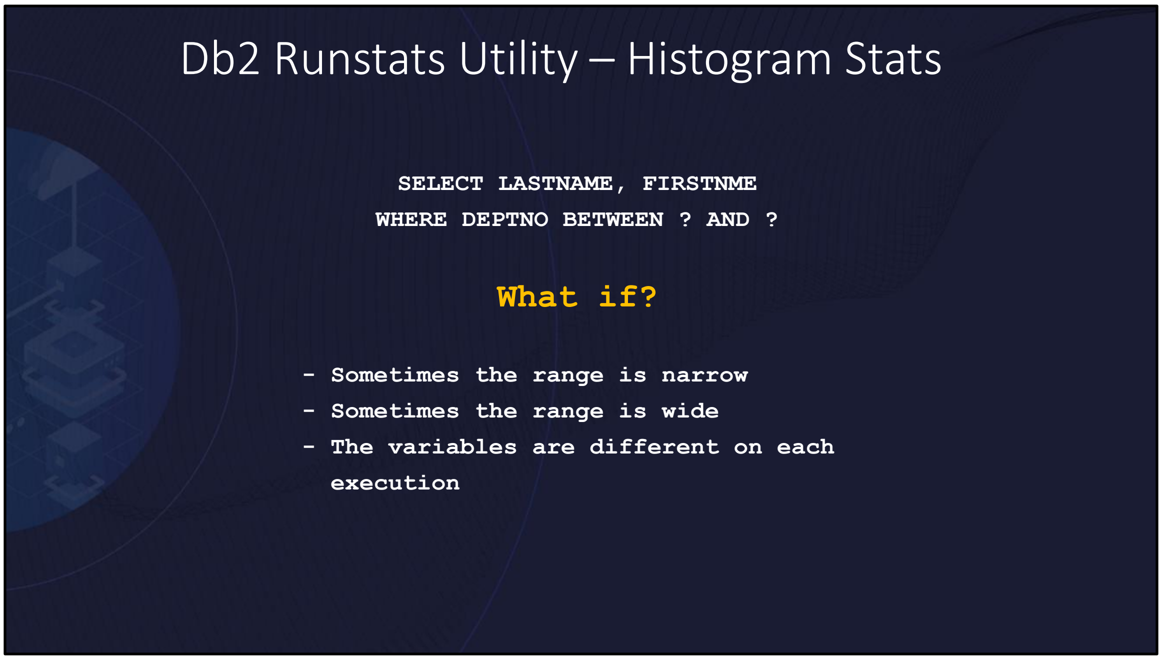
Db2 Runstats Utility – Histogram Stats

```
SELECT LASTNAME FROM EMP
WHERE DEPTNO BETWEEN 'P00' AND 'P99'
```



With XEMP02 Histogram Stats

Queries that use range predicates (<, >, BETWEEN, LIKE) are most likely to take advantage of available histogram statistics. This example shows a query retrieving all employees for departments less than or equal to “M99”. The access path graphs from Optimization Service Center reflect the access path before and after the addition of histogram statistics on the DEPTNO column. Without the histogram statistics, the optimizer only knows the LOW2KEY and HI2KEY of the column and uses an interpolation formula to estimate the number of records that will be returned. This estimate is 5,699 rows out of 51,834 rows on the table and the resulting access path is index access with list prefetch. With the addition of histogram statistics on the DEPTNO column, the optimizer knows that the data is skewed; in this case, most employees work in a department that begins with “P” (see previous page for actual statistics). The estimate of rows is reduced to 51,802 which is much closer to reality. The access path that is chosen when this information is known is a tablespace scan.



Db2 Runstats Utility – Histogram Stats

```
SELECT LASTNAME, FIRSTNME
WHERE DEPTNO BETWEEN ? AND ?
```

What if?

- Sometimes the range is narrow
- Sometimes the range is wide
- The variables are different on each execution

Actual count = 51,802 rows. The optimizer does not have specific information on ranges of values. Need to write the code as
dynamic SQL or use a REOPT option.

JAVA Dynamic example:

```
// Variables to hold the deptno values
String v1 = null;
String v2 = null;

// calls to methods (not shown) that deliver input values
v1 = getInput1();  // e.g. receives D01
v2 = getInput2();  // e.g. receives D11

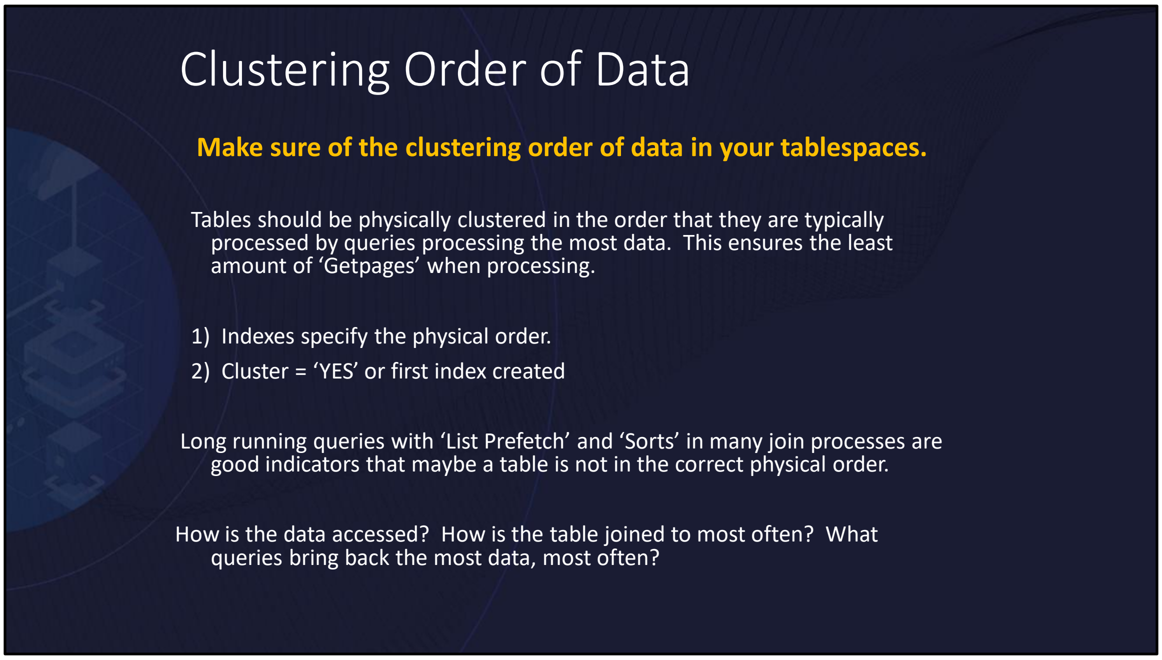
// NOTE: single quotes embedded around each of the two deptno values
String sql = "SELECT LASTNAME, FIRSTNME, HIREDATE FROM EMP "
        + "WHERE DEPTNO BETWEEN '" + v1 + "' AND '" + v2 + "'";

// conn is the Connection to Db2 assumed to have been made already
// Statement is the vehicle for passing SQL to Db2 and getting back results
Statement stmt = conn.createStatement();

// The sql statement is passed to Db2 in this Java statement
// Since a SELECT statement is passed, a ResultSet is returned
ResultSet rs = stmt.executeQuery(sql);

// This method would process row by row and field by field (not shown)
```

```
processResults(rs);
```



Clustering Order of Data

Make sure of the clustering order of data in your tablespaces.

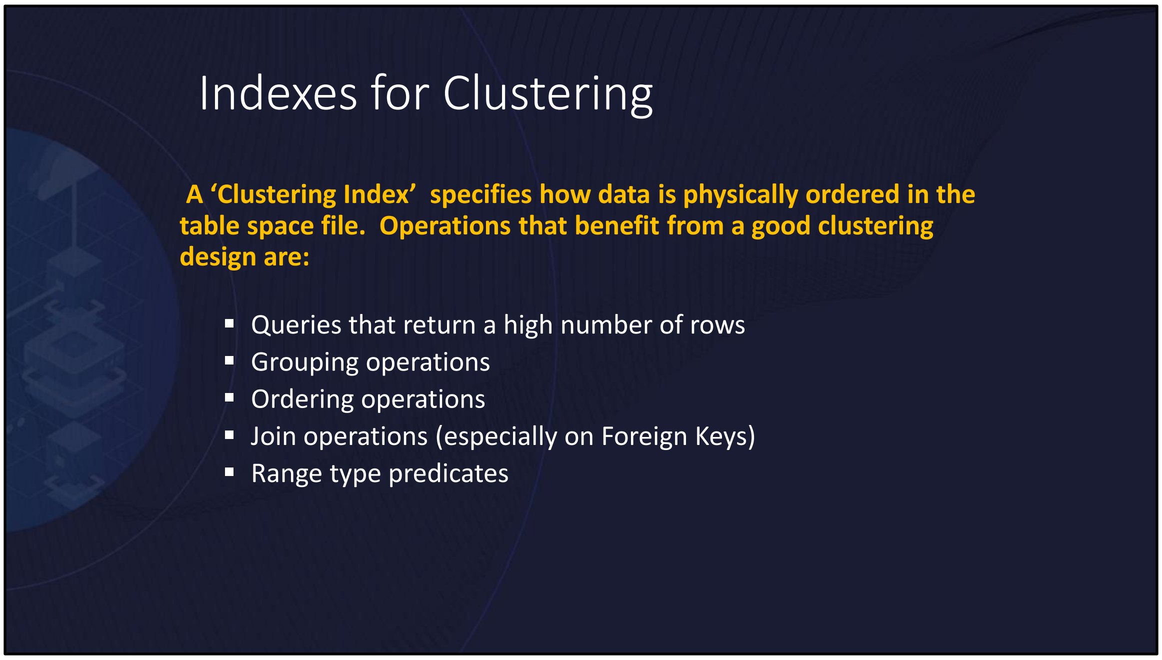
Tables should be physically clustered in the order that they are typically processed by queries processing the most data. This ensures the least amount of 'Getpages' when processing.

1) Indexes specify the physical order.
2) Cluster = 'YES' or first index created

Long running queries with 'List Prefetch' and 'Sorts' in many join processes are good indicators that maybe a table is not in the correct physical order.

How is the data accessed? How is the table joined to most often? What queries bring back the most data, most often?

Getting the correct physical clustering can save sorts, and I/Os.



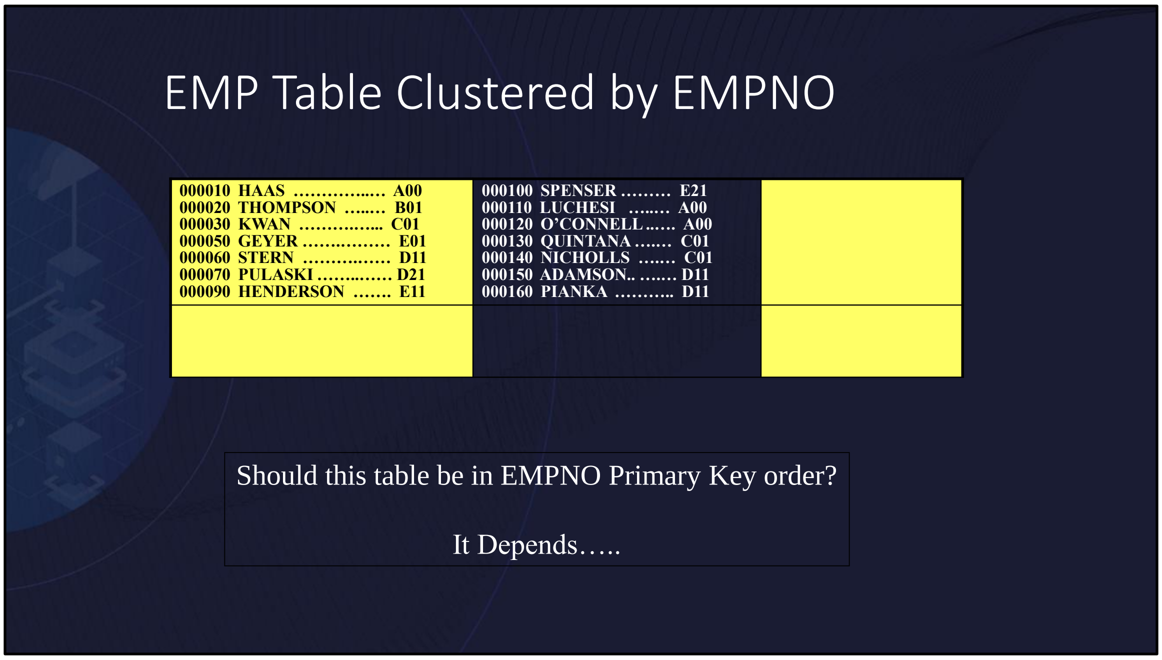
Indexes for Clustering

A 'Clustering Index' specifies how data is physically ordered in the table space file. Operations that benefit from a good clustering design are:

- Queries that return a high number of rows
- Grouping operations
- Ordering operations
- Join operations (especially on Foreign Keys)
- Range type predicates

The way the data is clustered in a table space should be specific to the queries that process through and/or return many rows of data. ra I/O to the index files. The more indexes, the longer REORG utility processes takes.

Know you data, and know your processing.



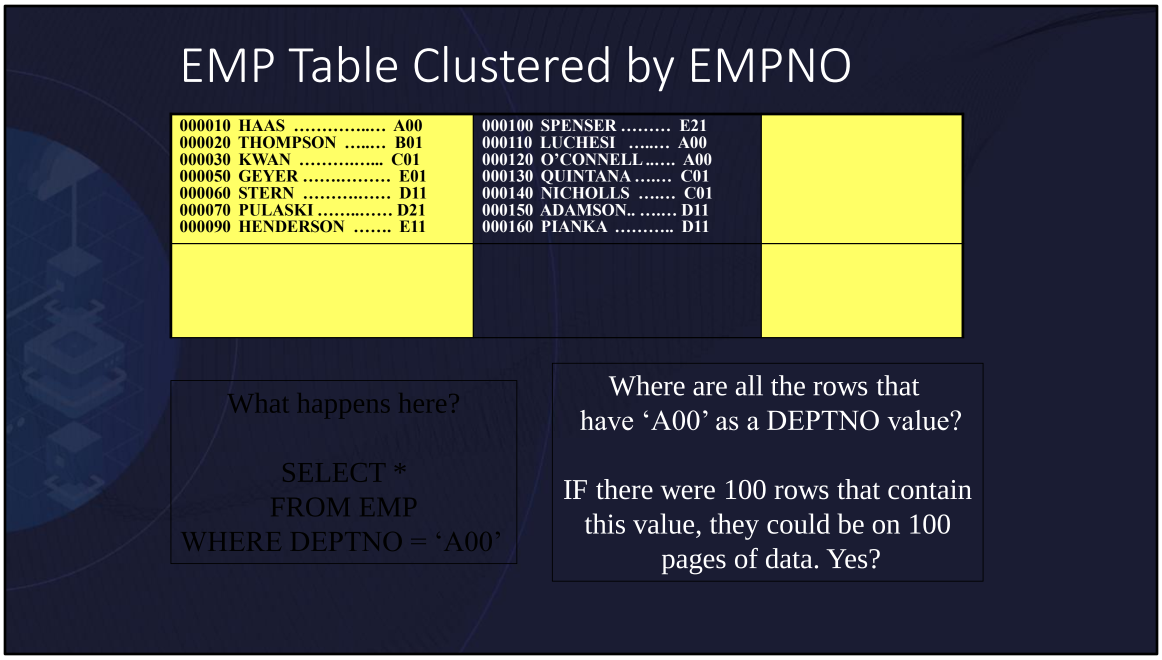
EMP Table Clustered by EMPNO

000010 HAAS ……………..… A00 000020 THOMPSON ….…. B01 000030 KWAN …………..… C01 000050 GEYER ……….……. E01 000060 STERN ………..……. D11 000070 PULASKI ……..…… D21 000090 HENDERSON ……. E11	000100 SPENSER ……… E21 000110 LUCHESI ….…. A00 000120 O'CONNELL…… A00 000130 QUINTANA ……. C01 000140 NICHOLLS ……. C01 000150 ADAMSON.. ……. D11 000160 PIANKA ……….. D11	

Should this table be in EMPNO Primary Key order?

It Depends…..

This is an example of the EMP table being in EMPNO primary key order.



EMP Table Clustered by EMPNO

000010 HAAS A00
000020 THOMPSON B01
000030 KWAN C01
000050 GEYER E01
000060 STERN D11
000070 PULASKI D21
000090 HENDERSON E11

000100 SPENSER E21
000110 LUCHESI A00
000120 O'CONNELL A00
000130 QUINTANA C01
000140 NICHOLLS C01
000150 ADAMSON.. .... D11
000160 PIANKA D11

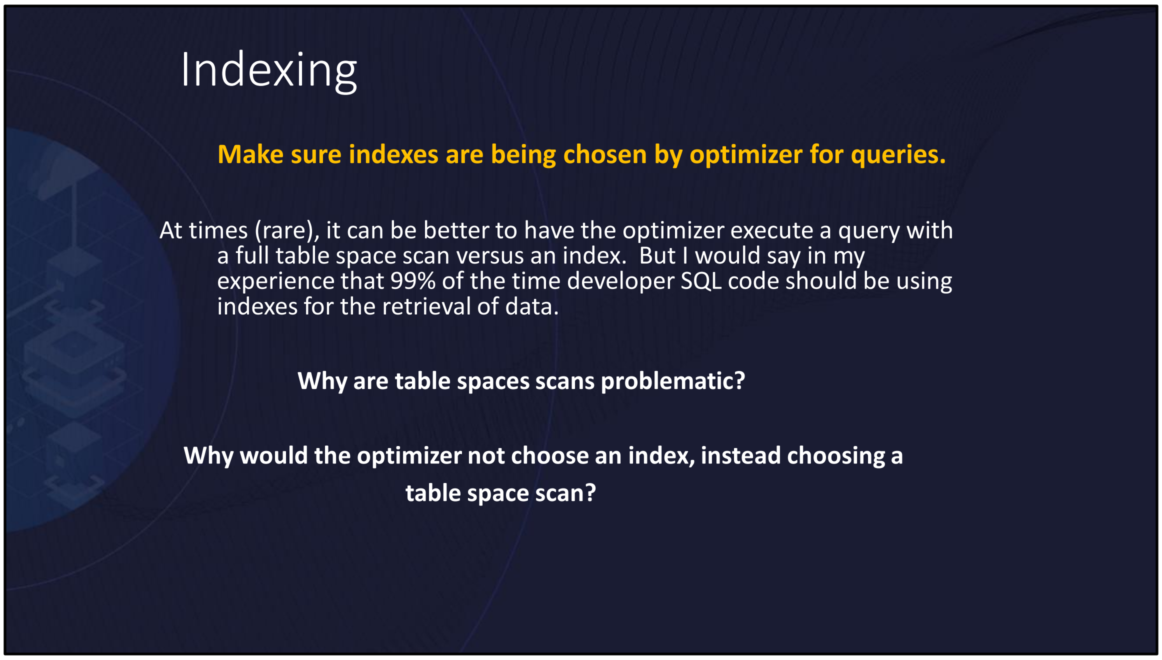
What happens here?

SELECT *
FROM EMP
WHERE DEPTNO = 'A00'

Where are all the rows that have 'A00' as a DEPTNO value?

IF there were 100 rows that contain this value, they could be on 100 pages of data. Yes?

With the table being in EMPNO order, any queries on DEPTNO, or any joins by DEPTNO will cause many getpages due to the DEPTNOs being scattered across the file.



Indexing

Make sure indexes are being chosen by optimizer for queries.

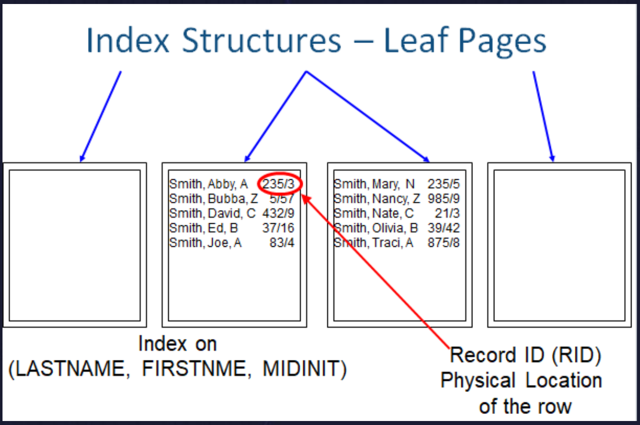
At times (rare), it can be better to have the optimizer execute a query with a full table space scan versus an index. But I would say in my experience that 99% of the time developer SQL code should be using indexes for the retrieval of data.

Why are table spaces scans problematic?

Why would the optimizer not choose an index, instead choosing a table space scan?

Getting the correct physical clustering can save sorts, and I/Os. A very small percentage of queries should be doing table scans, so it is important for developers to make sure their queries are using indexes, or understand why the optimizer chose a table scan.

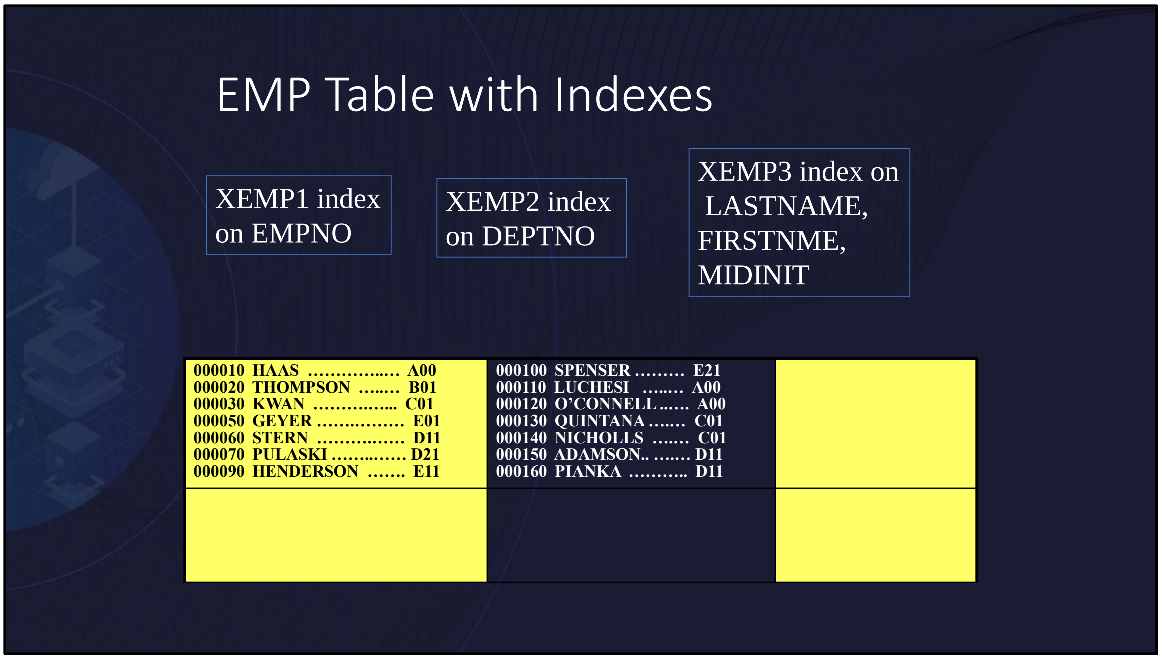
Why Too Many Indexes Cause Problems



Indexes contain some of the same data as what is in each row of data. For example:

If there exists an index of 3 columns (LASTNAME, FIRSTNME, MIDINIT), then these columns also exists in data rows.

For every Insert and Delete SQL statement executed, this ondex needs to be inserted into or deleted from also.
important for developers to make sure their queries are using indexes, or understand why the optimizer chose a table scan.



EMP Table with Indexes

XEMP1 index on EMPNO

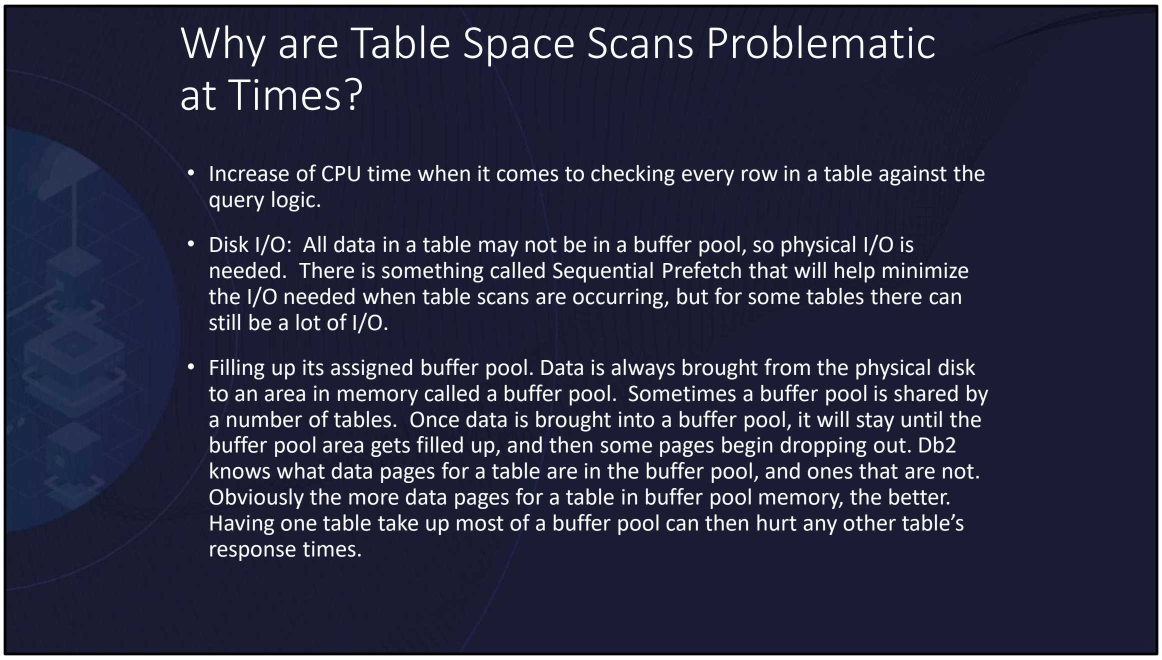
XEMP2 index on DEPTNO

XEMP3 index on LASTNAME, FIRSTNME, MIDINIT

```
000010  HAAS ……………..  A00        000100  SPENSER ………  E21
000020  THOMPSON ……..  B01        000110  LUCHESI  ……..  A00
000030  KWAN ……………..  C01        000120  O'CONNELL ……  A00
000050  GEYER ……………  E01        000130  QUINTANA …….  C01
000060  STERN ……………  D11        000140  NICHOLLS …….  C01
000070  PULASKI ………….  D21        000150  ADAMSON.. …….  D11
000090  HENDERSON …….  E11        000160  PIANKA ………..  D11
```

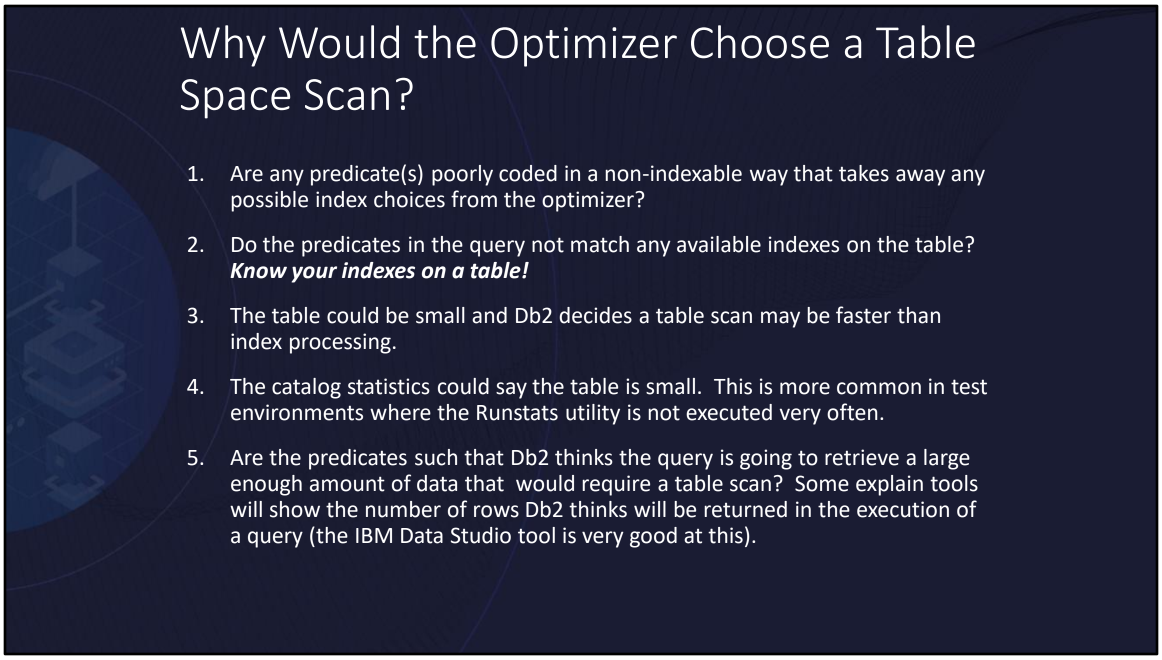
The more indexes the more physical I/O occurs for every insert and delete statement. In this example with the EMP table having 3 indexes, if a row is deleted its information must be deleted from each index also. Reverse happens on an insert. When an insert occurs, the new EMPNO needs added to the XEMP1 index file, the DEPTNO needs added to the XEMP2 index file, and same for the new employee's name to the XEMP3 index file. So that makes for 4 physical files affected for every insert and delete statement.

If an SQL update occurs for a column and that column is part of an index, then that index needs modified also. For indexes that is a delete followed by an insert to the index file.



Why are Table Space Scans Problematic at Times?

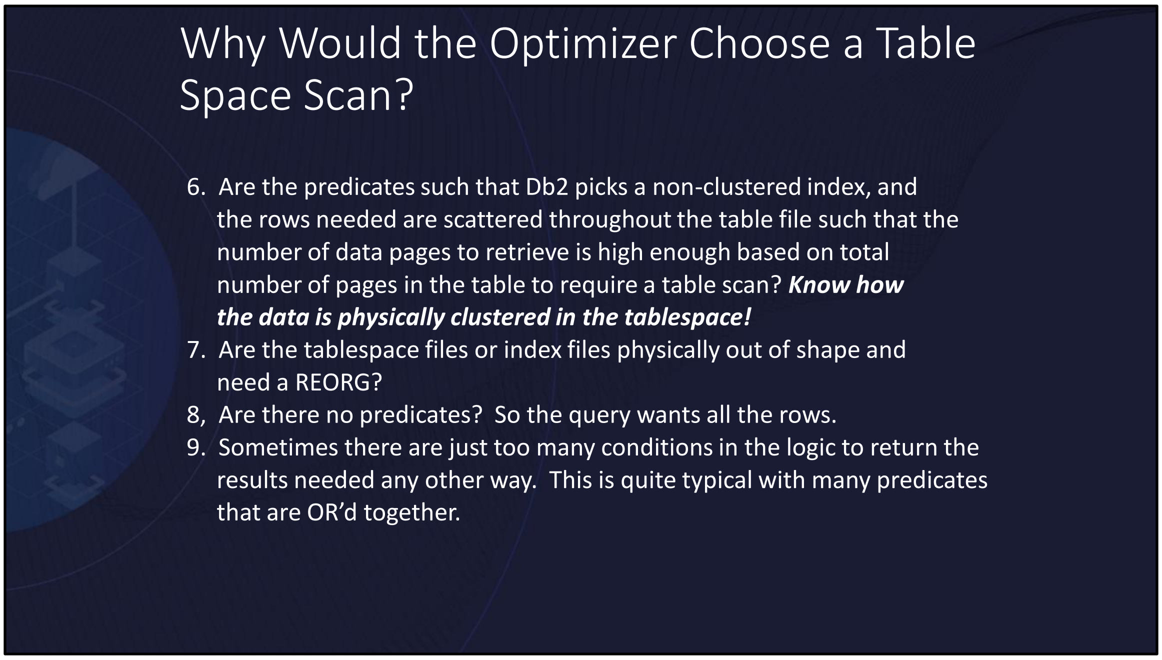
- Increase of CPU time when it comes to checking every row in a table against the query logic.
- Disk I/O: All data in a table may not be in a buffer pool, so physical I/O is needed. There is something called Sequential Prefetch that will help minimize the I/O needed when table scans are occurring, but for some tables there can still be a lot of I/O.
- Filling up its assigned buffer pool. Data is always brought from the physical disk to an area in memory called a buffer pool. Sometimes a buffer pool is shared by a number of tables. Once data is brought into a buffer pool, it will stay until the buffer pool area gets filled up, and then some pages begin dropping out. Db2 knows what data pages for a table are in the buffer pool, and ones that are not. Obviously the more data pages for a table in buffer pool memory, the better. Having one table take up most of a buffer pool can then hurt any other table's response times.



Why Would the Optimizer Choose a Table Space Scan?

1. Are any predicate(s) poorly coded in a non-indexable way that takes away any possible index choices from the optimizer?
2. Do the predicates in the query not match any available indexes on the table? ***Know your indexes on a table!***
3. The table could be small and Db2 decides a table scan may be faster than index processing.
4. The catalog statistics could say the table is small. This is more common in test environments where the Runstats utility is not executed very often.
5. Are the predicates such that Db2 thinks the query is going to retrieve a large enough amount of data that would require a table scan? Some explain tools will show the number of rows Db2 thinks will be returned in the execution of a query (the IBM Data Studio tool is very good at this).

Developers should:
- Know their data (cardinalities, columns with uneven distributions of data, etc.)
- Know the indexes on tables involved in their queries
- Know the clustering order of data in their tables
- Know the partitioning of data in their tables



Why Would the Optimizer Choose a Table Space Scan?

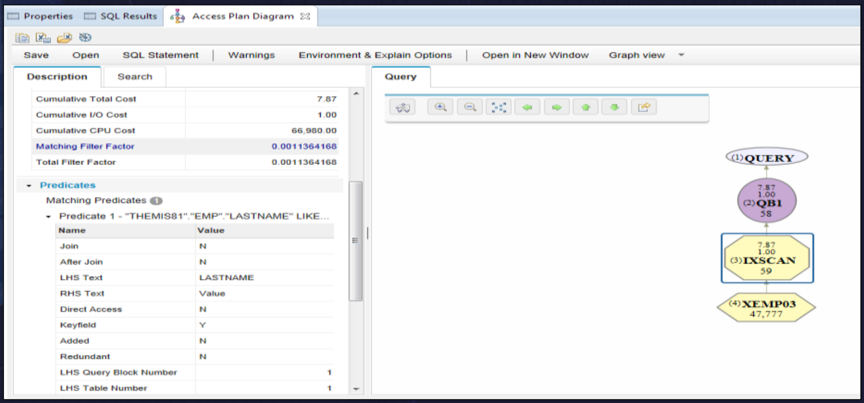
6. Are the predicates such that Db2 picks a non-clustered index, and the rows needed are scattered throughout the table file such that the number of data pages to retrieve is high enough based on total number of pages in the table to require a table scan? ***Know how the data is physically clustered in the tablespace!***
7. Are the tablespace files or index files physically out of shape and need a REORG?

8, Are there no predicates? So the query wants all the rows.

9. Sometimes there are just too many conditions in the logic to return the results needed any other way. This is quite typical with many predicates that are OR'd together.

Index Only Access V4

SELECT LASTNAME, FIRSTNME, MIDINIT
FROM EMP
WHERE LASTNAME LIKE 'Jo%'



Cumulative Total Cost	7.87
Cumulative I/O Cost	1.00
Cumulative CPU Cost	66,980.00
Matching Filter Factor	0.0011364168
Total Filter Factor	0.0011364168

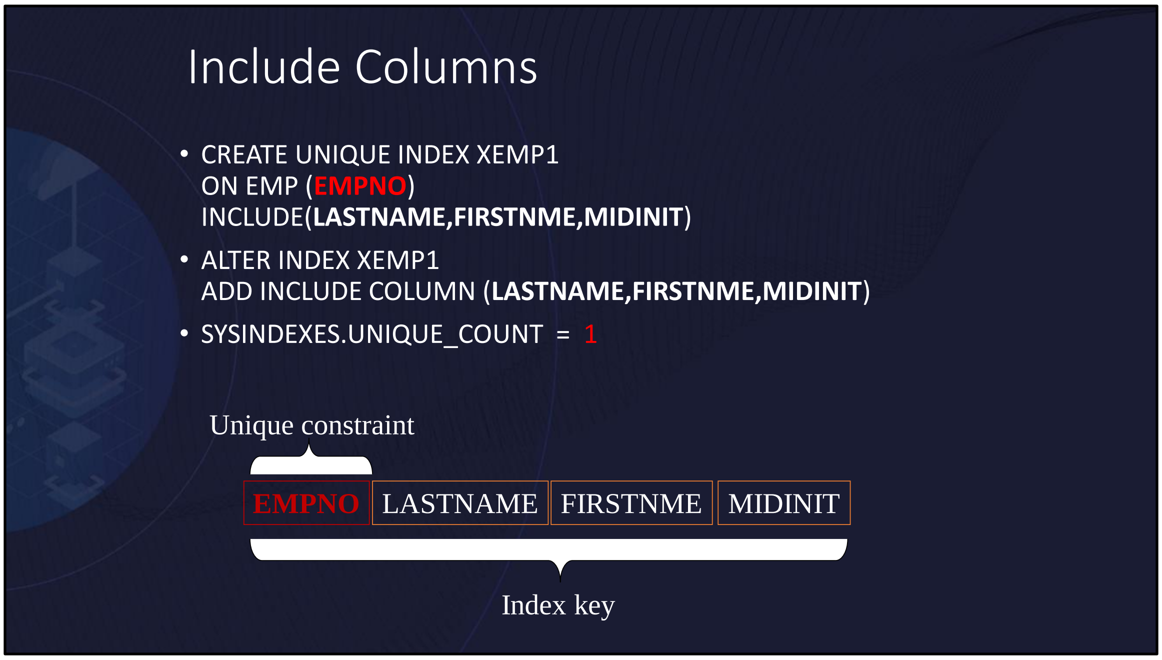
Predicates

Matching Predicates 1

Predicate 1 - "THEMIS81"."EMP"."LASTNAME" LIKE...

Name	Value
Join	N
After Join	N
LHS Text	LASTNAME
RHS Text	Value
Direct Access	N
Keyfield	Y
Added	N
Redundant	N
LHS Query Block Number	1
LHS Table Number	1

V4: Provides same information. Click on the IXSCAN node. Then open up the information of the left.



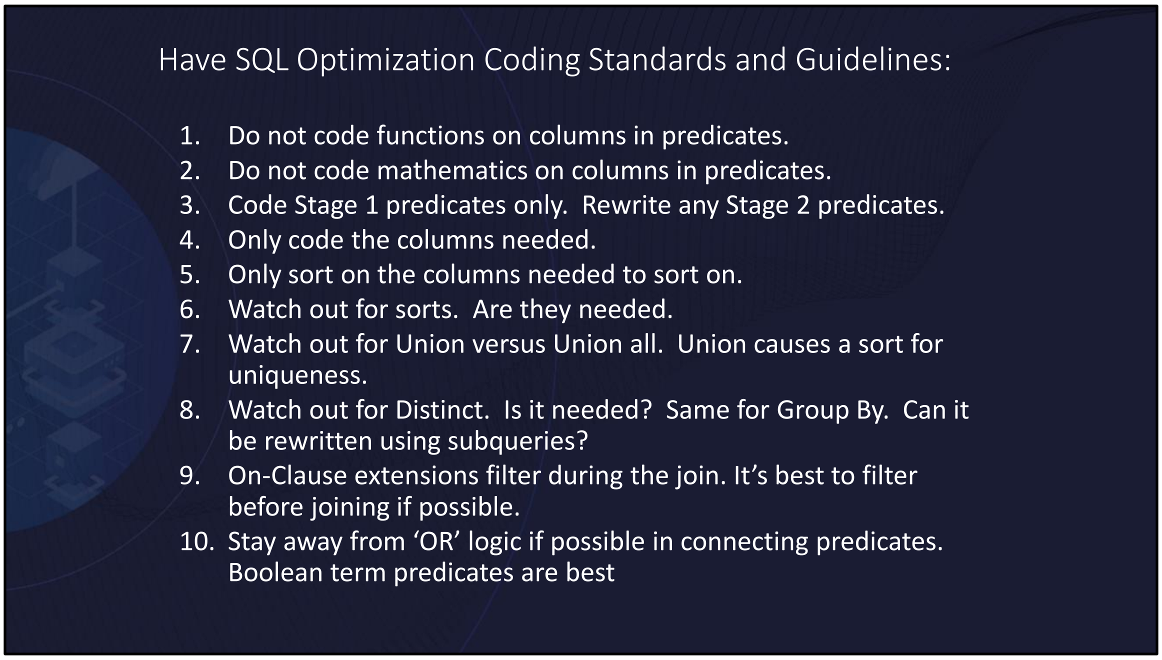
Include Columns

- CREATE UNIQUE INDEX XEMP1
  ON EMP (EMPNO)
  INCLUDE(**LASTNAME,FIRSTNME,MIDINIT**)
- ALTER INDEX XEMP1
  ADD INCLUDE COLUMN (**LASTNAME,FIRSTNME,MIDINIT**)
- SYSINDEXES.UNIQUE_COUNT = 1

Unique constraint
EMPNO
LASTNAME
FIRSTNME
MIDINIT
Index key

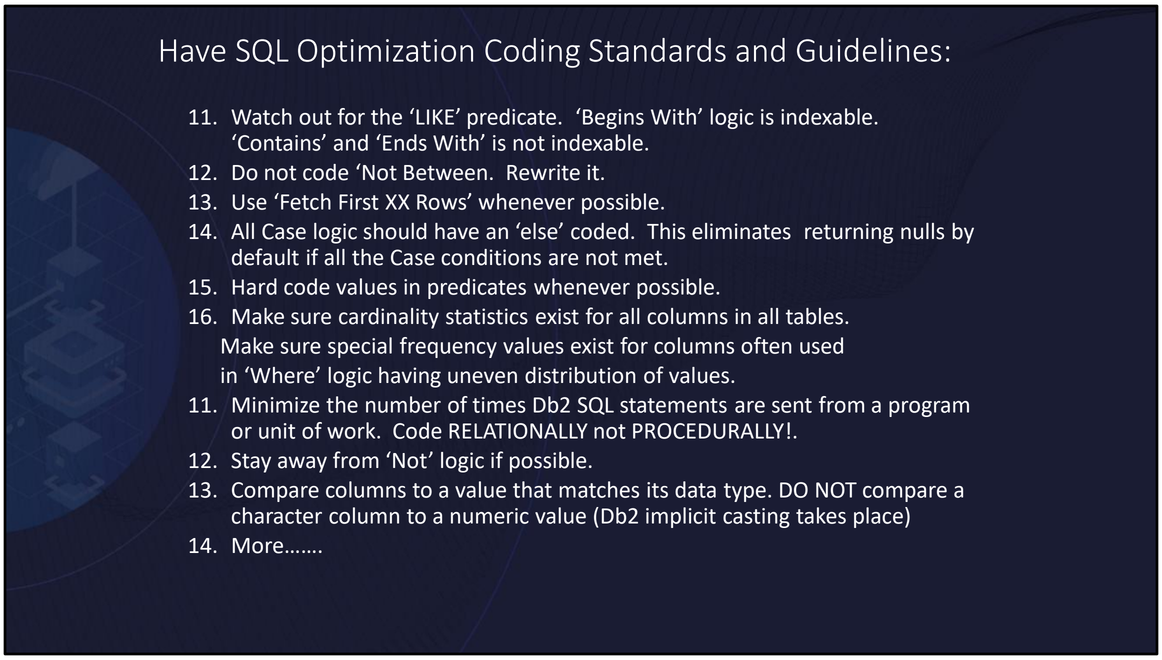
Julie, New Slide
H4 Include Columns
The SYSINDEXES catalog table column UNIQUE_COUNT keeps track of the number of columns that make up the unique constraint.

Including additional columns can promote index only access path, however be aware of the additional overhead of maintaining the index.



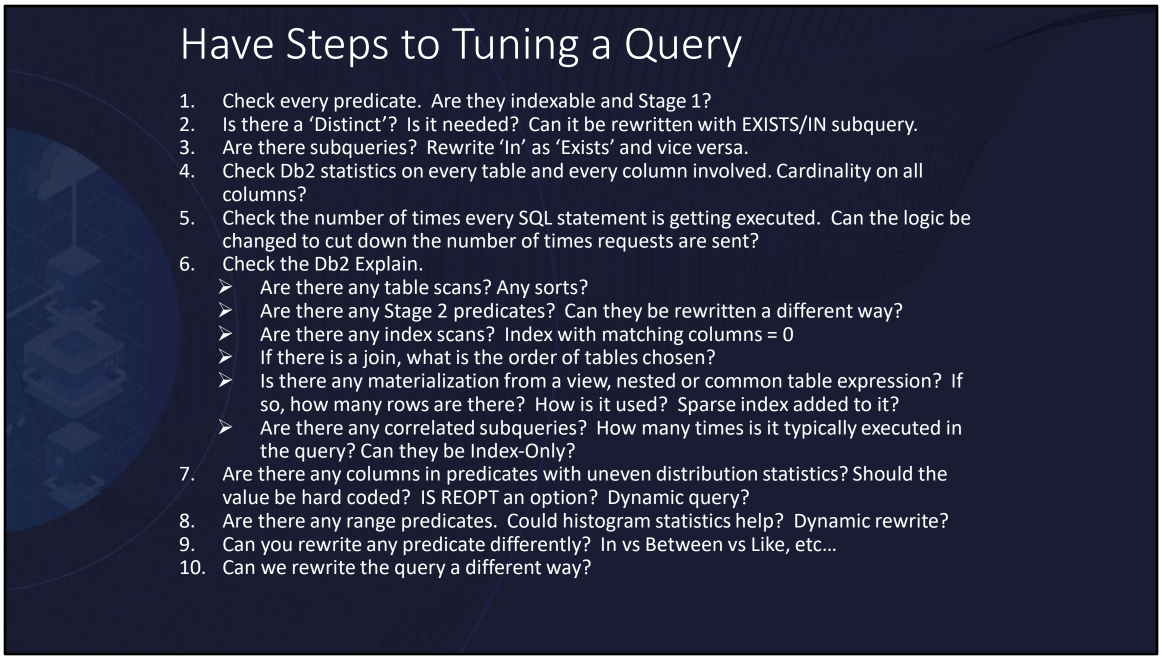
Have SQL Optimization Coding Standards and Guidelines:

1. Do not code functions on columns in predicates.
2. Do not code mathematics on columns in predicates.
3. Code Stage 1 predicates only. Rewrite any Stage 2 predicates.
4. Only code the columns needed.
5. Only sort on the columns needed to sort on.
6. Watch out for sorts. Are they needed.
7. Watch out for Union versus Union all. Union causes a sort for uniqueness.
8. Watch out for Distinct. Is it needed? Same for Group By. Can it be rewritten using subqueries?
9. On-Clause extensions filter during the join. It’s best to filter before joining if possible.
10. Stay away from ‘OR’ logic if possible in connecting predicates. Boolean term predicates are best



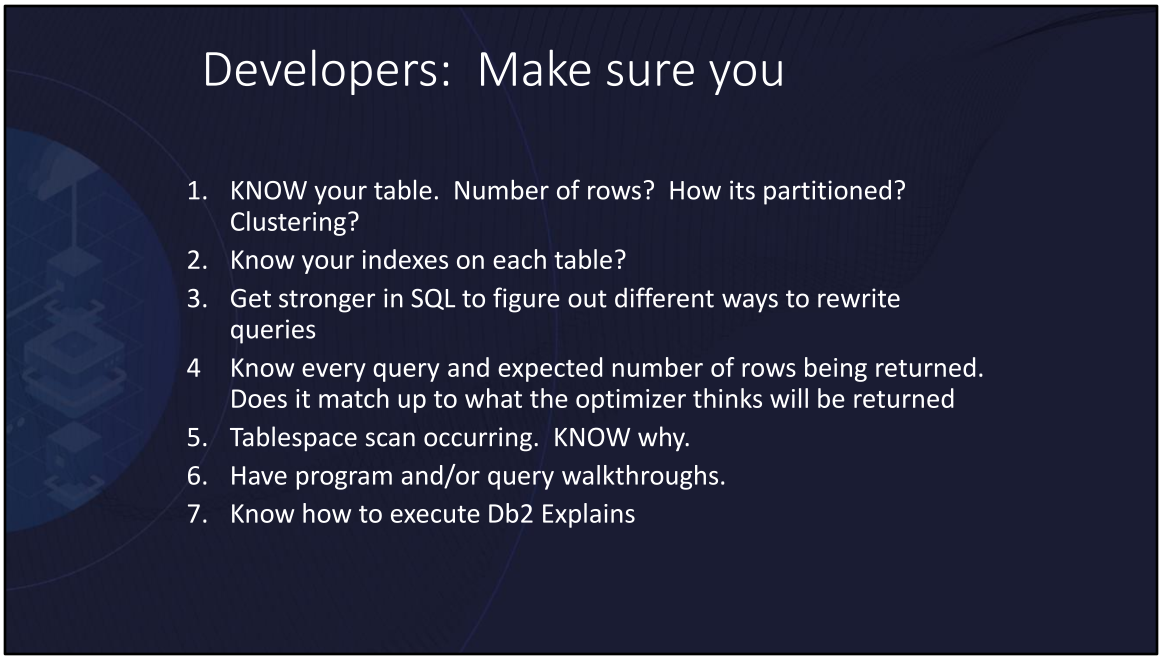
Have SQL Optimization Coding Standards and Guidelines:

11. Watch out for the ‘LIKE’ predicate. ‘Begins With’ logic is indexable. ‘Contains’ and ‘Ends With’ is not indexable.
12. Do not code ‘Not Between. Rewrite it.
13. Use ‘Fetch First XX Rows’ whenever possible.
14. All Case logic should have an ‘else’ coded. This eliminates returning nulls by default if all the Case conditions are not met.
15. Hard code values in predicates whenever possible.
16. Make sure cardinality statistics exist for all columns in all tables.
    Make sure special frequency values exist for columns often used in ‘Where’ logic having uneven distribution of values.
11. Minimize the number of times Db2 SQL statements are sent from a program or unit of work. Code RELATIONALLY not PROCEDURALLY!.
12. Stay away from ‘Not’ logic if possible.
13. Compare columns to a value that matches its data type. DO NOT compare a character column to a numeric value (Db2 implicit casting takes place)
14. More…….



Have Steps to Tuning a Query

1. Check every predicate. Are they indexable and Stage 1?
2. Is there a 'Distinct'? Is it needed? Can it be rewritten with EXISTS/IN subquery.
3. Are there subqueries? Rewrite 'In' as 'Exists' and vice versa.
4. Check Db2 statistics on every table and every column involved. Cardinality on all columns?
5. Check the number of times every SQL statement is getting executed. Can the logic be changed to cut down the number of times requests are sent?
6. Check the Db2 Explain.
   - Are there any table scans? Any sorts?
   - Are there any Stage 2 predicates? Can they be rewritten a different way?
   - Are there any index scans? Index with matching columns = 0
   - If there is a join, what is the order of tables chosen?
   - Is there any materialization from a view, nested or common table expression? If so, how many rows are there? How is it used? Sparse index added to it?
   - Are there any correlated subqueries? How many times is it typically executed in the query? Can they be Index-Only?
7. Are there any columns in predicates with uneven distribution statistics? Should the value be hard coded? IS REOPT an option? Dynamic query?
8. Are there any range predicates. Could histogram statistics help? Dynamic rewrite?
9. Can you rewrite any predicate differently? In vs Between vs Like, etc…
10. Can we rewrite the query a different way?



Developers: Make sure you

1. KNOW your table. Number of rows? How its partitioned? Clustering?
2. Know your indexes on each table?
3. Get stronger in SQL to figure out different ways to rewrite queries
4 Know every query and expected number of rows being returned. Does it match up to what the optimizer thinks will be returned
5. Tablespace scan occurring. KNOW why.
6. Have program and/or query walkthroughs.
7. Know how to execute Db2 Explains

Thank you for allowing me and Themis to share some of our experience and knowledge today!

Tony Andrews
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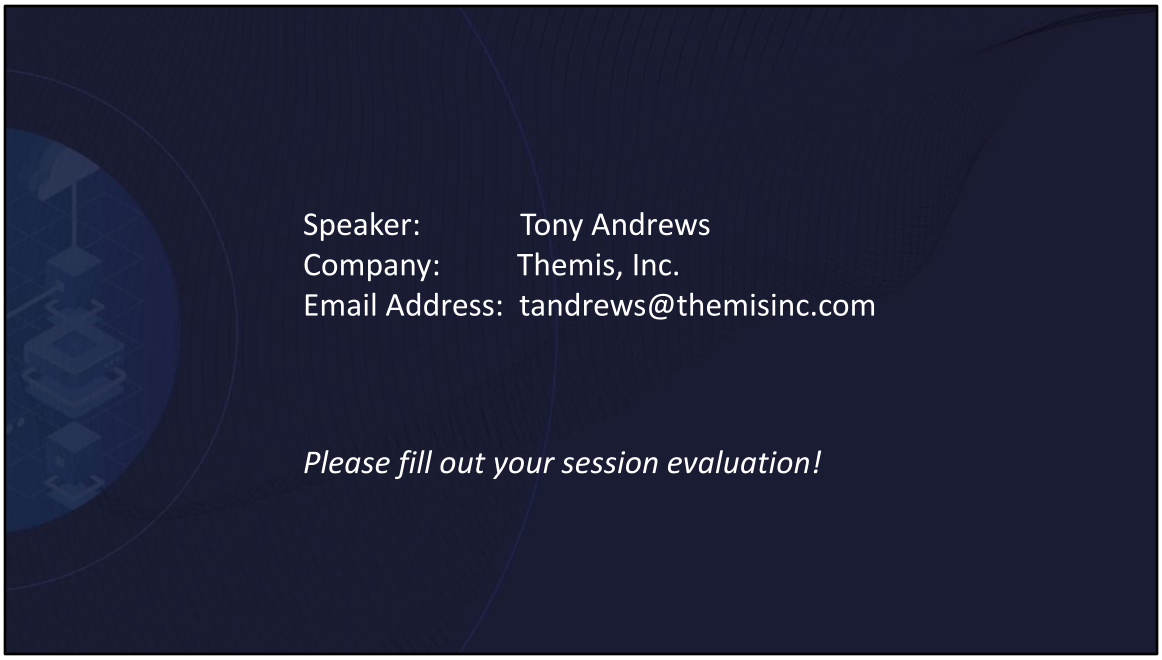
I hope that you learned something new today !!!!



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Please fill out your session evaluation!