SATURN 101: Part 3 – Improving Convergence

2018 User Group Meeting

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Final 03/12/18 - UGM2018 SAT101 Part 3 Improving Convergence

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SATURN Assignment 101 Part 3 - Recap on SAVEIT Approximations

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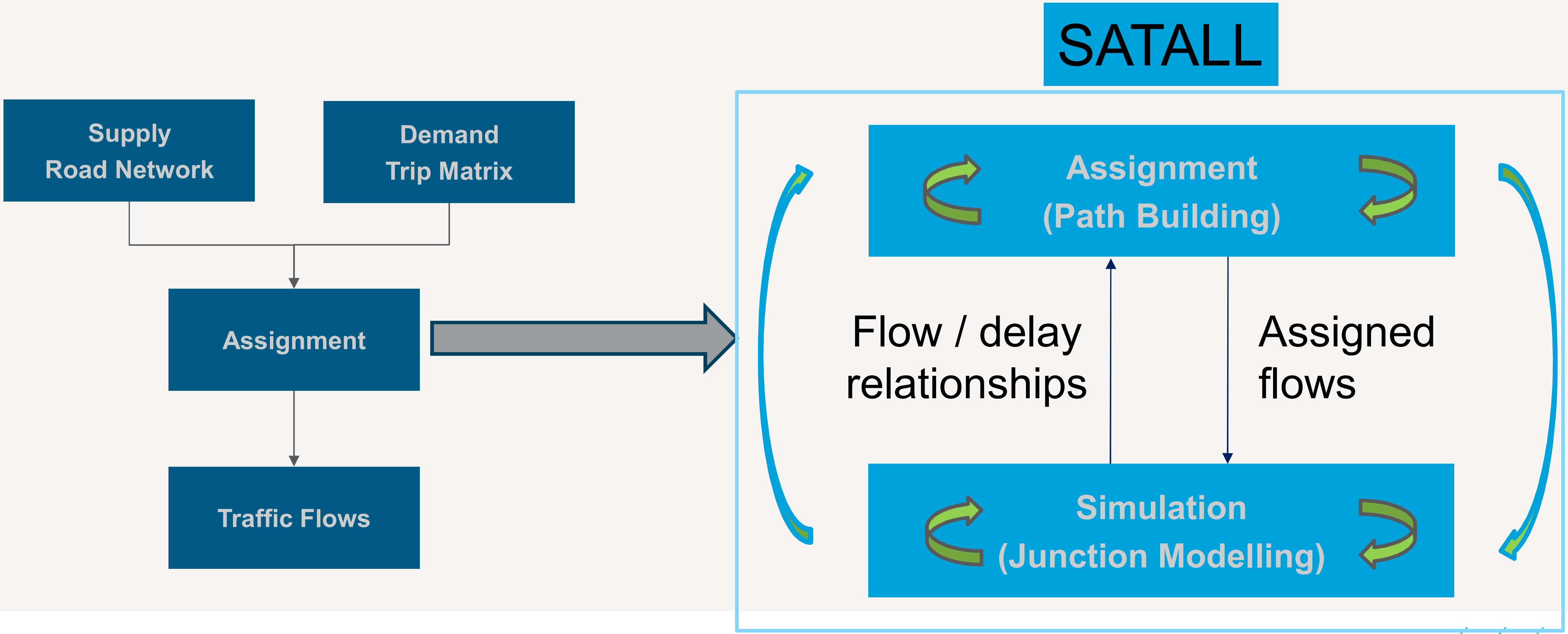
SATURN Assignment 101 - Quick Recap (from last year!)



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SATURN Assignment 101 - Assignment Process

Flows →

Loop	Assignment	Simulation	Cumulative (AON) Paths
1	20 Path Builds	20 Simulation Iterations	0 + 20 = 20
2	20 Path Builds	20 Simulation Iterations	20 + 20 = 40
3	20 Path Builds	20 Simulation Iterations	40 + 20 = 60
…			
n	20 Path Builds	20 Simulation Iterations	= n * 20

← **Flow / Delay Curves**

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Step 3a – SAVEIT Approximations

Cost data stored in the UFC file for secondary analysis

Recreates assignment using either :

- the original full set of paths used or a SAVEIT approximation

By default, UFC109=T & NITA_C=256 so

- full set saved unless cumulative path builds > 256
- otherwise SAVEIT used - maximum no. of path builds set by NITA_S

Value of NITA_S is very important

- If too small (e.g. 25!) then too few paths used in SAVEIT approximation
- Likely that very poor Wardrop solution (Approximation %GAP >> Final %GAP)
- Use v11.4 default: NITA_S=256 is sensible

Support feedback:

- Models with very large values of NITA_C or NITA_S (eg > 600)
- Not required – check what's required!
  - *very large UFC files, significant extra CPU for SAVEIT and long runtimes for secondary analysis*

Step 3b – Checking SAVEIT Performance

Reports in the LPT file

- Compares accuracy of main assignment versus SAVEIT
  - Take %Epsilon rather than %Delta

Bad Example: %Epsilon = 0.1743%

```
            WARDROP MUC USER EQUILIBRIUM ASSIGNMENT


 TREE BUILDING AND LOADING ALGORITHMS ARE BASED ON A SPIDER WEB
 AGGREGATION OF NETWORK NODES AND LINKS.



 >>>>> REASSIGNMENT STOPPED AFTER    25 ITERATIONS >>>>>
       MAXIMUM NUMBER OF ITERATIONS NITA EXCEEDED


 FINAL CONVERGENCE STATISTICS AND STOPPING VALUES

       25 GE         25 - NUMBER OF ITERATIONS (<NITA)
    11.11 LT       0.05 - % OF NEW A-O-N LOAD USED (<XFSTOP)
   0.1644               - % DELTA (ACTUAL COSTS LESS MINIMUM COSTS)
    0.019               - % CHANGE IN TOTAL TRAVEL COSTS (LAST ITER)
   0.1743 LT     0.0098 - % EPSILON: UNCERTAINTY IN THE OBJ. FUNCTION (<UNCRTS)
                           (RELATIVE TO THE OBJECTIVE FUNCTION)
    1.983 LT       0.05 - % REDUCTION IN THE UNCERTAINTY (<FISTOP)
                           (RELATIVE TO THE UNCERTAINTY)
    0.010               - % REDUCTION IN THE OBJ. FUNCTION
                           (RELATIVE TO THE OBJECTIVE FUNCTION)

         0.397465E+09 - FINAL OBJECTIVE FUNCTION VALUE
```

Good Example: %Epsilon = 0.0098%

```
            WARDROP MUC USER EQUILIBRIUM ASSIGNMENT


 TREE BUILDING AND LOADING ALGORITHMS ARE BASED ON A SPIDER WEB
 AGGREGATION OF NETWORK NODES AND LINKS.



 >>>>> SAVEIT CONVERGENCE ACHIEVED AFTER  150 ITERATIONS >>>>


 FINAL CONVERGENCE STATISTICS AND STOPPING VALUES

      150 GE        256 - NUMBER OF ITERATIONS (<NITA)
     1.03 LT       0.05 - % OF NEW A-O-N LOAD USED (<XFSTOP)
   0.0103               - % DELTA (ACTUAL COSTS LESS MINIMUM COSTS)
    0.000               - % CHANGE IN TOTAL TRAVEL COSTS (LAST ITER)
   0.0098 LT     0.0098 - % EPSILON: UNCERTAINTY IN THE OBJ. FUNCTION (<UNCRTS)
                           (RELATIVE TO THE OBJECTIVE FUNCTION)
    0.823 LT       0.05 - % REDUCTION IN THE UNCERTAINTY (<FISTOP)
                           (RELATIVE TO THE UNCERTAINTY)
    0.000               - % REDUCTION IN THE OBJ. FUNCTION
                           (RELATIVE TO THE OBJECTIVE FUNCTION)

         0.397085E+09 - FINAL OBJECTIVE FUNCTION VALUE
```

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Impact on TUBA Scheme Appraisal - Illustrative Example

Two Scenarios (With & Without Scheme), 60 year appraisal

	Ref Case	Run 1	Run 2	Run 3	Run 4	Run 5
NITA_S	256	25	99	256	256	256
NISTOP	4	4	4	5	4	4
RSTOP	98.5%	98.5%	98.5%	98.5%	97.5%	94.5%
AM - %Flow	98.9%	98.9%	98.9%	98.5%	98.0%	96.7%
AM - %GAP (Main)	0.009%	0.009%	0.009%	0.008%	0.010%	0.036%
AM - %GAP (SAVEIT)	0.010%	0.164%	0.016%	0.008%	0.012%	0.036%
PVB (Index)	100	85 !!!	95	95	95	95

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Part 3 – Resolving Poor Convergence

[and reducing runtimes]

Step 1 – Taking Stock

Reference Benchmark

- DIADEM-based Variable Demand Model
  - Four loop assignments undertaken in parallel
    - *TS1 (AM), TS2 (IP), TS3 (PM) and TS4 (Off-peak)*
- Check overall convergence using **SATSTAT**
  - For more detailed information – see **Table 1 in LPT**

Process	Loops	%Flow	%GAP	Total CPU (mins)	WebTAG?
AM Peak	96	98.0%	0.01%	82.8	Yes
Inter Peak	70	99.0%	0.02%	35.5	Yes
PM Peak	**120**	**96.4%**	**0.02%**	**120.1**	**No**
Off Peak	10	99.3%	0.00%	1.3	Yes

```
ASSIGNMENT/SIMULATION LOOP SUMMARY STATISTICS

Table 1: Convergence Statistics by Sub-Model and Loops

Ass. - DELTA FUNCTION (%) / NUMBER OF ITERATIONS
Sim. - FINAL AVER ABS CHANGE IN OUT CFP (PCU/HR) / NUMBER OF ITERATIONS
A/S Step - Step Length used on Ass/Sim Loop / Simulation Iterations
%FLOWS  - LINK FLOWS DIFFERING BY <   1% BETWEEN ASS-SIM LOOPS
%DELAYS - TURN DELAYS DIFFERING BY <   1% BETWEEN ASSIGNMENT & SIMULATION
%V.I. - VARIATIONAL INEQUALITY - SHOULD BE > 0
%GAP - WARDROP EQUILIBRIUM GAP FUNCTION POST SIMULATION

LOOP    Ass.       Sim.     A/S Step   %FLOWS  %DELAYS    %V.I.     %GAP

  1  0.375/30   0.181/51   1.000/ 1             49.1               3.550
  2  0.319/18   0.032/15   1.000/ 1     23.8    75.4    0.211      1.450
  3  0.189/18   0.072/24   0.897/ 2     33.9    83.0    0.0047     0.886
  4  0.157/18   0.088/32   1.000/ 1     43.6    86.2    0.025      0.678
  5  0.187/18   0.041/11   0.662/ 3     50.4    87.6    0.0056     0.353

100 0.0127/24   0.067/ 6   0.209/ 2     95.7    97.2    0.00029    0.021
101 0.0121/24   0.063/13   0.191/ 3     96.0    97.2    0.00096    0.025
102 0.0130/24   0.059/10   0.282/ 2     96.0    97.1    0.00041    0.024
103 0.0142/24   0.066/16   0.077/ 6     95.9    97.3    0.00060    0.028
104 0.0161/24   0.036/ 5   0.128/ 4     95.2    97.0    0.00048    0.029
105 0.0138/24   0.039/ 6   0.153/ 4     95.2    97.1    0.0015     0.025
106 0.0134/24   0.060/ 6   0.218/ 3     96.0    97.1    0.00025    0.028
107 0.0143/24   0.071/ 7   0.258/ 3     95.2    96.9    0.00030    0.025
108 0.0129/24   0.042/ 9   0.273/ 2     95.6    97.1    0.00093    0.027
109 0.0150/24   0.025/12   0.174/ 2     95.3    96.9    0.00026    0.029
110 0.0145/24   0.014/ 5   0.076/ 7     95.0    97.0    0.00040    0.019
111 0.0112/24   0.050/ 4   0.145/ 4     96.4    97.3    0.00058    0.048
112 0.0433/24   0.052/ 6   0.019/ 9     91.9    96.3    0.0010     0.025
113 0.0106/25   0.016/ 5   0.002/ 9     95.6    97.0    0.00000    0.024
114 0.0128/25   0.051/ 6   0.065/ 6     95.7    97.2    0.00030    0.022
115 0.0097/25   0.013/ 4   0.084/ 5     96.1    97.3    0.00004    0.018
116 0.0091/25   0.037/10   0.179/ 4     96.6    97.6    0.00033    0.026
117 0.0124/25   0.044/37   0.180/ 2     95.5    97.0    0.00013    0.028
118 0.0096/25   0.031/ 9   0.004/ 9     96.0    97.3   -0.00020    0.024
119 0.0098/25   0.022/ 8   0.134/ 4     96.0    97.3    0.00020    0.018
120 0.0105/25   0.034/ 7   0.145/ 3     96.4    97.4    0.00007    0.018

LOOP    Ass.       Sim.     A/S Step   %FLOWS  %DELAYS    %V.I.     %GAP
```

Findings: %Flows <u>oscillating</u> around 96%
%Gap < 0.02% and stable

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Step 2 – Examine %Flows & %Gap by Loop

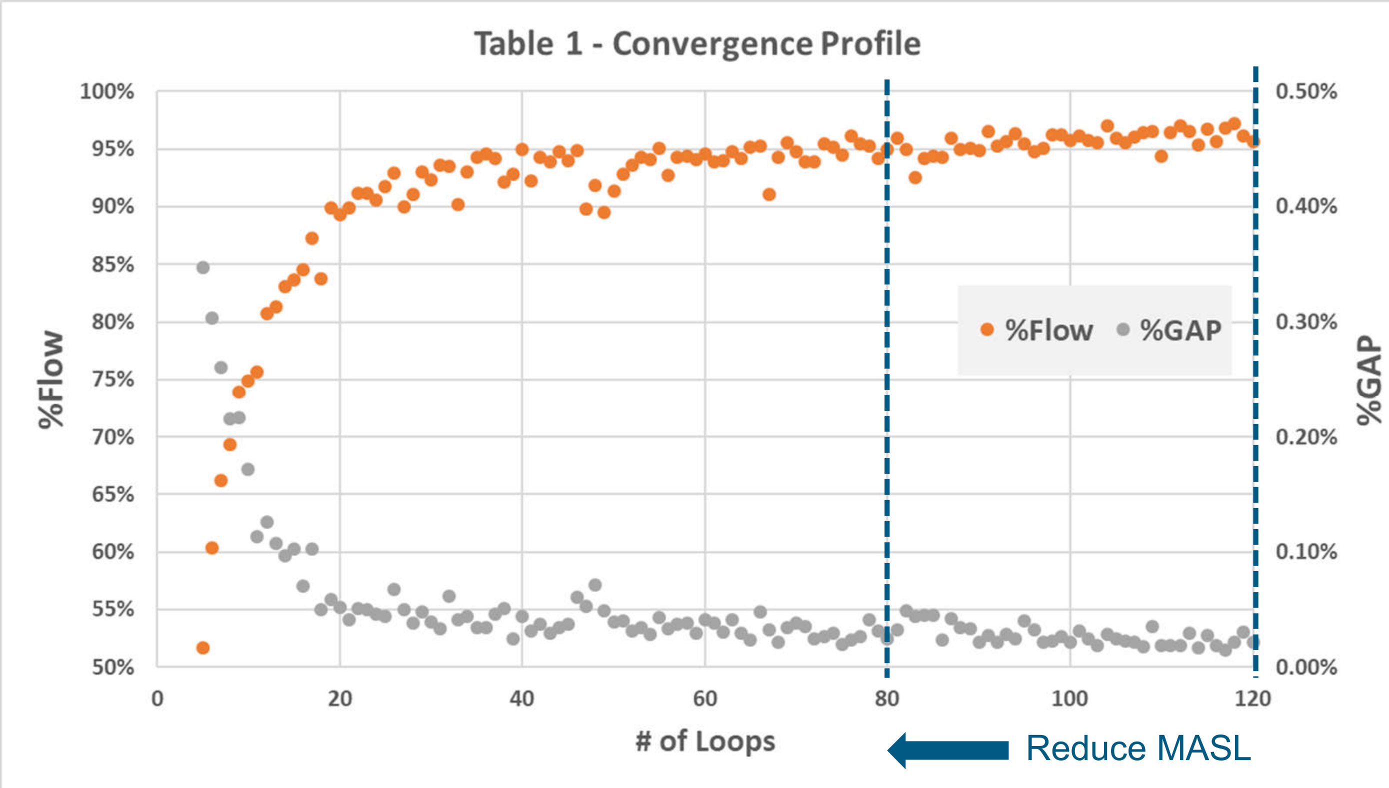
Investigate convergence profile

Table 1 shows

- PM fails to converge after 120 loops
  - %Flow = 96.4%, %GAP = 0.02%
- But similar performance for 80 loops
  - %Flow = 96.7%, %GAP = 0.02%

Extra loops not adding any significant improvement to convergence levels achieved

- Reduce MASL from 120 to 80
  - Likely reduction in CPU times of ~25%
- If not converge in (reasonable) 100 loops then investigate!
  - Don't just up the MASL value and hope for the best …
  - Saves a lot of time & more stable assignment



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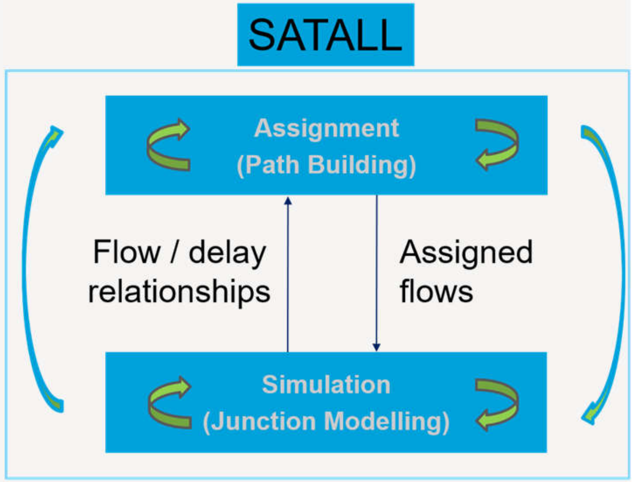
Step 3 – Where is the CPU being expended? (& peculiarity of the RTMs)



Look for CPU Runtime report

- Either P1X -> Convergence or bottom of the LPT File

Remember - within SATURN

- Assignment = Multi-threaded process (Very fast!)
- Simulation = Single-threaded process (Very slow!)

With the larger RTMs

- Majority of CPU time spent in single-threaded simulation
- Optimise parameters to re-balance algorithm
  - Increase proportion of faster assignment iterations
  - Reduce proportion of fewer slower simulation iterations

Recommendation

- Set NITS = 20 not 50 (RTM default)
- May need to increase MASL to compensate -> Test!

Process	Loops	Ass Time (mins)	Sim Time (mins)	UFC Time (mins)	%Ass Time	%Sim Time	Total CPU (mins)
AM Peak	96	34.6	44.5	3.4	**42%**	**54%**	82.8
Inter Peak	70	17.4	13.2	3.7	**51%**	**38%**	35.5
PM Peak	120	28.8	89.4	1.8	**24%**	**74%**	120.1
Off Peak	10	0.7	0.4	0.0	**56%**	**31%**	1.3

Step 4 – Take Stock again

(i) Starting Point

Process	Loops	%Flow	%GAP	Ass Time	Sim Time	Total CPU (mins)
AM Peak	96	98.0%	0.01%			82.8
Inter Peak	70	99.0%	0.02%			35.5
PM Peak	120	96.4%	0.02%			120.1
Off Peak	10	99.3%	0.00%			1.3
Elapsed Time						**120.1**

(ii) Reduce MASL from 120 -> 80

Process	Loops	%Flow	%GAP	Ass Time	Sim Time	Total CPU (mins)
AM Peak (Rev.)	80	97.3%	0.02%	28.9	37.1	69.6
Inter Peak	No change as terminates within 80 loops					
PM Peak (Rev.)	80	96.7%	0.02%	19.2	59.6	82.3
Off Peak	As per Inter Peak					
Elapsed Time						**82.3**

(iii) Reduce NITS (50->20)

Process	Loops	%Flow	%GAP	Ass Time	Sim Time	Total CPU (mins)
AM Peak (Fin.)	80	98.0%	0.02%	30.8	25.1	61.0
Inter Peak (Fin.)	65	98.6%	0.02%	19.2	11.6	36.4
PM Peak (Fin.)	80	96.4%	0.02%	23.1	40.0	66.2
Off Peak (Fin.)	11	99.2%	0.00%	1.8	1.2	3.2
Elapsed Time						**66.2**

Results so far:

- Overall saving = 1hr or 2x faster
- Don't forget to check SAVEIT values

Next step:

- Let's improve the PM convergence

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Part 3 – Checking the Simulation

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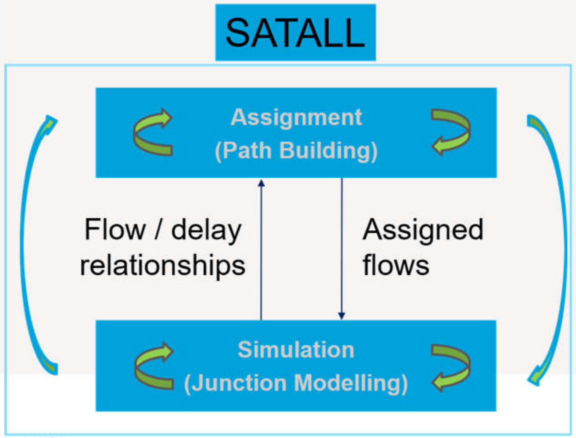
Step 5a – Search for the instabilities within the assignment

SATURN assignment is an iterative process

- Convergence = measure of the stability (flow) and proximity (Wardrop equilibrium) of the assignment
- Differences between successive estimates of flows & delays is key not the absolute value
- So: need to search for these differences

Popular misconception:

- Heavily congested networks do not automatically mean poor convergence



Search for the last Table L(8) in LPT File

Table L(8)

WORST TURN DELAY DIFFERENCES: (LOOP 120 REPETITION 3)
BETWEEN THE SIMULATED DELAYS (CURRENT) AND
THE DELAYS CALCULATED BY THE ASSIGNMENT (PREVIOUS)
(See 9.9.1 of the SATURN Manual)

RANK	A	B	C	D E L A Y S			CAPACITIES		ACT FLOW
				DIFFERENCE	CURRENT	PREVIOUS	CURRENT	PREVIOUS	PCU/HR
1	87964	81636	81635	652.74	887.17	234.43	49.66	49.66	69.74
2	72888	72889	78008	557.06	683.48	126.42	436.62	437.20	594.77
3	80854	81745	80774	-453.83	76.28	530.11	179.37	179.70	176.23
4	80854	81745	80402	-394.07	76.23	470.30	1124.59	1125.13	1115.25
5	83194	83195	82184	376.32	508.70	132.39	85.17	85.20	97.27
6	83194	83195	83196	343.14	480.55	137.42	9.18	9.20	10.48
7	87964	81636	81959	283.76	351.78	68.02	130.30	130.59	145.79
8	87964	81636	81960	281.97	355.92	73.95	274.63	274.34	307.27
9	81771	81749	84634	234.42	1026.85	792.43	52.11	50.97	76.10
10	76442	70597	70623	192.53	270.37	77.84	67.68	67.68	72.04

- Shows Top 10 largest differences in turn-delays between successive assignment-simulation loops
  - Less than <100 seconds is good
  - Watch out for '*' markers showing blocking back turning on/off

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Step 5b – Search for the locations where instabilities occur

Re-ordering for clarity

Table L(8)

WORST TURN DELAY DIFFERENCES: (LOOP 120 REPETITION 3)
BETWEEN THE SIMULATED DELAYS (CURRENT) AND
THE DELAYS CALCULATED BY THE ASSIGNMENT (PREVIOUS)
(See 9.9.1 of the SATURN Manual)

RANK	A	B	C	DELAYS DIFFERENCE	DELAYS CURRENT	DELAYS PREVIOUS	CAPACITIES CURRENT	CAPACITIES PREVIOUS	ACT FLOW PCU/HR
1	87964	81636	81635	652.74	887.17	234.43	49.66	49.66	69.74
7	87964	81636	81959	283.76	351.78	68.02	130.30	130.59	145.79
8	87964	81636	81960	281.97	355.92	73.95	274.63	274.34	307.27
2	72888	72889	78008	557.06	683.48	126.42	436.62	437.20	594.77
3	80854	81745	80774	-453.83	76.28	530.11	179.37	179.70	176.23
4	80854	81745	80402	-394.07	76.23	470.30	1124.59	1125.13	1115.25
5	83194	83195	82184	376.32	508.70	132.39	85.17	85.20	97.27
6	83194	83195	83196	343.14	480.55	137.42	9.18	9.20	10.48
9	81771	81749	84634	234.42	1026.85	792.43	52.11	50.97	76.10
10	76442	70597	70623	192.53	270.37	77.84	67.68	67.68	72.04

Three links to focus on:

Link (A-B)	Ave Delay Diff (secs)	Total Flow (pcu/hr)	Total Delay Diff (pcu-hrs)
87964 – 81636	+332	523	**+48.2**
72888 – 72889	+557	595	**+92.0**
80854 – 81745	-402	1291	**-144.3**

Secondary Sources available

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Step 5c – Secondary Sources

Stability in the Cyclic Flow Profiles

- ‘Out’ profiles = exit flows from the junction
  - Least well converged Node 72889
    - *Target values ~ 5 or lower*

Simulation Repetitions

- Will repeat to provide more accurate solution
- Ideally only one pass through
  - Check repetitions for reappearing turns

Blocking back instabilities

- Table L(8) also flags turns where blocking back is switching on/off between successive loops

```
LEAST WELL CONVERGED SIMULATION NODES:
  IN PROFILES -  72627 -        5.44
 OUT PROFILES -  72889 -       26.40

** PROGRAMMER WARNING ** IN UP_FLUP_ACT_105
   POSSIBLY TRAPPING UNDERFLOW OF QRFN - SHOULD NOT BE -VE
   NASS=  120 LM=  11935 MMEX=  17475
    FLUP_ACT(LM)=-.223E-05 GRH=-.223E-05 TTARMH=0.327E-02
   PLEASE REPORT THIS TO SATURN SOFTWARE IF QRFUP NOT INSIGNIFICANTLY SMALL
```

Table L(8)

```
WORST TURN DELAY DIFFERENCES: (LOOP 120 REPETITION  2)
BETWEEN THE SIMULATED DELAYS (CURRENT) AND
THE DELAYS CALCULATED BY THE ASSIGNMENT (PREVIOUS)
     (See 9.9.1 of the SATURN Manual)
```

RANK	A	B	C	DELAYS DIFFERENCE	DELAYS CURRENT	DELAYS *PREVIOUS*	CAPACITIES *CURRENT*	CAPACITIES *PREVIOUS*	ACT FLOW *PCU/HR*
1	86050	80634	80631	2346.08	2352.42	6.34	45.00	533.11	100.92*+
2	87964	81636	81635	688.44	922.88	234.43	49.66	49.66	70.73
3	72888	72889	78008	557.70	684.12	126.42	437.20	454.07	595.71
4	80854	81745	80774	-455.17	74.94	530.11	179.70	181.52	175.53
5	80854	81745	80402	-395.41	74.89	470.30	1125.13	1143.72	1113.55
6	81067	86436	87608	387.11	787.55	400.44	65.34	152.36	84.02
7	83194	83195	82184	383.33	515.72	132.39	85.20	86.21	97.64
8	83194	83195	83196	350.16	487.57	137.42	9.20	9.64	10.54
9	81067	86436	80855	349.26	767.15	417.90	468.52	556.67	602.48
10	81067	86436	80812	317.14	762.71	445.56	643.92	1182.88	812.95

*/+ - EXIT LINK BLOCKING BACK NOW/PREVIOUSLY

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Step 5c – P1X Sources

Plot link data for:

- Changes in Demand Flow between successive loops
    - *Switching*
- Changes in ‘Block Back Factors’
    - *Turning on/off*

Plot node data by:

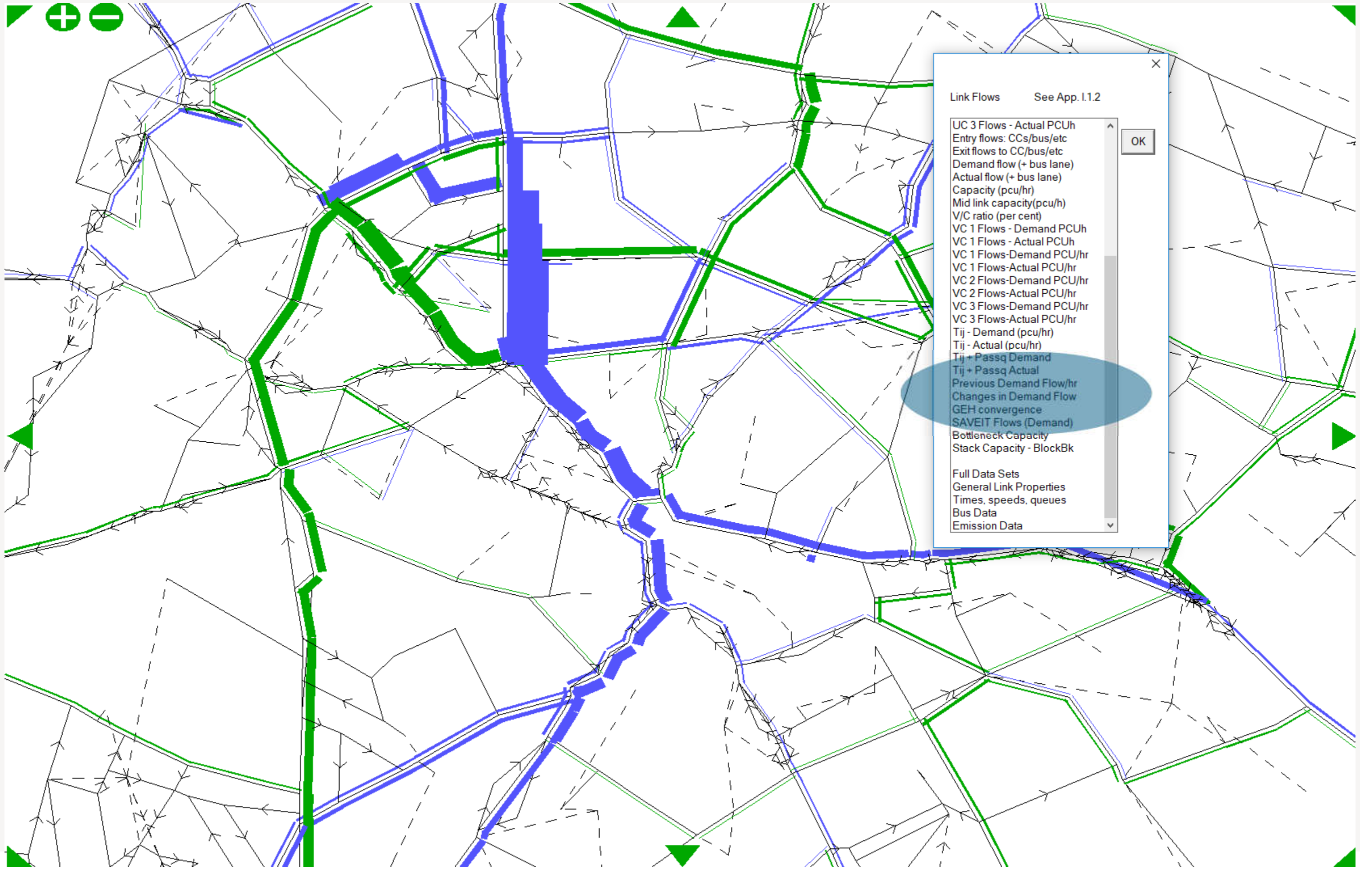
- Convergence ‘In’ or ‘Out’ Profile

P1X Node Graphics:

- For more detailed information

Remember:

- Focussing on changes



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Step 6 – Address Problem Coding (i)

Spider's Web of Centroid Connectors

Multiple centroid loading points

- Coupled with detailed simulated junction coding

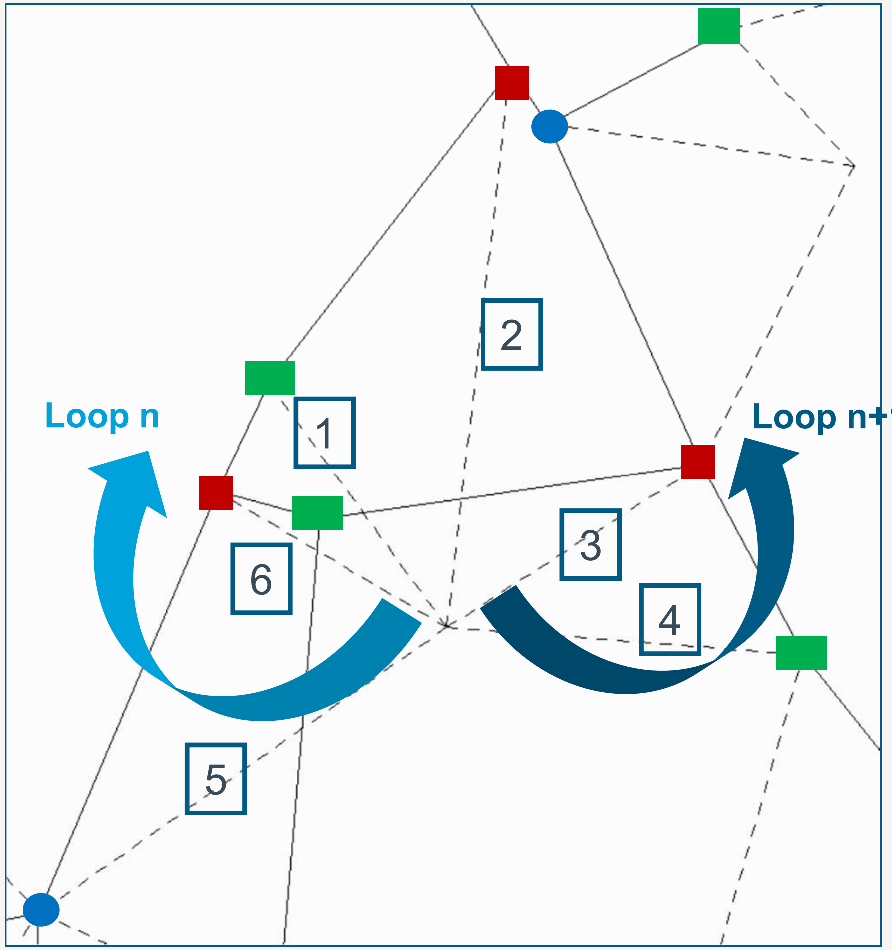
Imbalance between zones & network coverage

If congested, likely to cause instability in link flows due to oscillation in CC flows

For example

- Loop N favours CCs 1 & 6
- Loop N+1 switches to CCs 3 & 4
- Oscillates

Greater impact in forecast years?



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Step 6 – Address Problem Coding (ii)

Short Links causing stacking problems

Frequent occurrence

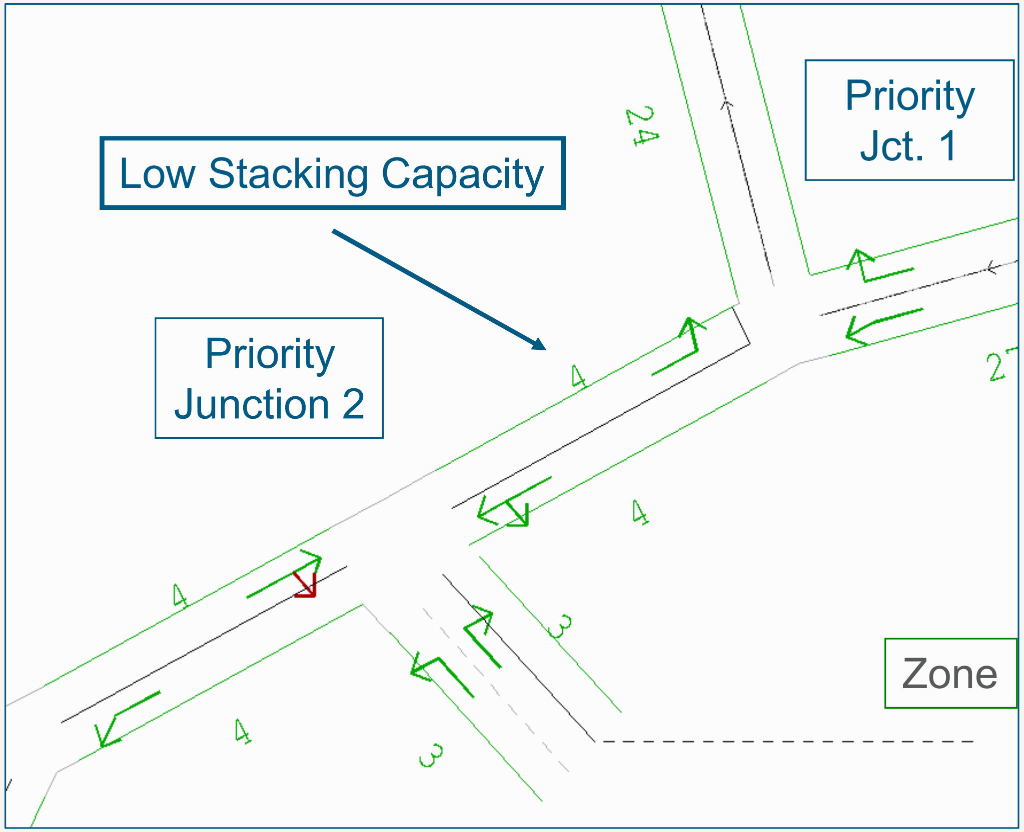
For example, link 2-1 has < 5 pcus stacking capacity

- Blocking back from Node 1
- Zonal flow from Node 2 now turns left
- No blocking back at Node 1
- Zonal flow from Node 2 now turns right
- **Repeat**

Leads to instability in link flows & costs

- Will be captured in Table L(8)
  - Look for +/- change in block back marker ('+')

Check for Serious Warning 188



Step 6 – Address Problem Coding (iii)

Turn 72888-72889-78008

Flare Coding

Provide more realistic coding options for partial lanes

In certain cases, negative impact on simulation stability when V/C >100%

Eg: Table L(8) #2 turn 72888-72889-78008

Advice:

Check junction coding & demand forecasts

Code as dedicated RT Lane?

› Reduce sensitivity

Updates for Table 2 in 11.5 Beta to indicate flare turn

RANK	A	B	C	D E L A Y S DIFFERENCE	CURRENT	PREVIOUS	CAPACITIES CURRENT	PREVIOUS	ACT FLOW PCU/HR
1	87964	81636	81635	652.74	887.17	234.43	49.66	49.66	69.74
2	72888	72889	78008	557.06	683.48	126.42	436.62	437.20	594.77

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Step 7 – Migrate to latest version

SATURN v11.5

Continuous development work to improve convergence

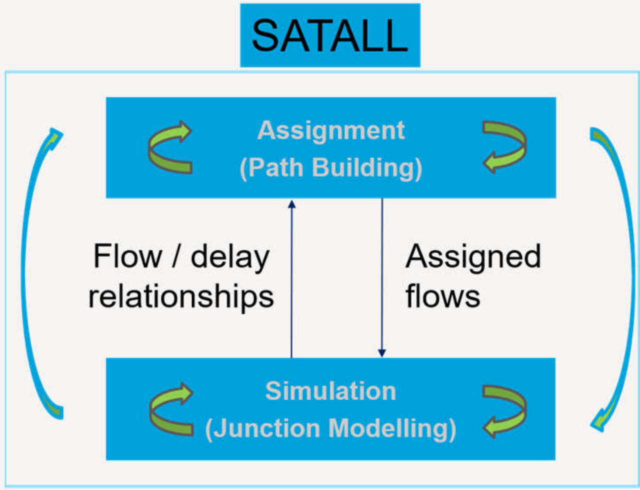
- Address inconsistencies within internal algorithms
- Combat questionable user inputs

Practical testing undertaken on large range of networks

- Noticeable improvements since 11.3.12W

If problems with convergence AND

- Sorted out the coding problems AND
- Tried the latest release THEN
- Contact SATURN support for assistance



Comparing 11.3.12W versus 11.4.07H for original 2031 TPS Ref Case TS3 (PM Peak) *MASL=120 NITS=50*

Version	Process	Loops	%Flow	%GAP	WebTAG?
11.3.12W	PM Peak	120	96.4%	0.02%	**No**
11.4.07H	PM Peak	108	97.8%	0.01%	**Yes**

Converges with SATURN 11.4.07H

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