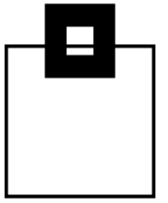
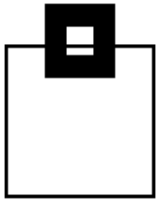


Total environment simulation
–
Workload Replay in an agile world

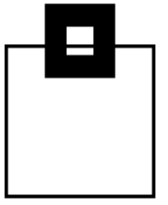
Ulf Heinrich
SEGUS Inc

Agenda



- Testing, virtualizing and simulating – the aspects of reliable quality assurance
- Db2 database/object cloning – what's state of the art and what's beyond
- XML commander – the comprehensive automation of flexibility, covering
  - FTP/routing
  - JCL
  - ISPF file tailoring, panels, messages
  - Db2 commands
- Different flavors of (pro-active) testing and how it can be automated:
  - Anomaly alerting based on Incompatibility Change Indicators (ICIs)
  - Dynamic/static access path change detection e.g. Plan Management
  - Cloning exploiting Backup System
  - Workload-KPI verification using SQL replay and KPI comparison
- Real world experience highlighting the benefits of automated testing

The aspects of reliable quality assurance



Agile development requires near-time delivery

- Continuous Delivery (CD) is an approach to produce software in short cycles
- CD ensures that changes can be released at any time, considering building, testing and releasing faster and more frequently
- Key is a focus on more incremental updates
- CD requires a straightforward and repeatable deployment

The aspects of reliable quality assurance

- If your shop can‘t accepted outages for hours/days…
  - Make sure you consider
    - Time to detect anomalies
    - Time to analyze effect and origin
    - Time to evaluate a forward and a backward strategy
    - Time to fix/recover

…. you gotta TEST, TEST, TEST

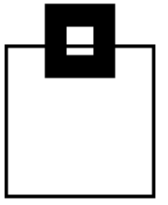
- Carefully
- Thoroughly
- Rigorously

The aspects of reliable quality assurance

Db2 comes with the right capabilities to protect your applications

- Always have IFCID 376 look for potential incompatibilities
  - Use APPLCOMPAT to minimize affected SQL from Db2 updates
- Use EXPLAIN to precheck access path changes
- Use BACKUP SYSTEM, or CONSISTENT COPY to have a consistent base for cloning
- Use efficient monitoring traces and be aware of applications being affected by changed behavior

What's required for a virtual environment



1st DDL:

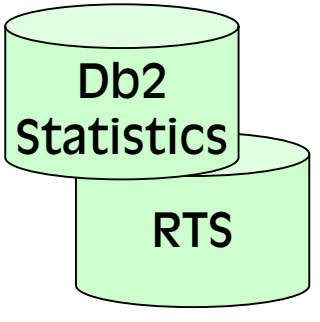
```
SELECT …
  FROM …
 WHERE …
```

- Which objects are referenced in the SQL
  - SELECT <columns> FROM <table> or <view> or …
  - WHERE <local predicates>
  - ORDER BY or GROUP BY or UNION or … <columns>
- Which objects are defined and how
  - INDEX
  - PARTITIONING

What's required for a virtual environment

2nd STATISTICS:

- SYSIBM.SYSCOLDIST
- SYSIBM.SYSCOLSTATS ˙
- SYSIBM.SYSCOLUMNS
- SYSIBM.SYSINDEXES
- SYSIBM.SYSINDEXPART
- SYSIBM.SYSKEYTARGETS (same as SYSCOLUMNS)
- SYSIBM.SYSKEYTGTDIST (same as SYSCOLDIST)
- SYSIBM.SYSROUTINES
- SYSIBM.SYSTABLES
- SYSIBM.SYSTABLESPACE
- SYSIBM.SYSTABSTATS
- SYSIBM.TABLESPACESTATS °
- SYSIBM.INDEXSPACESTATS °



- degree of parallelism only and, after APAR PK62804, also „sometimes“ used to bound filter factor estimates

° only for dynamic SQL – so far

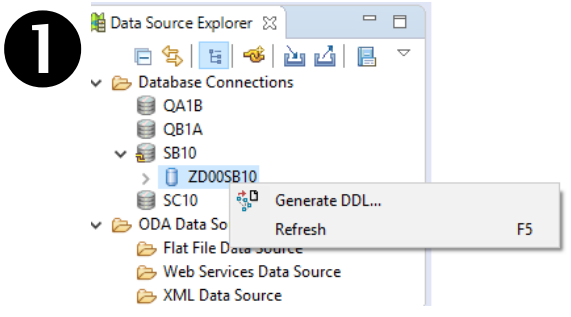
What's required for a virtual environment

- 3rd ENVIRONMENT:

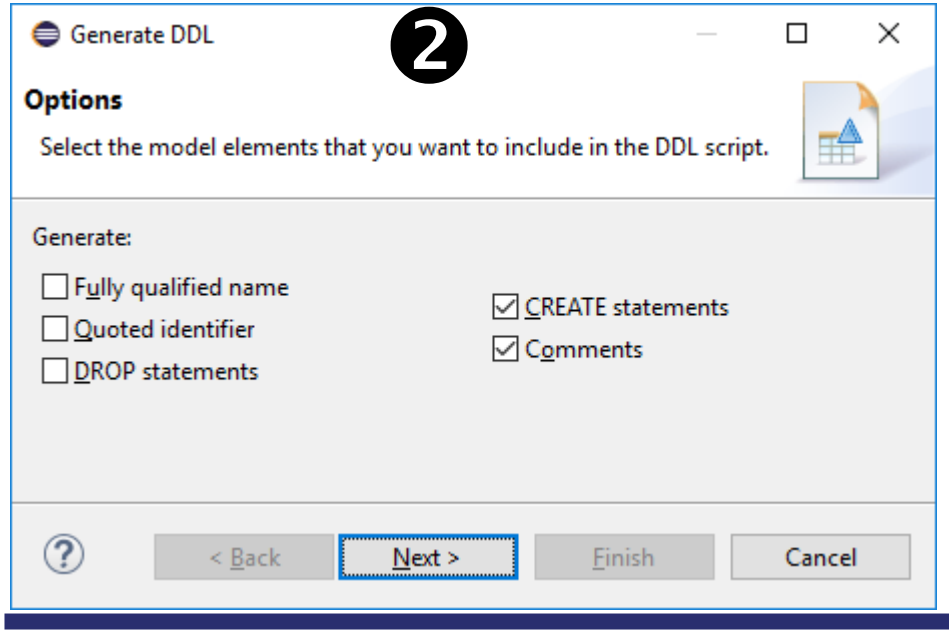
- CP speed
- # of CPs
- BPs
- RID pool
- Sort pool

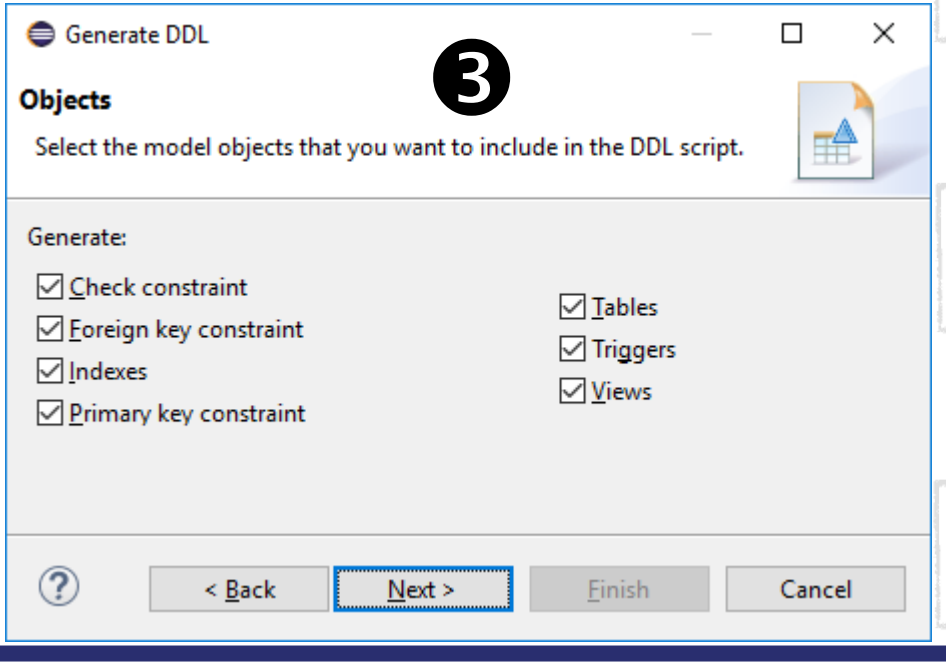
Optimizer

How to virtualize an environment – DDL




```
SELECT ...
  FROM ...
 WHERE ...
```





How to virtualize an environment – statistics

SYSCOLDIST / SYSKEYTGTDIST
CARDF
COLGROUPCOLNO / KEYGROUPKEYNO
COLVALUE / KEYVALUE
FREQUENCYF
HIGHVALUE
LOWVALUE
NUMCOLUMNS / NUMKEYS
QUANTILENO
STATSTIME

SYSCOLUMNS / SYSKEYTARGETS
COLCARDF / CARDF
HIGH2KEY
LOW2KEY
n/a / STATS_FORMAT

SYSCOLSTATS
COLCARD
HIGHKEY
LOWKEY

SYSINDEXES
CLUSTERING*
CLUSTERRATIO
CLUSTERRATIOF
DATAREPEATFACTORF
FIRSTKEYCARDF
FULLKEYCARDF
NLEAF
NLEVELS

SYSROUTINES
CARDINALITY*
INITIAL_INSTS*
INITIAL_IOS*
INSTS_PER_INVOC*
IOS_PER_INVOC*

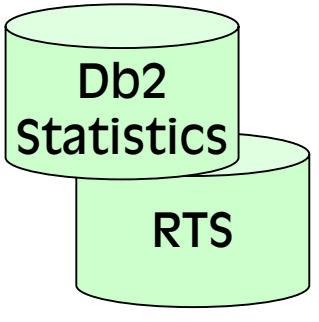
SYSTABSTATS
CARD
CARDF
NPAGES

SYSTABLESPACE
NACTIVE
NACTIVEF

SYSTABLESPACESTATS
SYSINDEXSPACESTATS
TOTALENTRIES
TOTALROWS

SYSTABLES
CARDF
EDPROC*
NPAGES
NPAGESF
PCTROWCOMP

SYSINDEXPART
LIMITKEY*

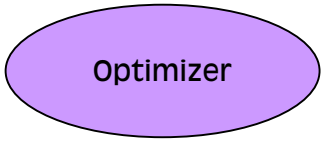


* Columns are not updated by RS
_ Columns are not updatable

How to virtualize an environment – hardware

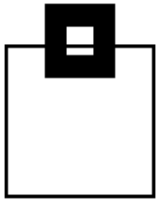
Production Modelling

- Supports optimizer overrides for optimizer relevant system settings
  - Zparms
    - SIMULATED_CPU_SPEED
    - SIMULATED_COUNT
  - SYSIBM.DSN_PROFILE_ATTRIBUTES*
    - SORT_POOL_SIZE
    - MAX_RIDBLOCKS
    - For bufferpools



*Find DDL in member DSNTIJOS of your SDSNSAMP

How to simulate changes – DDL



```
SELECT  …
  FROM  …
 WHERE  …
```

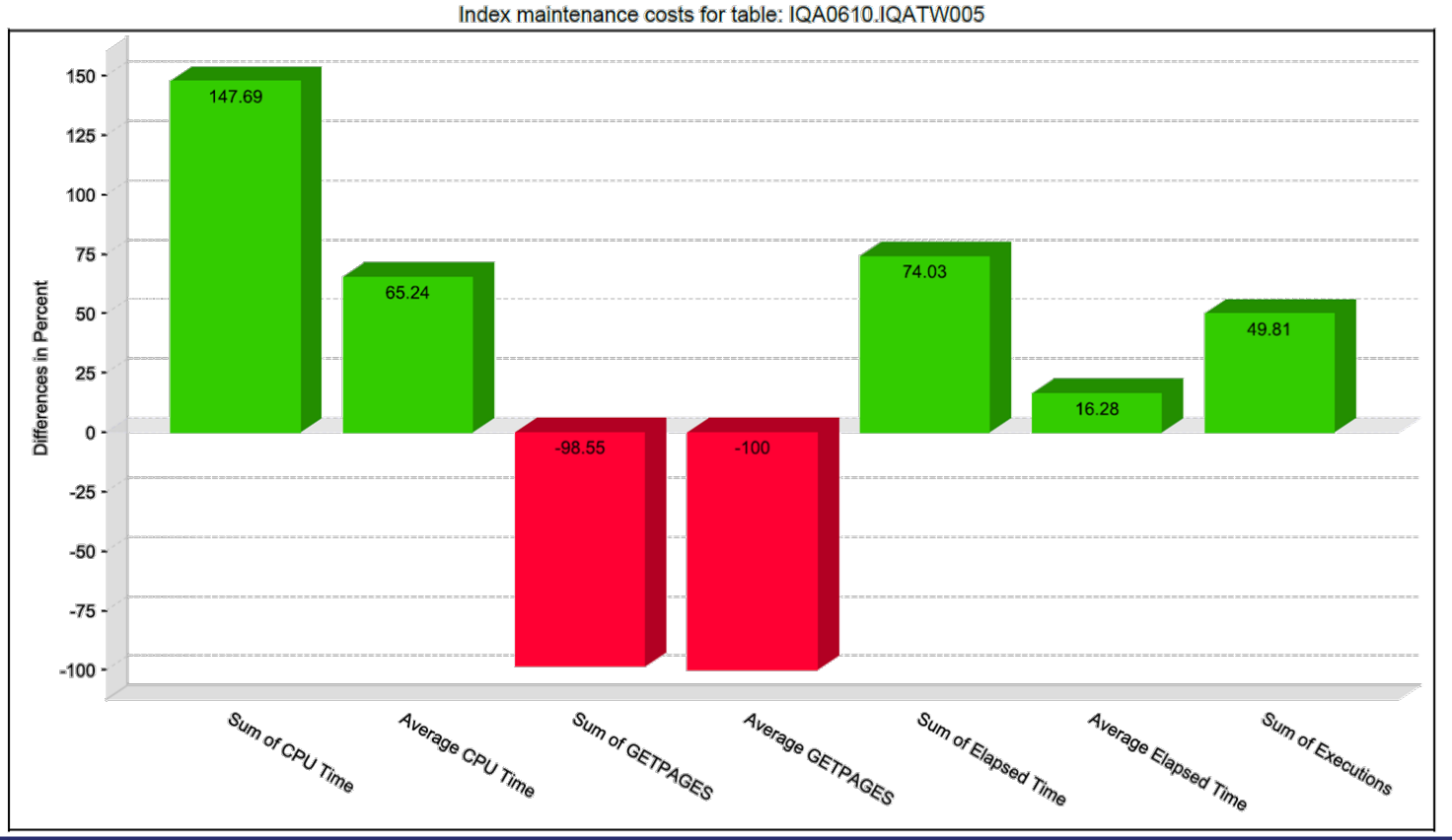
How to reliably simulate index changes:

DSN_VIRTUAL_INDEXES*	SYSINDEXES	Description
TBCREATOR	TBCREATOR	Auth. ID of owner/schema of table on which the entry is simul.
TBNAME	TBNAME	Name of the table on which the entry is being simulated
IXCREATOR	IXCREATOR	Auth. ID/schema of the owner of the index
IXNAME	IXNAME	Name of the index to simulate
ENABLE		Whether entry will be considered ('Y') or not ('N')
MODE		Whether the index is being created ('C') or dropped ('D')
UNIQUERULE	UNIQUERULE	Index is uniqueness: D for No (duplicates are allowed); U for Yes
COLCOUNT	COLCOUNT	The number of columns in the key
CLUSTERING	CLUSTERING	Whether the index is clustered ('Y' or 'N')
NLEAF	NLEAF	# of active leaf pages in the index, or -1 if unknown
NLEVELS	NLEVELS	# of levels in the index tree, or -1 if unknown
INDEXTYPE	INDEXTYPE	The index type: '2' - NPSI; 'D' – DPSI
PGSIZE	PGSIZE	Size, in bytes, of the leaf pages in the index: 4K, 8K, 16K, 32K
FIRSTKEYCARDF	FIRSTKEYCARDF	# of distinct values of the first key column, or -1 if unknown
FULLKEYCARDF	FULLKEYCARDF	# of distinct values of the key, or -1 if unknown
CLUSTERRATIOF	CLUSTERRATIONF	Clustering ratio, or -1 if unknown
PADDED	PADDED	Index keys padded for varying-length column data ('Y' or 'N')
COLNO1		Column # of the first column in the index key
ORDERING1		Ordering ('A' or 'D') of the first column in the index key
COLNOn		Column # repeated up to 64
ORDERINGn		Ordering ('A' or 'D') repeated up to 64

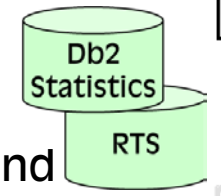
*Find DDL in member DSNTIJOS of your SDSNSAMP
! needs to have the same schema name (authid) as the PLAN_TABLE !

How to simulate changes – DDL

Comparing KPIs before and after Index creation clearly shows whether an index helps or hinders Db2.



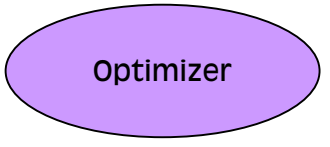
How to simulate changes – statistics



- Relationships exist among certain columns of certain tables:
  - Columns in SYSCOLUMNS, SYSCOLDIST, and SYSINDEXES
  - CARDF (SYSCOLDIST): CARDF is related to COLCARDF and FIRSTKEYCARDF and FULLKEYCARDF. It must be at minimum:
    - A value between FIRSTKEYCARDF and FULLKEYCARDF if the index contains the same set of columns
    - A value between MAX(colcardf of each col) and the product of all the columns COLCARDFs in the group
  - CARDF (SYSTABLES): CARDF must be equal or larger than any other cardinalities, such as COLCARDF, FIRSTKEYCARDF, FULLKEYCARDF, and CARDF in SYSCOLDIST
  - FREQUENCYF and COLCARDF or CARDF: The number of frequencies collected must be less than or equal to COLCARDF for the column or CARDF for the column group
  - FREQUENCYF: The sum of frequencies collected for a column or column group must be less than or equal to 1
- Refer to chapter 37 of: „Managing Performance“

How to simulate changes – hardware

- CPU simulation
  - Check a faster newer machine (Upsize)
  - Check a slower older machine (Downsize)

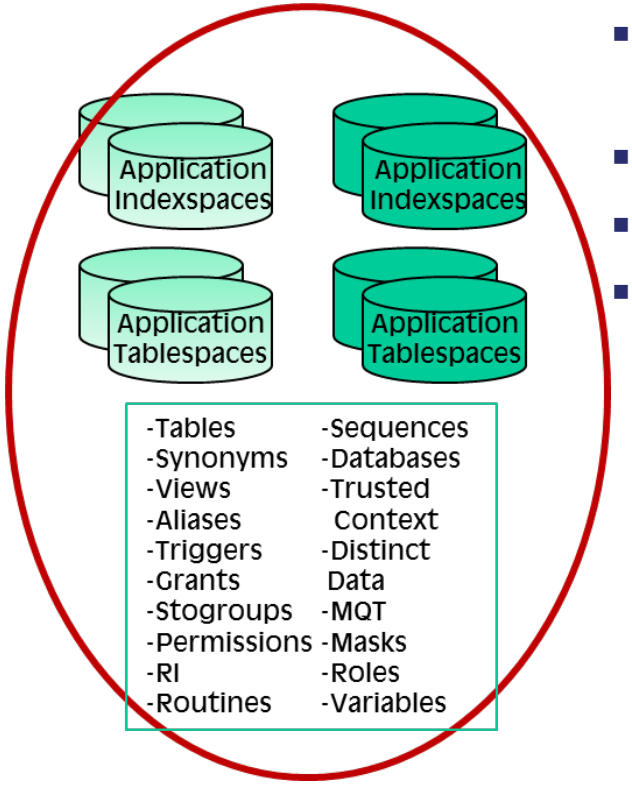


- ZPARM simulation
  - Change size of SRTPOOL
  - Change size of RID Pool
  - Change size of data cache or Star Join Pool

- BUFFERPOOL
  - Change size of any BUFFERPOOL

Db2 database/object cloning

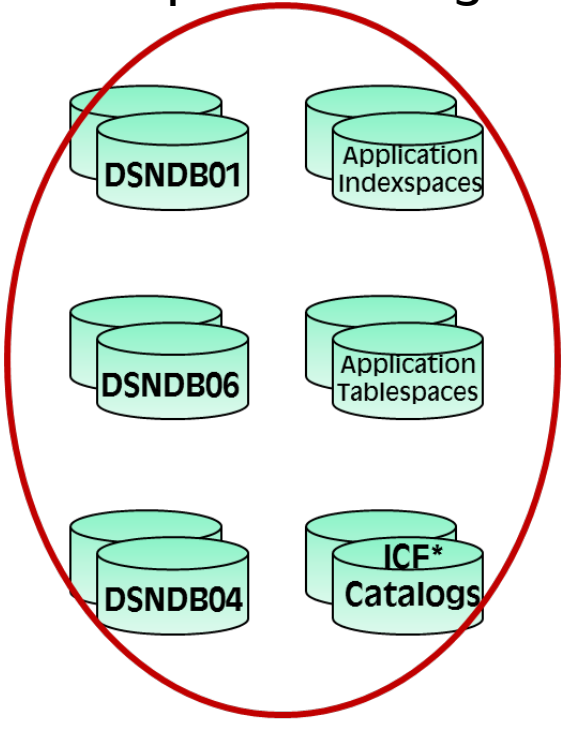
- Instant Cloning for clone based code level checks:
  - Scope of Cloning: Object level



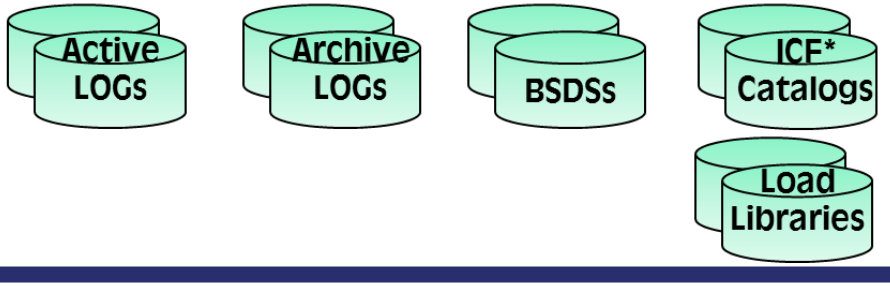
- Fully exploiting instant copy technology (e.g. Flashcopy)
- Supports DDL and/or data cloning
- Flexible include/exclude of dependent objects
- Powerful renaming capabilities

Db2 database/object cloning

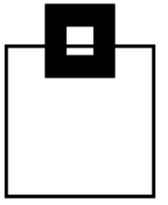
- Instant Cloning for clone based code level checks:
  - Scope of Cloning: Subsystem level



- Fully exploit instant copy technology (e.g. Flashcopy – ESS, Timefinder, Snapshot)
- DS←→NDS, as well as cross-version cloning possible
- Highly customizable and fully automated if driven by scripts, like a XML scenario scheme



Db2 database/object cloning



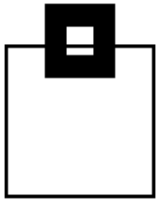
- Required Steps
  - Clone your source data
    - Dump via ADRDSSU
    - Split Mirror systems and break the mirror
    - FLASH Copy / Disk dump and then Restore
    - Any other method…
  - Stop the target system
  - Restore the source data (using the new ssid vcat)
  - Rename (if naming should be different and/or target is not isolated from source)
  - Adjust LOGs, BSDSs, DSNZPARM, DSNHDECP
  - Start target
  - Execute NEWCAT to adjust Db2 object names

Db2 database/object cloning

- XML controlled cloning
  - Due to its nature XML is a fully flexible, human- and machine-readable language
  - It may, or may not have elements and/or attributes, but has to be well-formed only
  - Since a complex cloning procedure may, or may not have individual steps, including some very customer specific tasks, XML is a perfect choice to drive a cloning scenario

```
        <name>Validate datasets</name>
        <description>Check installation specific datasets</description>
    </menuitem>
  - <menuitem>
        <name>Gather information</name>
        <description>Get all needed information</description>
    </menuitem>
  - <menuitem>
        <name>Stop DB2</name>
        <description>Stop target DB2</description>
    </menuitem>
  - <menuitem>
        <name>Restore</name>
        <description>Restore volumes</description>
    </menuitem>
```

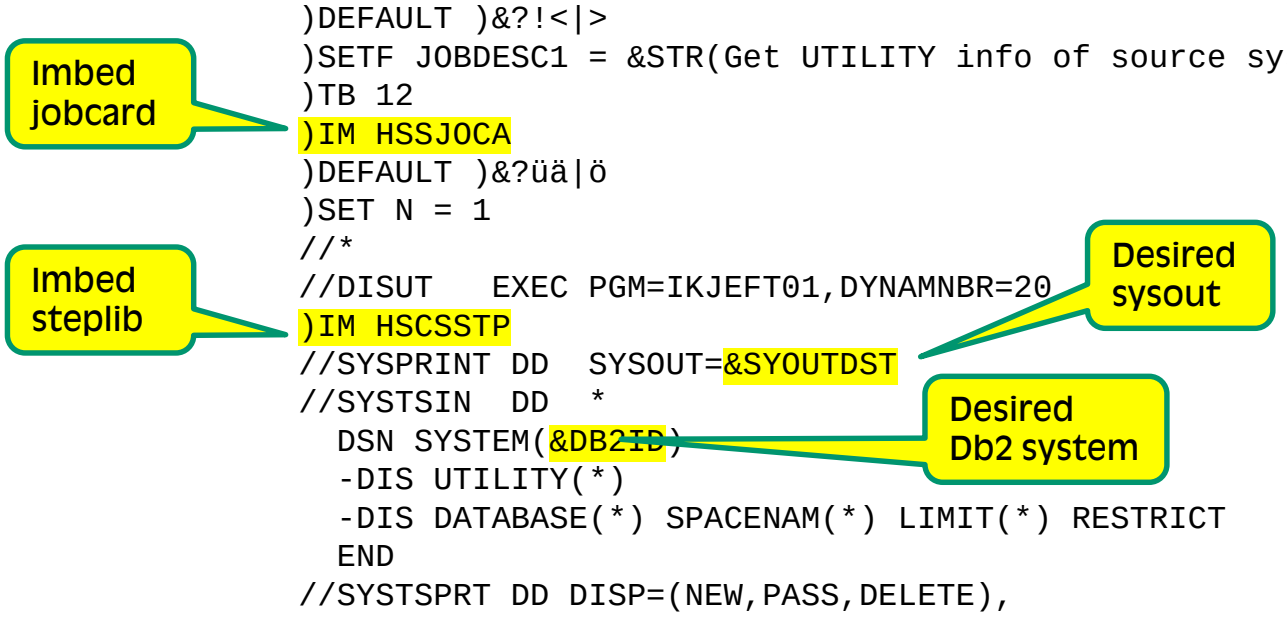
Db2 database/object cloning



- FTP and Routing
  - Usually source and target subsystem reside on different LPARs, machines, or even locations
  - A fundamental part of cloning automation is to take care of routing and transferring required data, no matter if being logged in on source, or target
    - Temporary/Workfile datasets are shared via FTP
    - Commands are routed by adding the system name
      `ROUTE LPRS,/F DB2S,STOP DB2`
    - Jobs can be route either via
      `ROUTE XEQ LPRSNJE`, or `SCHENV=LPRSDB2S`

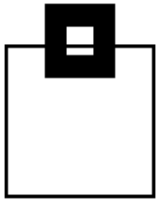
Db2 database/object cloning

- JCL, Panels, Commands, Messages
  - ISPF tailoring services are a great vehicle to prepare skeleton JCL, panels, commands and messages for automation, but keep the flexibility for a variety of individual systems and clone runs




```
)DEFAULT )&?!<|>
)SETF JOBDESC1 = &STR(Get UTILITY info of source system)
)TB 12
)IM HSSJOCA
)DEFAULT )&?üä|ö
)SET N = 1
//*
//DISUT   EXEC PGM=IKJEFT01,DYNAMNBR=20
)IM HSCSSTP
//SYSPRINT DD  SYSOUT=&SYOUTDST
//SYSTSIN  DD  *
  DSN SYSTEM(&DB2ID)
  -DIS UTILITY(*)
  -DIS DATABASE(*) SPACENAM(*) LIMIT(*) RESTRICT
  END
//SYSTSPRT DD DISP=(NEW,PASS,DELETE),
```

Db2 database/object cloning



- A clone-environment is designed for automated testing and should be isolated and automatically scratched afterwards
- However, since we have potentially sensitive production data, consider auditing the entire system, like
  - SELECTs (against sensitive data)
  - Modifications (INS/UPD/DEL)
  - DDL
  - DCL
  - Utilities
  - Commands
  - Assignment, or modification of a user ID/authorization – especially privileged users
- You may want to terminate the system when unauthorized access occurs

Automated testing – anomaly allerting

The scope and the environment for automated testing can be chosen flexibly, but of course SQL replay is intended for a test environment.

As a result, the testing scope and associated Cost matches the needs. E.g. for a non-critical system with a small change to test a quick access path precheck might be enough. For a highly critical financial OLTP system, facing a major Db2 update, we better run a fully automated clone with a complete replay test that covers multiple workload sets over night.

	Application Level
ICI Detection	Test and/or Production
AP Check	Test* and/or Production
Instant Cloning	Test
Capture/Replay	Test

Automated testing – anomaly allerting

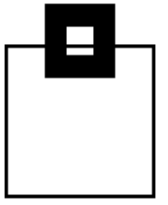
In recent versions, IBM has modified the behavior of certain Db2 functionality

- Built-in Functions (BiFs)
- Reserved Words
- SQL Return Codes
- Deprecated Functionality

It is important that you are aware of, and track, the incompatibilities that may cause issues/problems… why?

- Applications no longer function
- Applications function differently
- The results of your SQL SELECT statements can change

Access path change detection



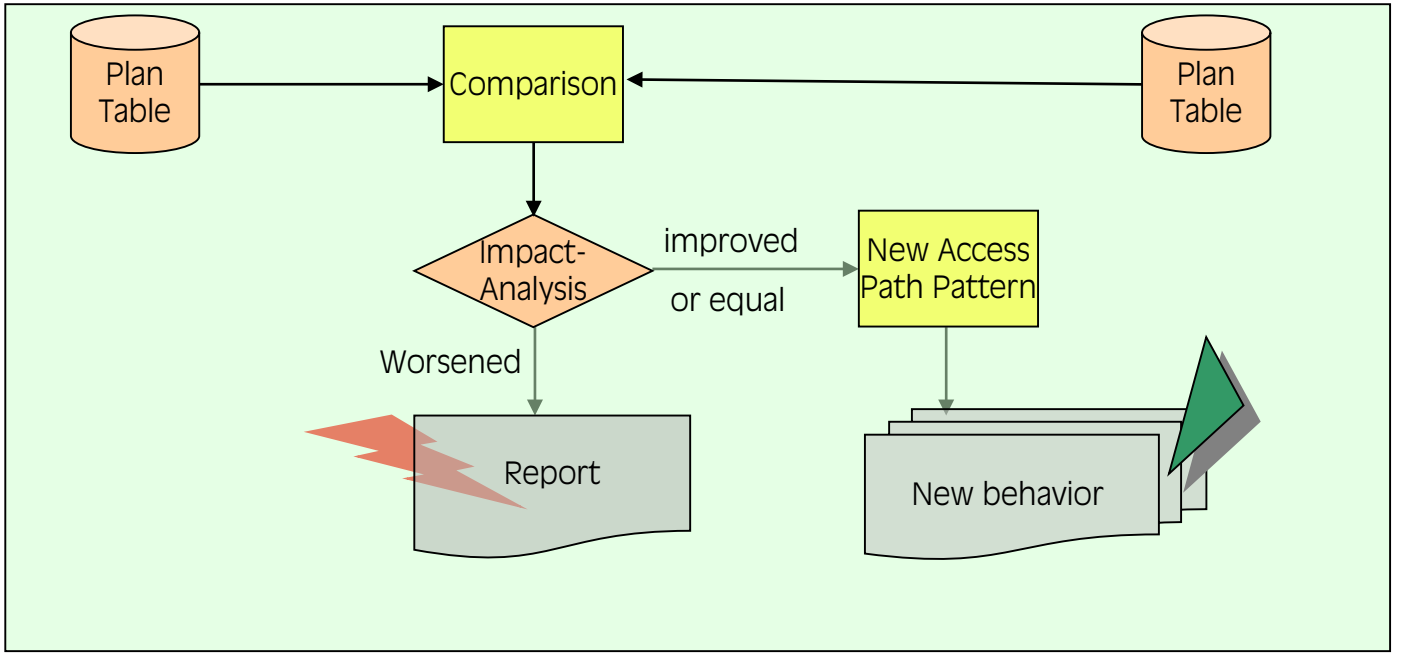
- (RE-)BIND EXPLAIN only explains based on static SQL optimization rules
  - A feature to populate details of an existing, or a new package without affecting the access path
    - Good for gathering explain data when previously bound with EXPLAIN(NO)
    - Reliable way to prescreen access paths for static packages

- EXPLAIN STATEMENTCACHE explains dynamic statements in the DSC

- EXPLAIN ALL <stmt> explains based on dynamic SQL optimization rules
  - A feature to populate details of a new statement without affecting the access path
    - Reliable way to prescreen access paths for dynamic SQL
    - E.g. RTS # pages/rows = 0
      - → EXPLAIN: tablespace scan
      - → BIND EXPLAIN(ONLY): index access

Access path change detection

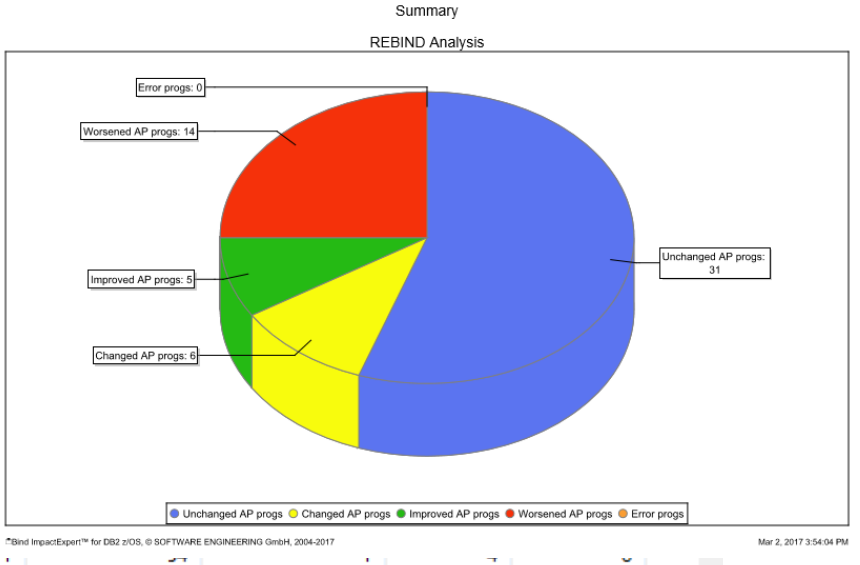
- Automatically and reliably check access path changes



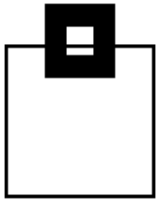
Access path change detection

- Access Path Check:
  Static & Dynamic SQL

STMT No.	Section Number	DSC STMT ID	Impact	Serviceunits Old	Serviceunits Ne				
2547	13	2547	DEGRADED	85					
796	2	796	DEGRADED	152					
804	3	804	DEGRADED	152					
812	4	812	DEGRADED	152					
820	5	820	DEGRADED	152					
671	2	671	DEGRADED	152					
679	3	679	DEGRADED	152					
687	4	687	DEGRADED	152					
695	5	695	DEGRADED	152					
3	3	3	DEGRADED	130	1	46	1	6	8
4	4	4	DEGRADED	95	2	34	1	4	8
5	5	5	DEGRADED	82	1	29	1	4	8
6	6	6	DEGRADED	149	1	53	1	4	8
968	7	968	IMPROVED	171	16	60	6	8	5
1167	9	1167	IMPROVED	174	10	62	4	10	5
235	1	235	IMPROVED	178	10	63	4	8	6
1194	2	1194	IMPROVED	150	191	53	67	12	1
2409	7	2409	IMPROVED	21	23	8	9	5	1
1194	2	1194	IMPROVED	175	191	62	67	12	1



Workload KPI verification at a glance



Workload Capture/Replay with KPI verification:

→ Workload Capture/Replay adds application level testing and automates executing sets of captured workload.

- Highly efficient IFCID (OPx) capturing to catch SQL for automated execution in the isolated, cloned environment.
- Workload sets can be saved to represent quarter's end, year's end and other specific workload patterns.
- Tested workload is automatically compared on a KPI level (e.g. # of getpages, rows returned, rows processed…) to report only anomalies.

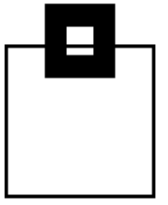
Workload KPI verification

- Using IFCIDs along with OPx buffers delivers in-depth information without the overhead of SMF processing
- Correlation headers add detailed authentication data

- IFCID 316* and 318 externalize data from the Dynamic Statement Cache (DSC), even when a flushing situation occurs (LRU, RUNSTATs, ALTER, DROP, REVOKE, …)
  (+317* for the full SQL statement)
- IFCIDs 400* and 401 externalize data from the EDM pool – let's call it the **S**tatic **S**tatement **C**ache – even when a flushing situation occurs (EDM pool is full)
  (+SYSPACKSTMT for the full SQL statement)

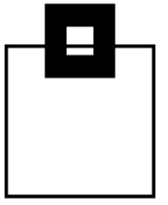
*This IFCID is not really an IFCID but more of a „switch" to enable externalization of static SQL metrics

Workload KPI verification



- Counters
  - More than 100 KPIs, like
    - executions, getpages, IX/TS scans, rows processed/examined, ...
- Zero-Counters
  - Failure indicators that should always be zero, like
    - RID list overflow, RID list append, RID pool failure, ...
- Timings
  - More than 80 KPIs, like
    - CPU/elapsed time, claim/lock/latch wait time, thread read/write
- Identification
  - About 20 IDs, like
    - SQL ID, end user, workstation, transaction, ...
- Environmental
  - Metadata, like collection ID, currentdata, isolation level, ...

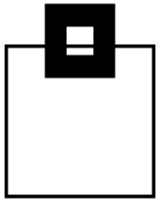
Workload KPI verification



- SQL workload that has been captured can be divided into two groups:
  1. Re-executable statements
     - SELECT A, B, C FROM MYTABLE WHERE B = 'B'
  2. Non re-executable statements
     - SELECT A, B, C FROM MYTABLE WHERE B = ?
     - SELECT A, B, C FROM MYTABLE WHERE B = :B

- SQL with literals and host variables needs to be prepared for re-execution

Workload KPI verification



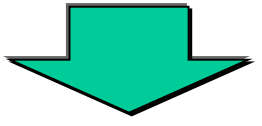
In dynamic SQL statements host variables are represented as question marks (parameter markers). There are *typed* and *untyped* parameter markers.

- Typed parameter markers are specified with their target data type (via CAST).
- Untyped parameter markers are specified in the form of a single question mark.

Workload KPI verification

To make non re-executable statements executable, we replace parameter markers and host variables with real values, considering the characteristics of the affected column.

SELECT A, B, C FROM MYTABLE WHERE B = ?

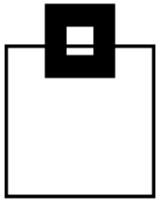


SELECT A, B, C FROM MYTABLE WHERE B = 'B'

A simple shot is a character = 'A' and numeric = 5 replacement.

A more sophisticated solution checks catalog statistics for more solid replacements.

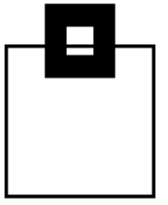
Workload KPI verification



- The captured statements can (and should) represent various workloads to cover a representative scope
  - Month's end processing
  - Quarter's end processing
  - Year's end processing
  - Typical OLTP
  - Typical batch

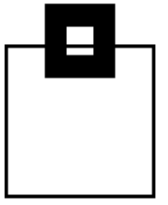
... and can be bundled in workload sets to be individually chosen for testing.

Workload KPI verification



- Executing the captured statements dynamically doesn't require the associated applications
  - There are typically no static programs/packages as part of the Db2 clone
- Consider parameters allowing to chose the number of executions per statement
- Ignore certain SQL errors/warnings, like
  - Duplicate key
  - Object exists
  - Grantee already has the permission
  - +100
  - …

Workload KPI verification

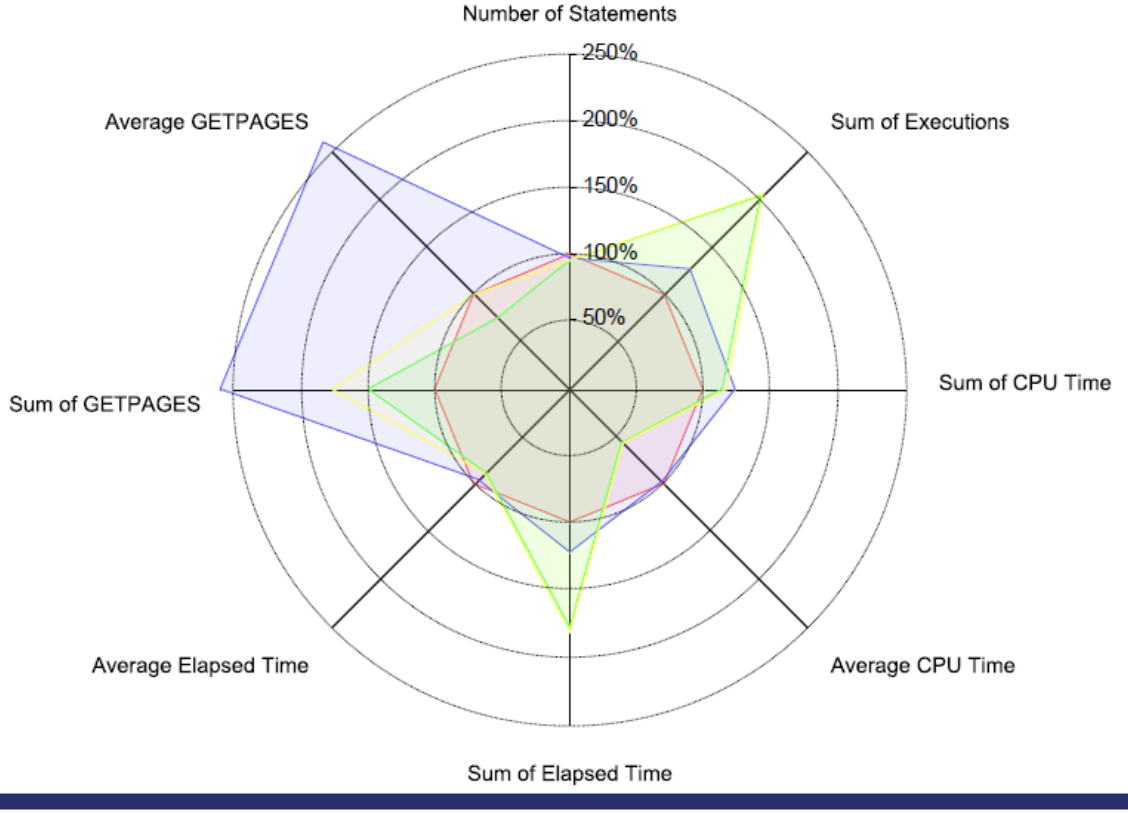


- Before starting the mass execution, verify to be in our own cloned and encapsulated environment!
- The entire execution needs to be monitored (using OPx based, highly-efficient capturing technology) to gather comparison metrics and KPIs, like
  - CPU consumption
  - Access path pattern
  - Rows processes/examined
  - …

  for a before and after comparison of changes, like:
  - New application release
  - System changes
  - Db2 APAR/PTF/new Db2 12 modification level
  - Environment/hardware changes

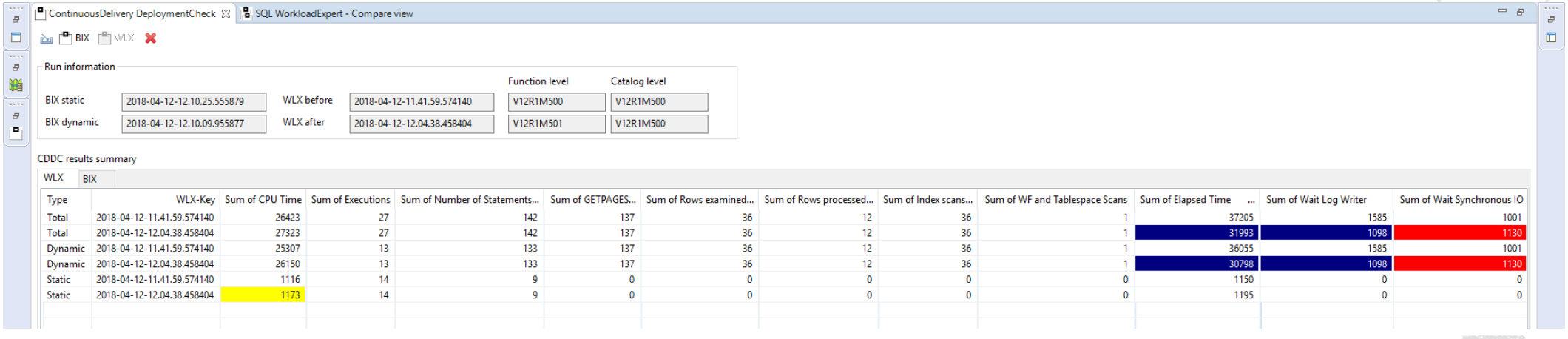
Workload KPI verification

The big benefit of KPI verification is the ability to handle massive amounts of testing without the overhead of having to review individual executions.



Workload KPI verification

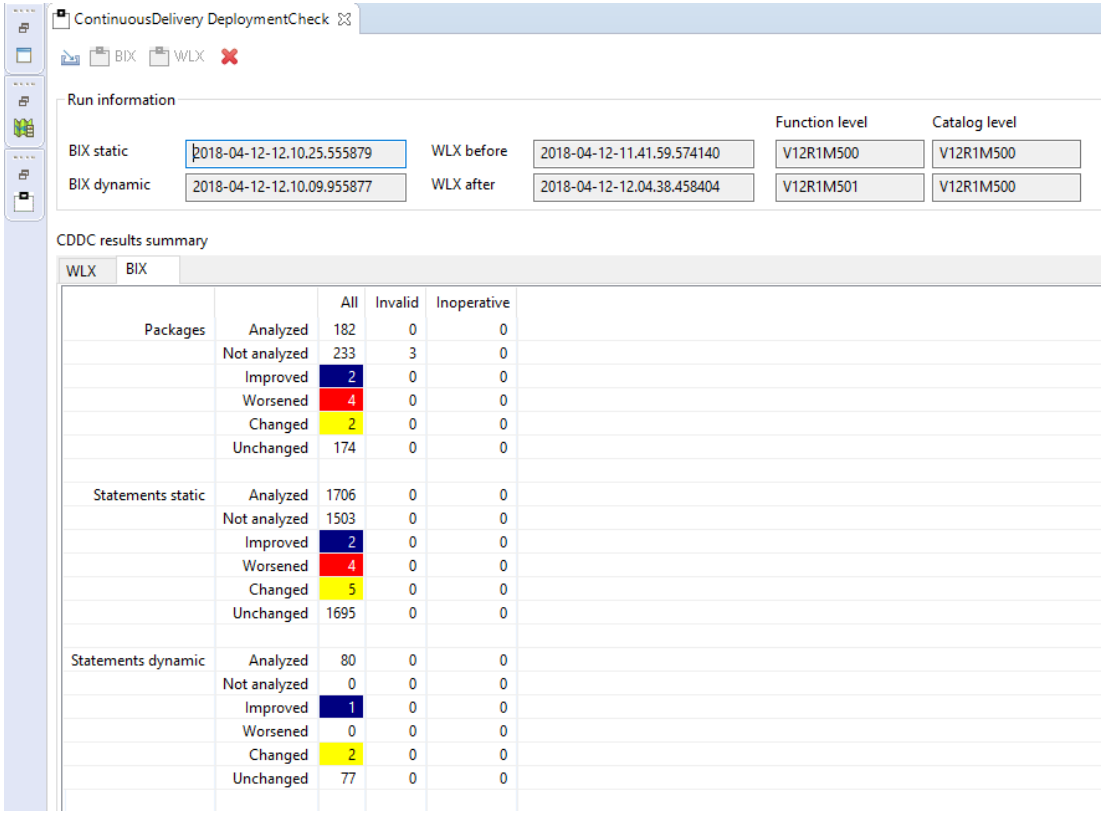
Drill down capabilities allow looking into details, when anomalies are detected



Type	WLX-Key	Sum of CPU Time	Sum of Executions	Sum of Number of Statements...	Sum of GETPAGES...	Sum of Rows examined...	Sum of Rows processed...	Sum of Index scans...	Sum of WF and Tablespace Scans	Sum of Elapsed Time ...	Sum of Wait Log Writer	Sum of Wait Synchronous IO
Total	2018-04-12-11.41.59.574140	26423	27	142	137	36	12	36	1	37205	1585	1001
Total	2018-04-12-12.04.38.458404	27323	27	142	137	36	12	36	1	31993	1098	1130
Dynamic	2018-04-12-11.41.59.574140	25307	13	133	137	36	12	36	1	36055	1585	1001
Dynamic	2018-04-12-12.04.38.458404	26150	13	133	137	36	12	36	1	30798	1098	1130
Static	2018-04-12-11.41.59.574140	1116	14	9	0	0	0	0	0	1150	0	0
Static	2018-04-12-12.04.38.458404	1173	14	9	0	0	0	0	0	1195	0	0

Workload KPI verification

Drill down capabilities allow looking into details, when anomalies are detected

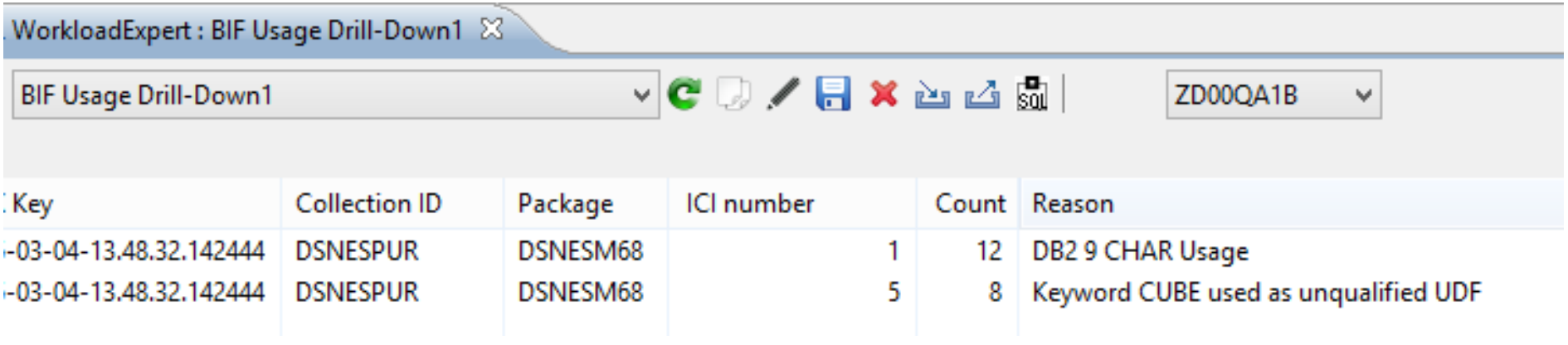


		All	Invalid	Inoperative
Packages	Analyzed	182	0	0
	Not analyzed	233	3	0
	Improved	2	0	0
	Worsened	4	0	0
	Changed	2	0	0
	Unchanged	174	0	0
Statements static	Analyzed	1706	0	0
	Not analyzed	1503	0	0
	Improved	2	0	0
	Worsened	4	0	0
	Changed	5	0	0
	Unchanged	1695	0	0
Statements dynamic	Analyzed	80	0	0
	Not analyzed	0	0	0
	Improved	1	0	0
	Worsened	0	0	0
	Changed	2	0	0
	Unchanged	77	0	0

Workload KPI verification

BIF Usage is a major area of concern and occurs quite often.

The ability to test multiple sets of workloads, detects even quarters-end, or years-end query issues before they occur in production.



Key	Collection ID	Package	ICI number	Count	Reason
-03-04-13.48.32.142444	DSNESPUR	DSNESM68	1	12	DB2 9 CHAR Usage
-03-04-13.48.32.142444	DSNESPUR	DSNESM68	5	8	Keyword CUBE used as unqualified UDF