2019 User Group Meeting – Area Charging

November 2019

UNIVERSITY OF LEEDS

FVVB Ltd

ATKINS

Member of the SNC-Lavalin Group

Modelling Area Charging

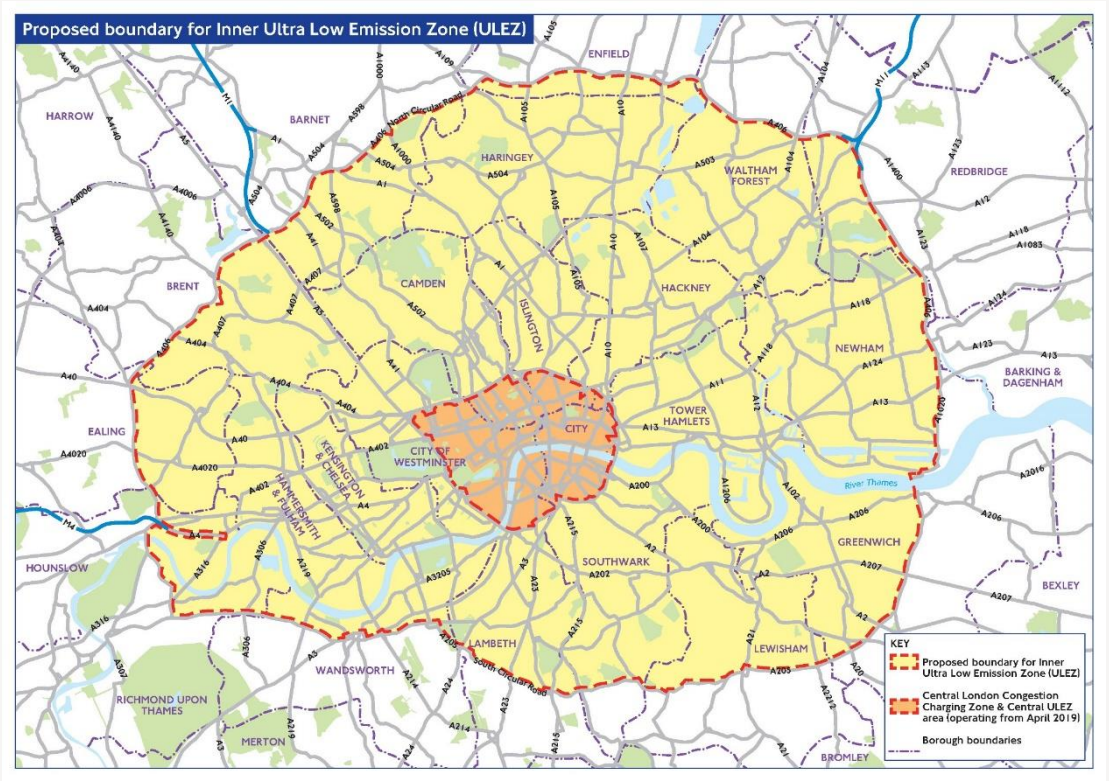
Modelling Charging Systems

New Area Charging Functionality developed in collaboration with TfL

- Required for modelling proposed ULEZ from 2021 under Mayor's Transport Strategy

Existing tolling method insufficient

- Existing Congestion Charging modelling using cordon charge
  - SALT (2003) -> SALT-C -> HAM P1 -> HAM P3 (2016)
  - Applied as entry / exit charge only
- Limitations:
  - Simplified approach
  - Double-counting of charges if multiple crossings
  - Only able to represent a **single** charging area
    - *Difficulties with previous CC Western Extension*
    - *Impossible to model separate / combined CZZ + ULEZ*



An Overview of Area Charging

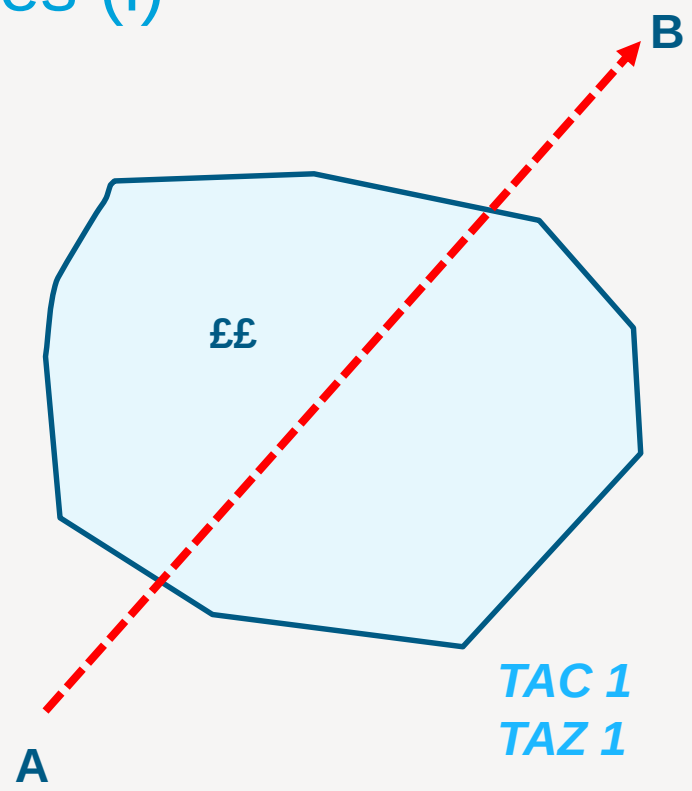
Key Differences from Toll-based Charges (i)

With Area Charges

- Every vehicle using the roads within an area pays a charge
- Vehicles not charged at the cordon but charged for travelling within the area
- The charged area consists of all links inside a water-tight cordon
  - Charge Area simply defined by specifying all the links in the cordon

Definitions

- **TAC** = **T**raffic **A**rea **C**harging System
- **TAZ** = **T**raffic **A**rea **Z**one within the Charging System



A-B "Total" Charged = ££

Key Differences from Toll-based Charges (ii)

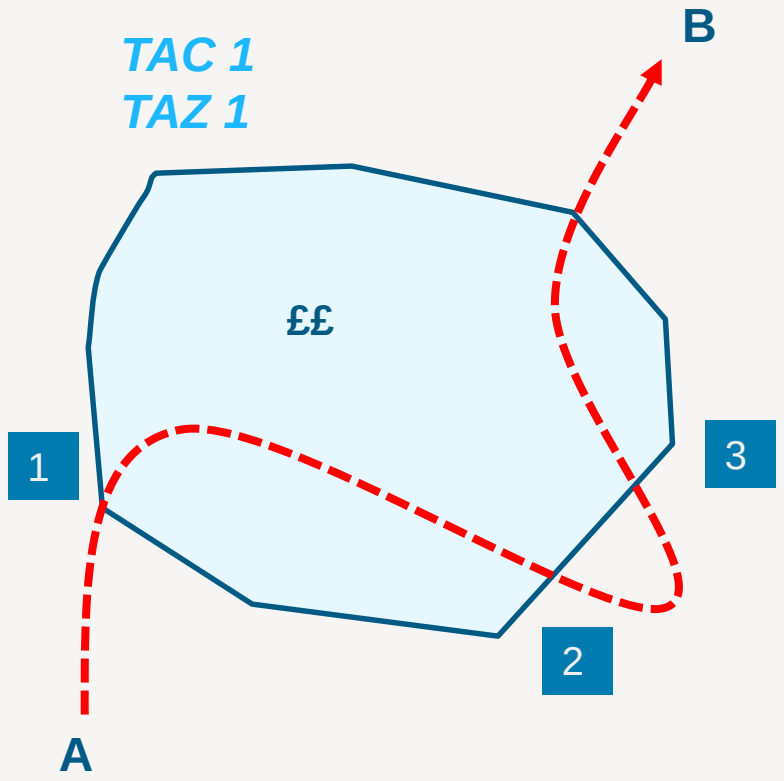
Multiple Crossings

› Once the charge has been paid, an O-D trip may leave and re-enter the charge area as many times as it likes without paying again.

› Area-based charging differs from defining a set of tolls on all entry and exit links to the same area where a toll may be paid more than once on exit/re-entry.

Travel within the TAC

› Traffic that uses roads within the area but neither leaves or enters the area may be charged.



A-B "Total" Charged = ££

Key Differences from Toll-based Charges (iii)

Multiple Zones

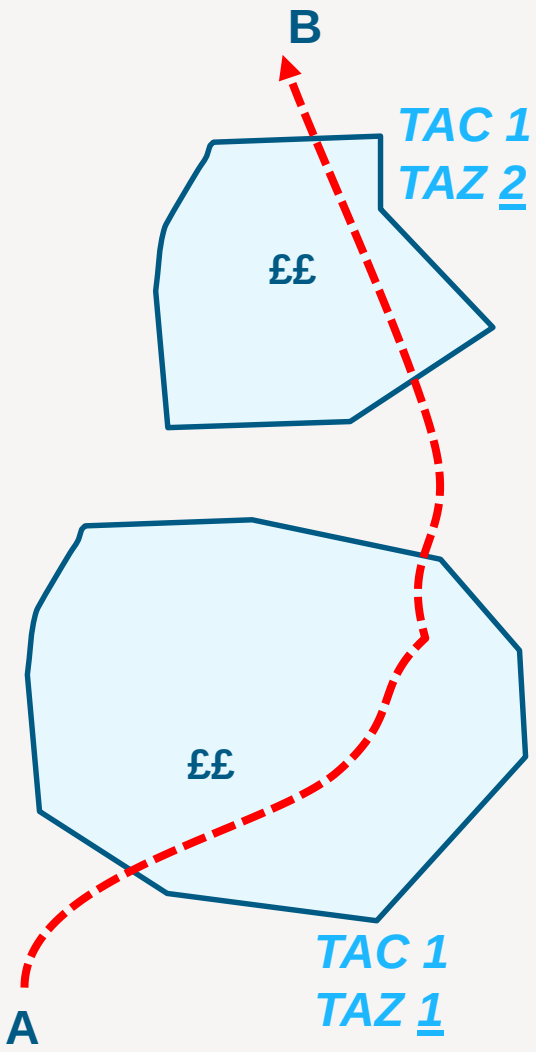
› Possible to define separate geographical areas within the same charging system

› In other words: once a trip enters one area and pays the charge it can enter/re-enter any other areas with the same charge system without paying an additional charge.

Definitions

› An individual cordoned area is called an “Area Zone” (TAZ)

› An “Area Charge” (TAC) can apply to multiple Area Zones (TAZs)
  › In this example, TAC1 consists of TAZ1 and TAZ2



A-B “Total” Charged = ££

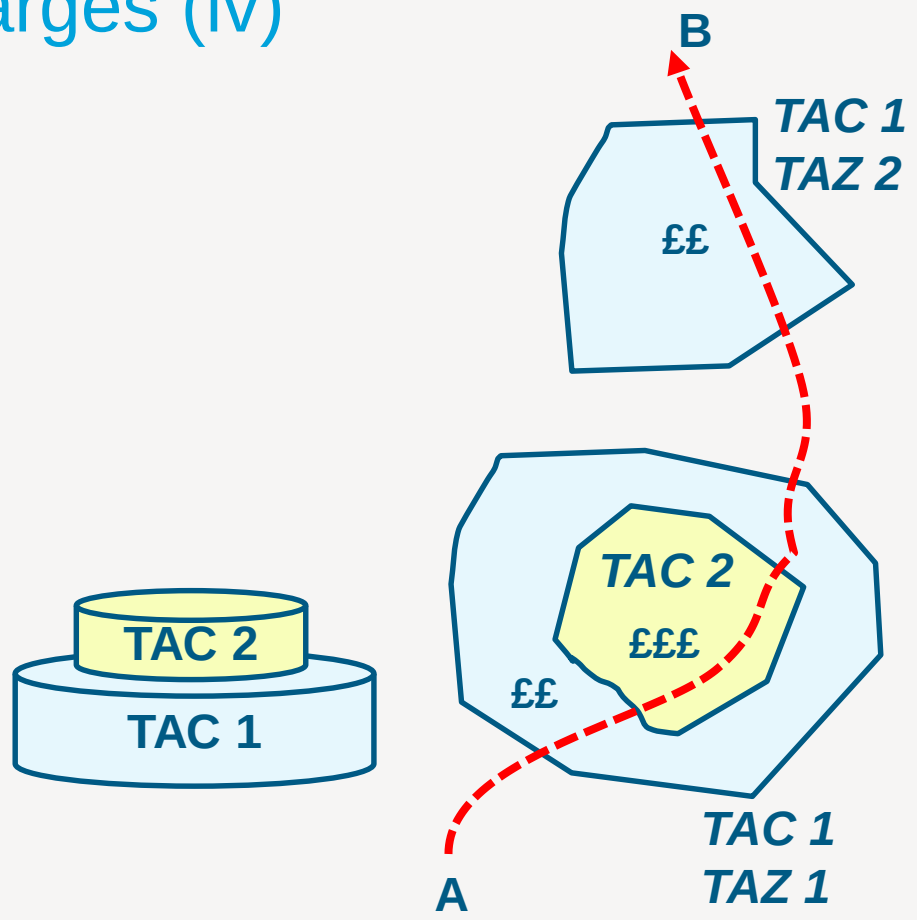
Key Differences from Toll-based Charges (iv)

Multiple Charge Systems

- Possible to have multiple charge systems
- In other words: multiple charge systems with different sets of charges and different sets of areas/zones

Restrictions

- Maximum of 2 TACs
  - For example:
    - *Central London Congestion Charging Zone*
    - *Ultra Low Emission Zone*
- Computational and data intensive!



A-B "Total" Charged = ££ + £££

Different Trip Types: Mandatory or Discretionary

Mandatory Trips

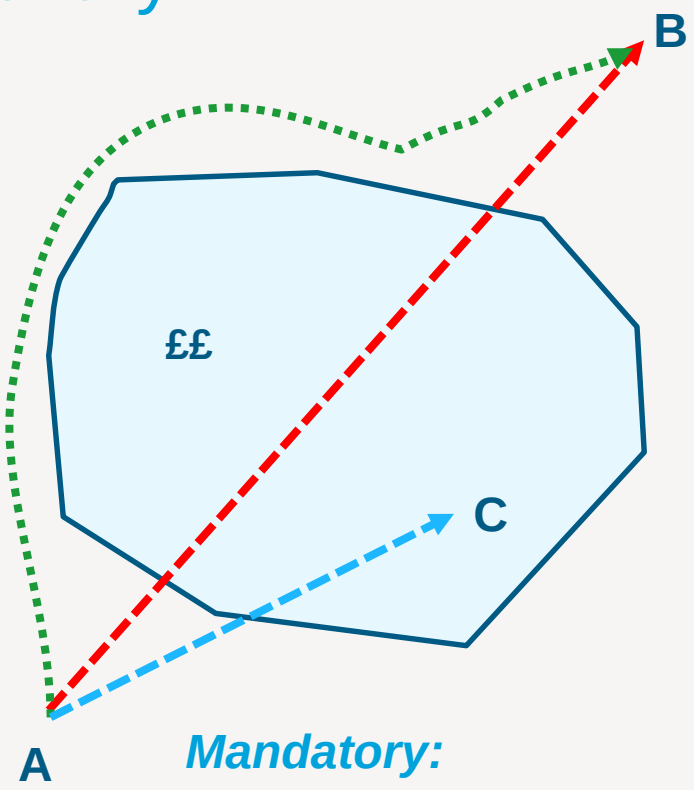
- If either one of the O or D lies inside a charge area itself then it has no option other than paying the charge are called ‘Mandatory Trips’.
  - For example, Trip A-C

Discretionary Trips

- O-D trips where neither O nor D lie within a charge area but their minimum cost route involves payment of the charge (ie goes through the area) are called ‘Discretionary Trips’.
  - For example, Trip A-B

For modelling purposes

- Likely to be greater interest in the trips opting for the discretionary charges rather than just all trips charged
- Similarly interest in congestion effects arising from those re-routeing to avoid the charges.



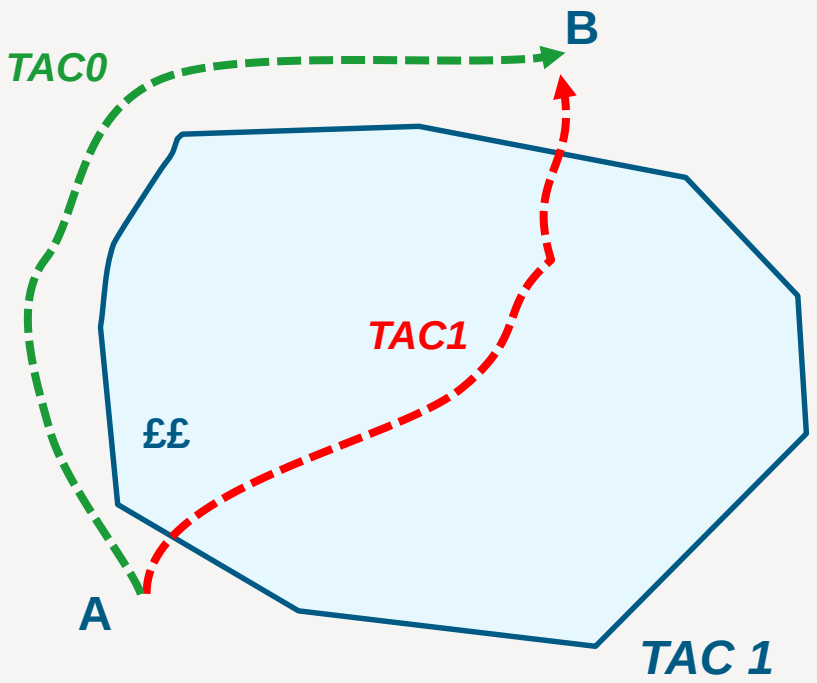
Mandatory:
A-C “Total” Charged = ££

Discretionary
A-B “Total” Charged = ££
if passing through

Charging System / Regimes (i) – For one TAC

Charging system are key to understanding the modelling approach and the outputs:

- Used to describe the possible options available to the user (and, hence, the network available to them to use)
- With single charge system (TAC1), we can have only two possible regimes:
  - *TAC0* = not pay Charge
  - *TAC1* = pay Charge
- Outputs reported either by their regime identifier and/or charge system (*TAC0*, *TAC1*)
  - Discretionary flows using either *TAC0* or *TAC1*
- NB: Working towards reporting by Traffic Area (charge) Regimes (TARs) for final release rather than TACs (ie TAR0 but TAC0)

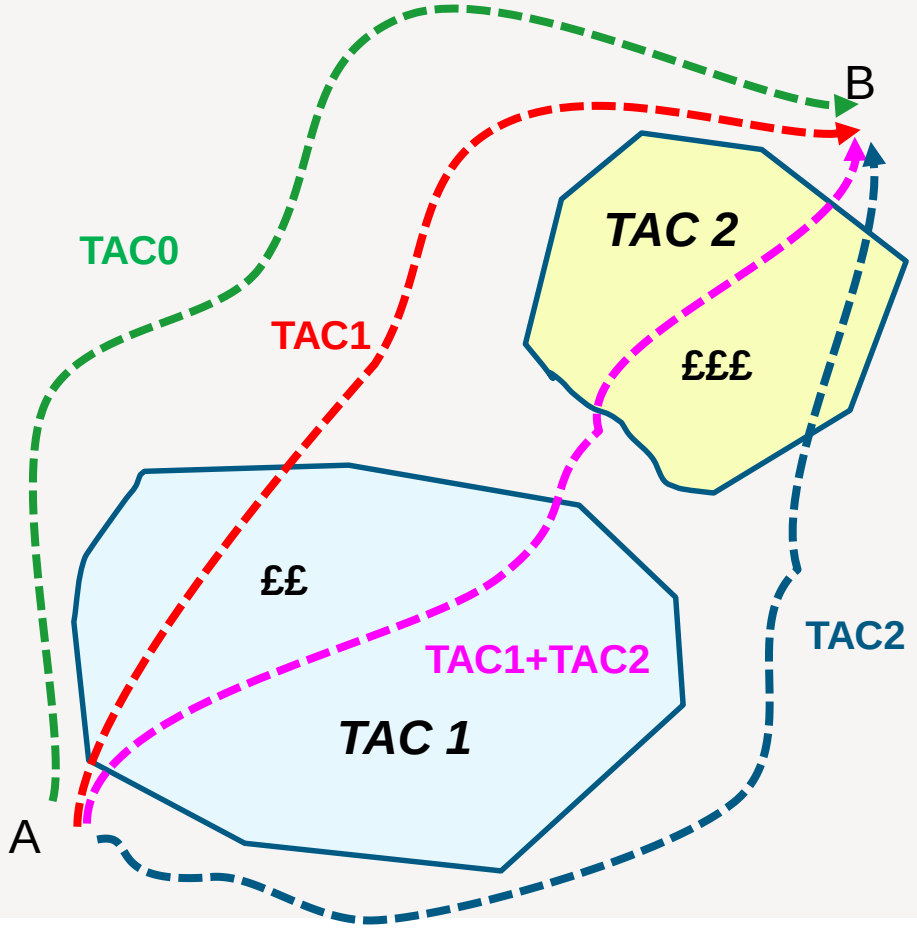


Charging Regimes (ii) – For two TACs

Similar principles for two TACs:

- With two charge system (TAC1+TAC2), we can have four possible regimes
  - TAC0 = not pay either Charge
  - TAC1 = pay 1st Charge
  - TAC2 = pay 2nd Charge
  - TAC1+TAC2 = pay both 1st and 2nd Charge

- NB: Working towards reporting by Traffic Area Regimes (TARs) for final release
  - TAR0 = not pay either Charge
  - TAR1 = pay 1st Charge
  - TAR2 = pay 2nd Charge
  - TAR3 = pay both 1st and 2nd Charge

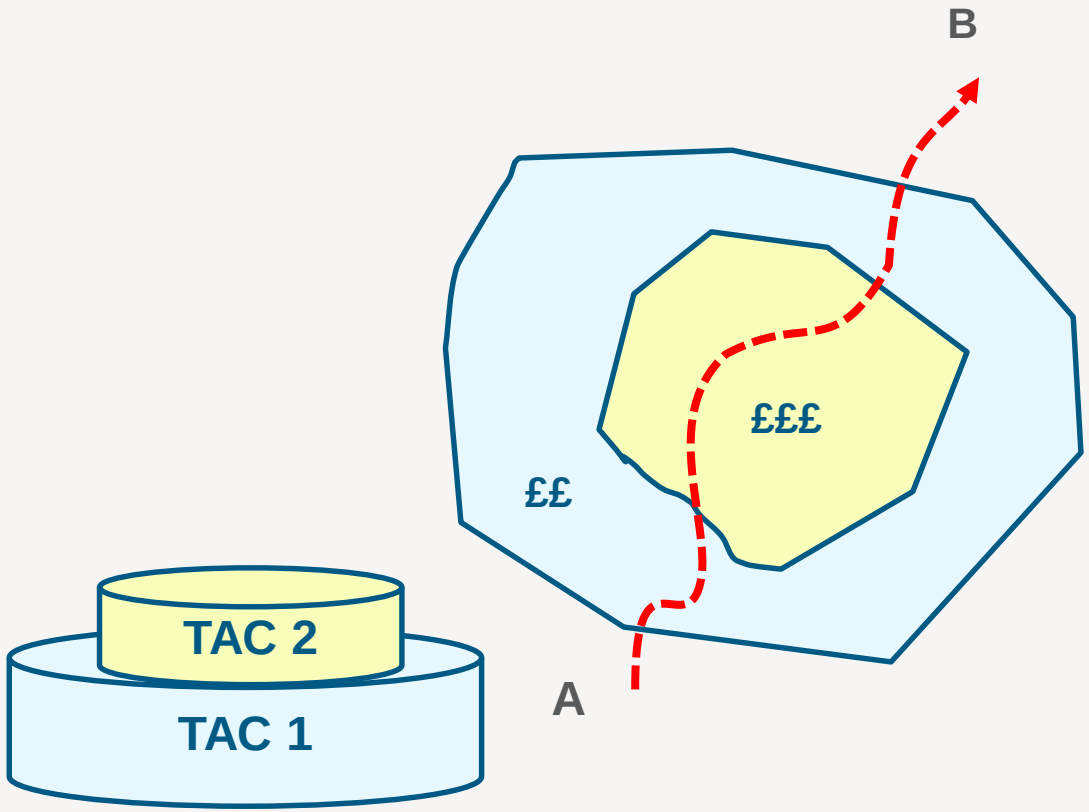


Supplementary Charges

Supplementary Charges

- Possible to add an extra or *supplementary* charge for one Charge System to use a different Charge System
  - i.e. an additional charge when a trip entering one charge system enters another charge system
  - *For example: if TAC1 (ULEZ) = £1 charge, TAC2 (CCZ) = £2 & Supplementary charge = £1.50*
    - *Trip from A to B = TAC1 (£1) + TAC2 (£2) + Supplementary (£3) = £4.50*

- Coded but not fully extensively tested
  - TfL requirement for ULEZ forecast years



Compliance within the Assignment (to be withdrawn)

Development Option

A development option to enable an existing user class to be split internally into ‘COMpliant’ and ‘non-compliant’ trips within the assignment process

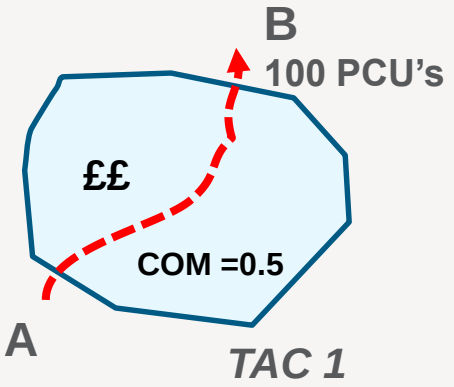
- Intended for ULEZ modelling with compliance based on vehicle emission standards
- Outputs are demand weighted combination

Drawbacks

- Currently only permits single factor + complicated if compliance differs between charging systems
- Outputs complicated
  - whilst valid, outputs too complicated to readily decipher!
  - need to run analysis programs multiple times with compliance switches to provide all answers

Alternatives

- Code compliant trips as separate user classes
- Downsides: More UCs / layers / data fields etc but runtimes reduced by ‘twinning’ option to share existing built paths



A-B Total Received = (100 x 0.5) x ££

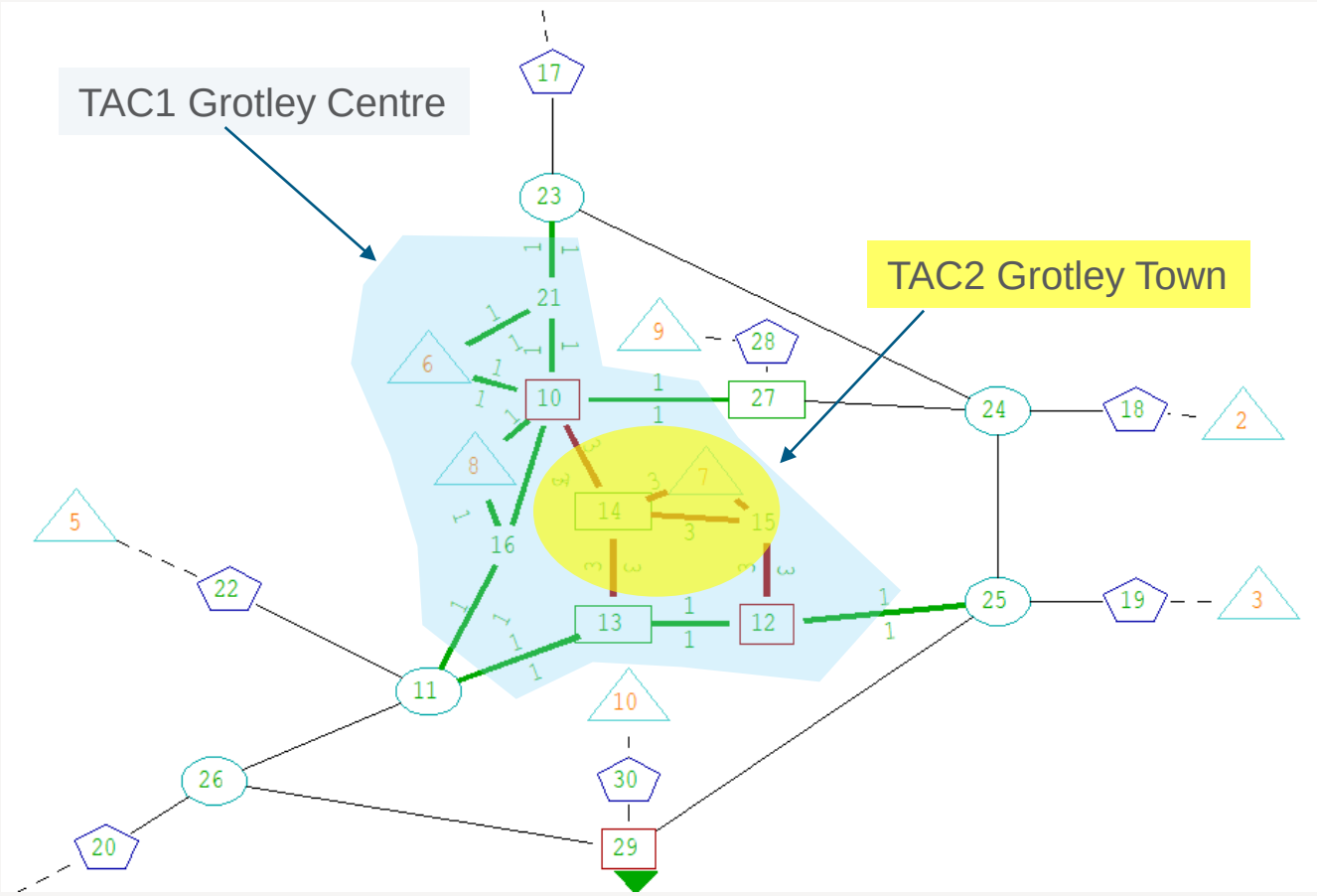
Setting up an Area Charging Model Run – Grotley Test Example

Straightforward

Using Grotley Test example for ULEZ scheme

- Existing 2 User Class (UC) network
  - UC1 = ‘Cars’ & UC2 = ‘Goods’
- 2 Area Charging Systems
  - *TAC 1 = Grotley Town (ULEZ)*
  - *TAC 2 = Grotley Central (Congestion)*
- ULEZ compliance by UC
  - Cars = 40% compliant
  - Goods = 100% non-compliant
- Charges by UC
  - UC1 Cars (non-comp): TAC1 = £1, TAC2 = £2
  - UC2 Cars (comp): TAC1 = £0, TAC2 = £2
  - UC3 Goods (non-comp): TAC1 = £4, TAC2 = £8

Grotley Network



Setting up an Area Charging Model Run (ii) – Demand

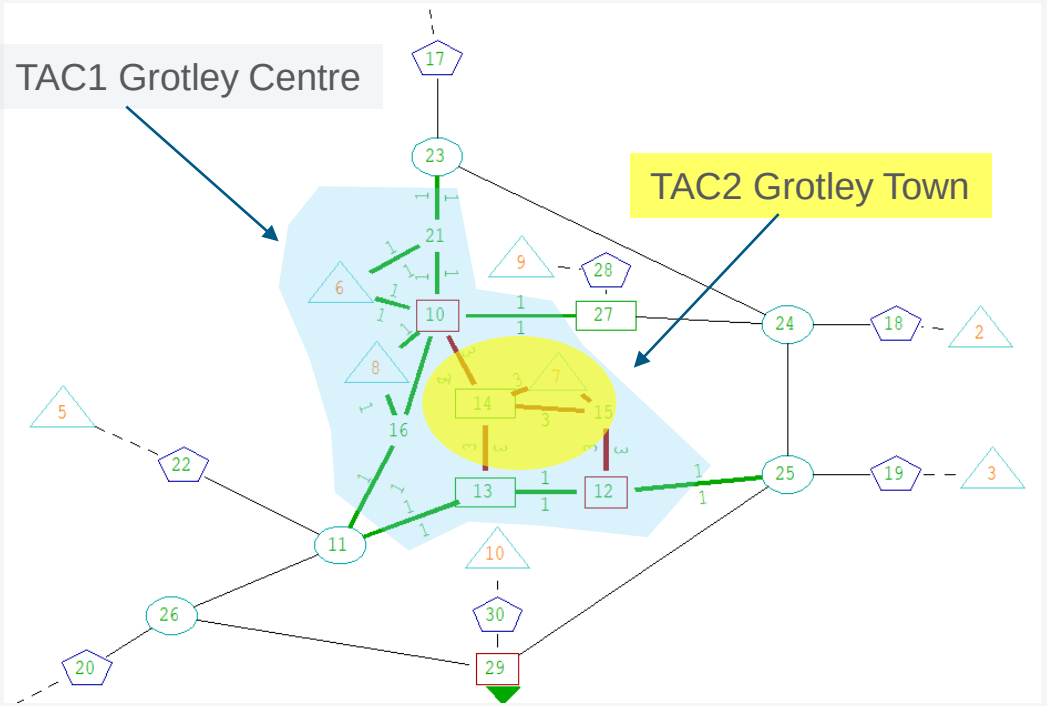
Demand Matrices

- No changes required …
  - …. unless wishing to modelling ULEZ compliance by UC

Changes for ULEZ Compliance

- For Grotley example
  - Split existing demand matrices into separate UC
    - *UC1 Car -> UC1 Car (non-compliant)* *[ie 60% of existing UC1]*
    - *-> UC2 Car (compliant)* *[ie 40% of existing UC1]*
      - *Identical except for different Area Charging levels*
    - *Rename UC2 Taxi -> UC3 Taxi*
- Update 44444 & 88888 for extra UCs
  - Ensure new 'Compliant' and 'Non-compliant' UCs are adjacent in 88888 card!
    - *Enables new option to be used to share the path building (as same PPK/PPM values) & reduce runtimes*

Grotley Network



Setting up an Area Charging Model Run (iii) - Network

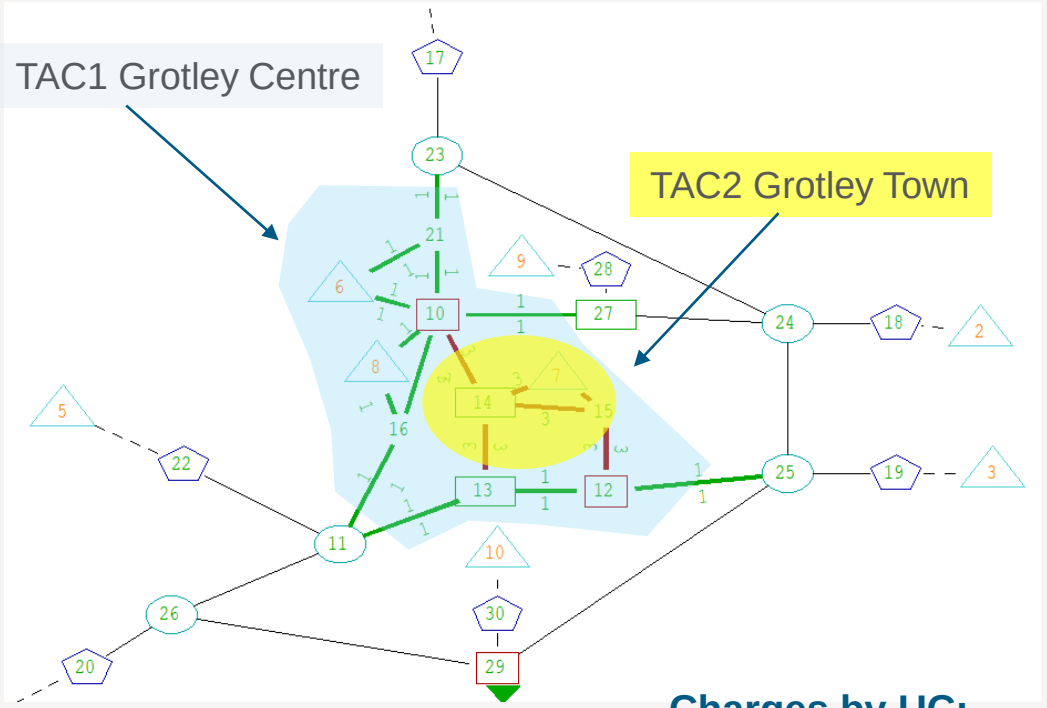
Network Changes

- Add new 44444 card
- For TAC1
  - State **TAC Charge 1**
  - Define charge(s) by UC (in pence)
  - State **TAZ** and provide 'name'
    - *Define TAZ by its cordon links*
  - Repeat for other TAZ within TAC1
- End with 99999
- For TAC2
  - Repeat as for TAC1

TAC Coding

```
44444
TAC Charge 1
100 0 400
TAZ Grotley Town
   21   23
   10   27
   12   25
   13   11
   16   11
99999
TAC Charge 2
200 200 800
TAZ Grotley Central
   14   10
   14   13
   15   12
99999
99999
```

Grotley Network



Charges by UC:
TAC1 = £1, £0, £4
TAC2 = £2, £2, £8

Internal SATURN Processes

SATURN Internal Calculations (i)

Area Charging builds upon existing processes:

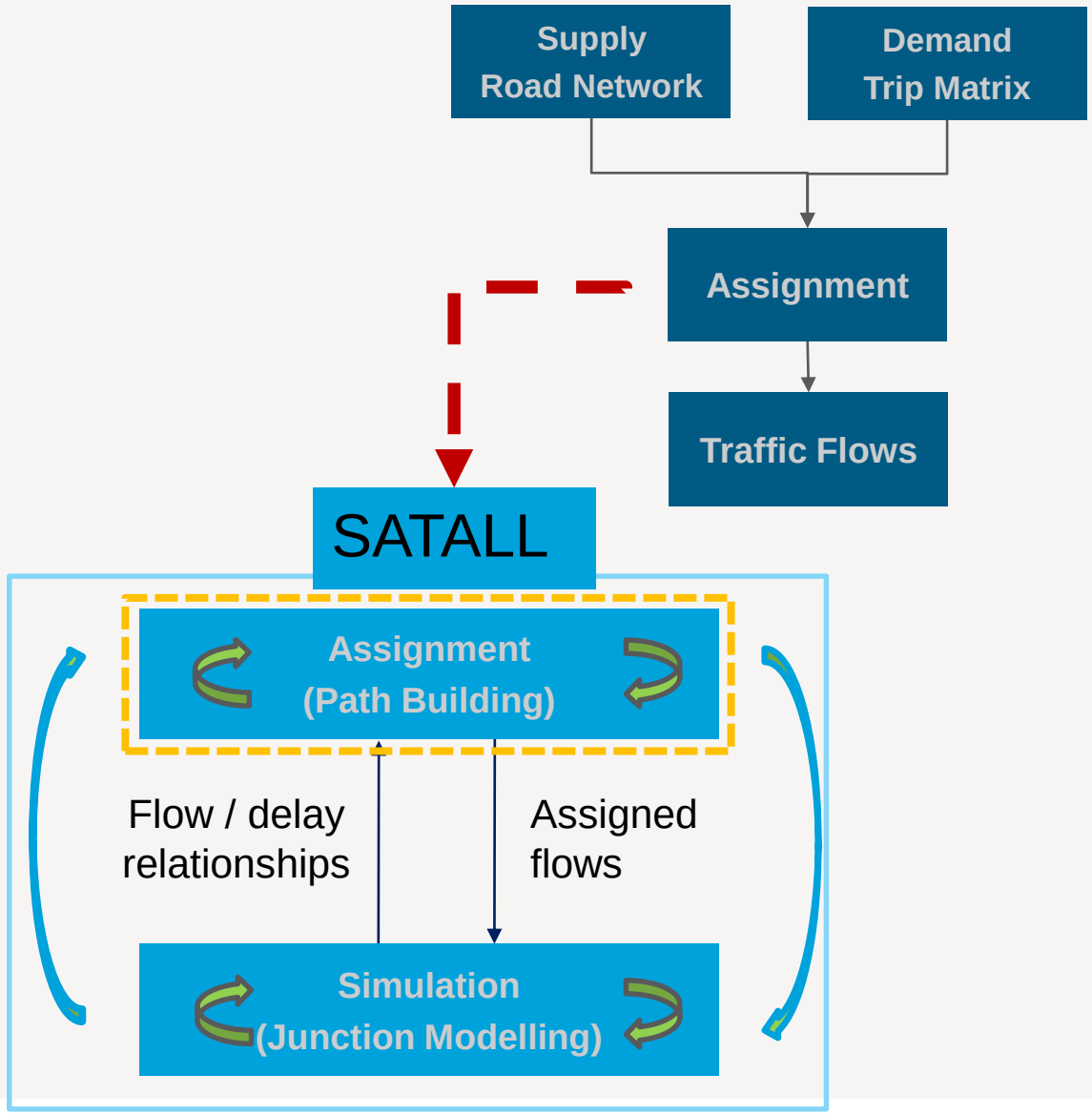
- Undertaken within Assignment – no changes to simulation

Data storage:

- Additional DA codes for Area Charging information
  - Flows, skims etc
- 'Blocked' output matrices
  - for different charge system outputs
- Requiring larger array sizes
  - LoHAM X7 -> X?

Analysis Options:

- Some new batch files & P1X analysis options to handle TAC-based assignments



SATURN Internal Calculations (ii)

Modified path-building process

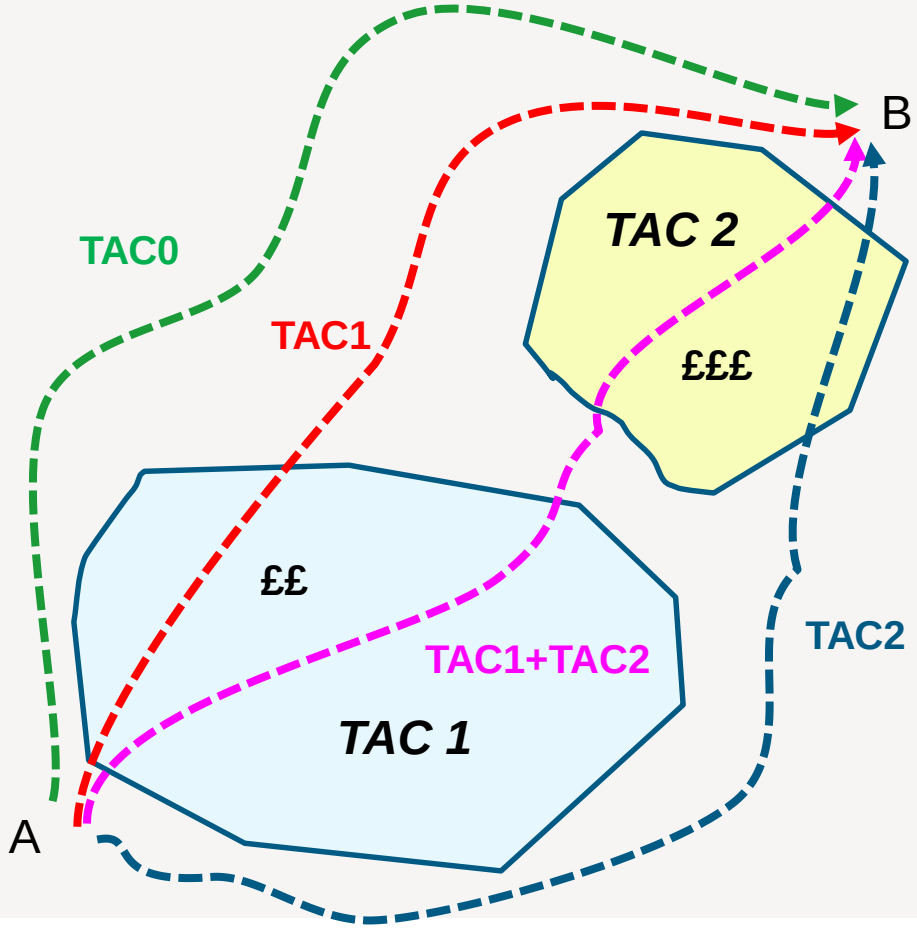
- Create sub-area networks accessible for:
  - each User Class … as before so no change!
  - And then further by area charge regime too

Full UC Network Available

Each Link defined as either in TAC0, TAC1, TAC2 or TAC1+2

UC Sub-Area Network available for assignment

‘TAN0’? (TAC0 links only)	‘TAN1’? (TAC0 + TAC1 links)
‘TAN2’ ? (TAC0 + TAC2 links)	‘TAN3’? (TAC0 + TAC1 + TAC2 Links)



- NB: Working towards reporting by Traffic Area Regimes (TARs) for final release

SATURN Internal Calculations (iii)

Path-building process

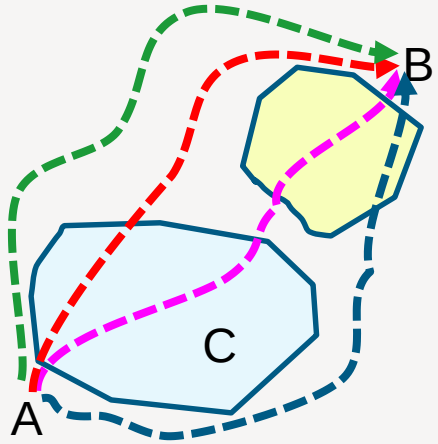
- Each path has marker showing those that pass through charging areas (and, hence, have charge) and those that avoid

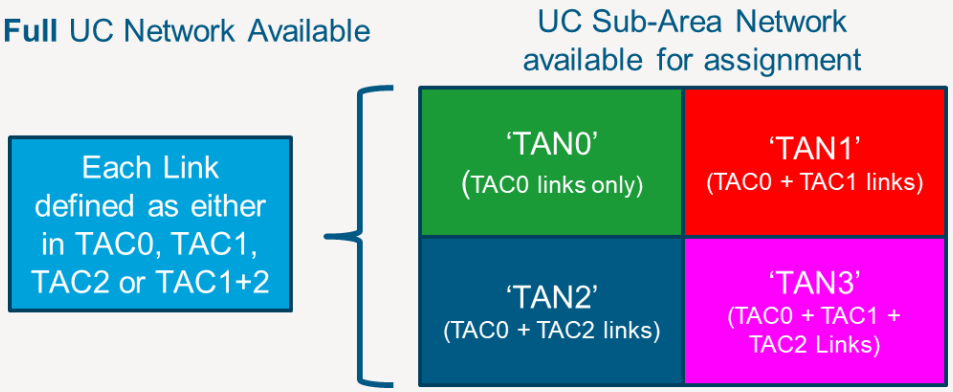
Assignment

- For each user class, determine optimum route between each OD-pair based on minimum generalised costs (incl. charges)
  - Mandatory trips (eg A-C) – have to pay a charge
  - Discretionary trips (eg A-B) – may or may not
    - *Determined by the minimum generalised cost*

Increased Model Runtimes

- Greater number of sub-area networks (**2x** for 1TAC, **4x** for 2TAC)
- Assignment longer but similar simulation
  - Clear role for SATGPU
  - New option: shared paths for 'twinned' (adjacent) User Classes





SATURN Internal Calculations (iv) – Blocked Matrices

Input Matrix - demand

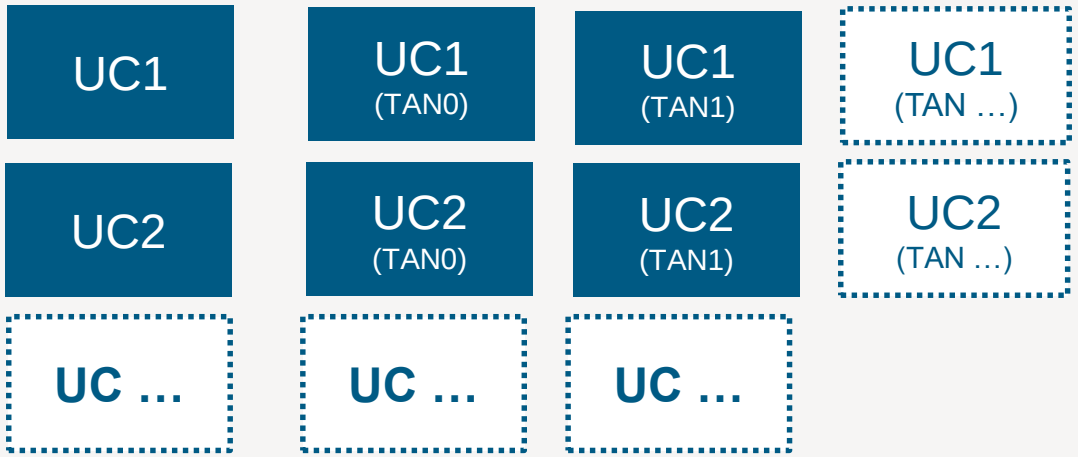
› Traditional single ‘column’ matrix stacked per level

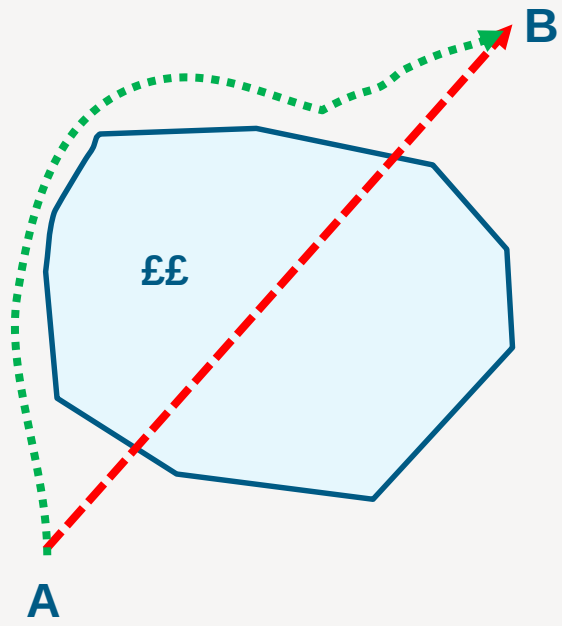
Output Matrices - demand & skims

› Information generated & stored by sub-area network / regime

› Using BLOCKED matrices

Standard UFM **Blocked UFM**





Full UC Network Available

Each Link defined as either TAC0 or TAC1

UC Sub-Area Network available for assignment

TAN0? (TAC0 links only)

TAN1? (TAC0 + TAC1 links)

› Use MXUNBLOCK to convert to standard format

Analysis and Outputs

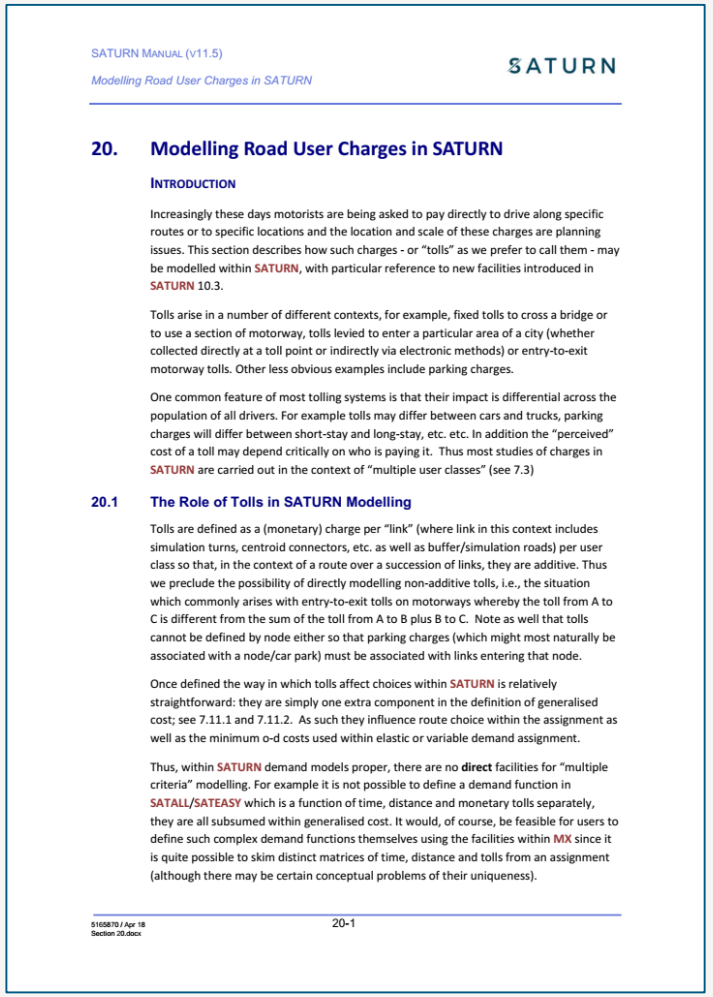
Outputs and Analysis - Introduction

Outputs and Analysis broadly split into the following topics

- Summary Statistics
- P1X analysis
- Trip Matrices
- Cost Matrices

Work in Progress

- Current focus on secondary analysis
  - Extended functionality
- P1X option names and Batch file names are likely to change
- Check latest Section 20 for more information



SATURN Manual (v11.5)

Modelling Road User Charges in SATURN

SATURN

20. Modelling Road User Charges in SATURN

Introduction

Increasingly these days motorists are being asked to pay directly to drive along specific routes or to specific locations and the location and scale of these charges are planning issues. This section describes how such charges - or "tolls" as we prefer to call them - may be modelled within SATURN, with particular reference to new facilities introduced in SATURN 10.3.

Tolls arise in a number of different contexts, for example, fixed tolls to cross a bridge or to use a section of motorway, tolls levied to enter a particular area of a city (whether collected directly at a toll point or indirectly via electronic methods) or entry-to-exit motorway tolls. Other less obvious examples include parking charges.

One common feature of most tolling systems is that their impact is differential across the population of all drivers. For example tolls may differ between cars and trucks, parking charges will differ between short-stay and long-stay, etc. etc. In addition the "perceived" cost of a toll may depend critically on who is paying it. Thus most studies of charges in SATURN are carried out in the context of "multiple user classes" (see 7.3)

20.1 The Role of Tolls in SATURN Modelling

Tolls are defined as a (monetary) charge per "link" (where link in this context includes simulation turns, centroid connectors, etc. as well as buffer/simulation roads) per user class so that, in the context of a route over a succession of links, they are additive. Thus we preclude the possibility of directly modelling non-additive tolls, i.e., the situation which commonly arises with entry-to-exit tolls on motorways whereby the toll from A to C is different from the sum of the toll from A to B plus B to C. Note as well that tolls cannot be defined by node either so that parking charges (which might most naturally be associated with a node/car park) must be associated with links entering that node.

Once defined the way in which tolls affect choices within SATURN is relatively straightforward: they are simply one extra component in the definition of generalised cost; see 7.11.1 and 7.11.2. As such they influence route choice within the assignment as well as the minimum o-d costs used within elastic or variable demand assignment.

Thus, within SATURN demand models proper, there are no **direct** facilities for "multiple criteria" modelling. For example it is not possible to define a demand function in SATALL/SATEASY which is a function of time, distance and monetary tolls separately, they are all subsumed within generalised cost. It would, of course, be feasible for users to define such complex demand functions themselves using the facilities within MX since it is quite possible to skim distinct matrices of time, distance and tolls from an assignment (although there may be certain conceptual problems of their uniqueness).

5165870 / Apr 18
Section 20.docx

20-1

Outputs and Analysis (i) – Summary Statistics

Summary Statistics

- Summary and descriptive statistics including Total charges paid, Total flows paying charges etc for each user class and charge regime
  - printed within LPT file
  - Also available as part
    - *of standard simulation statistics in SATLOOK and P1X*
- Further details / breakdowns to be added to the summaries
  - especially ‘mandatory’ trips

NB: some items still labelled as ‘Tolls’ rather than ‘Charges’ in Beta

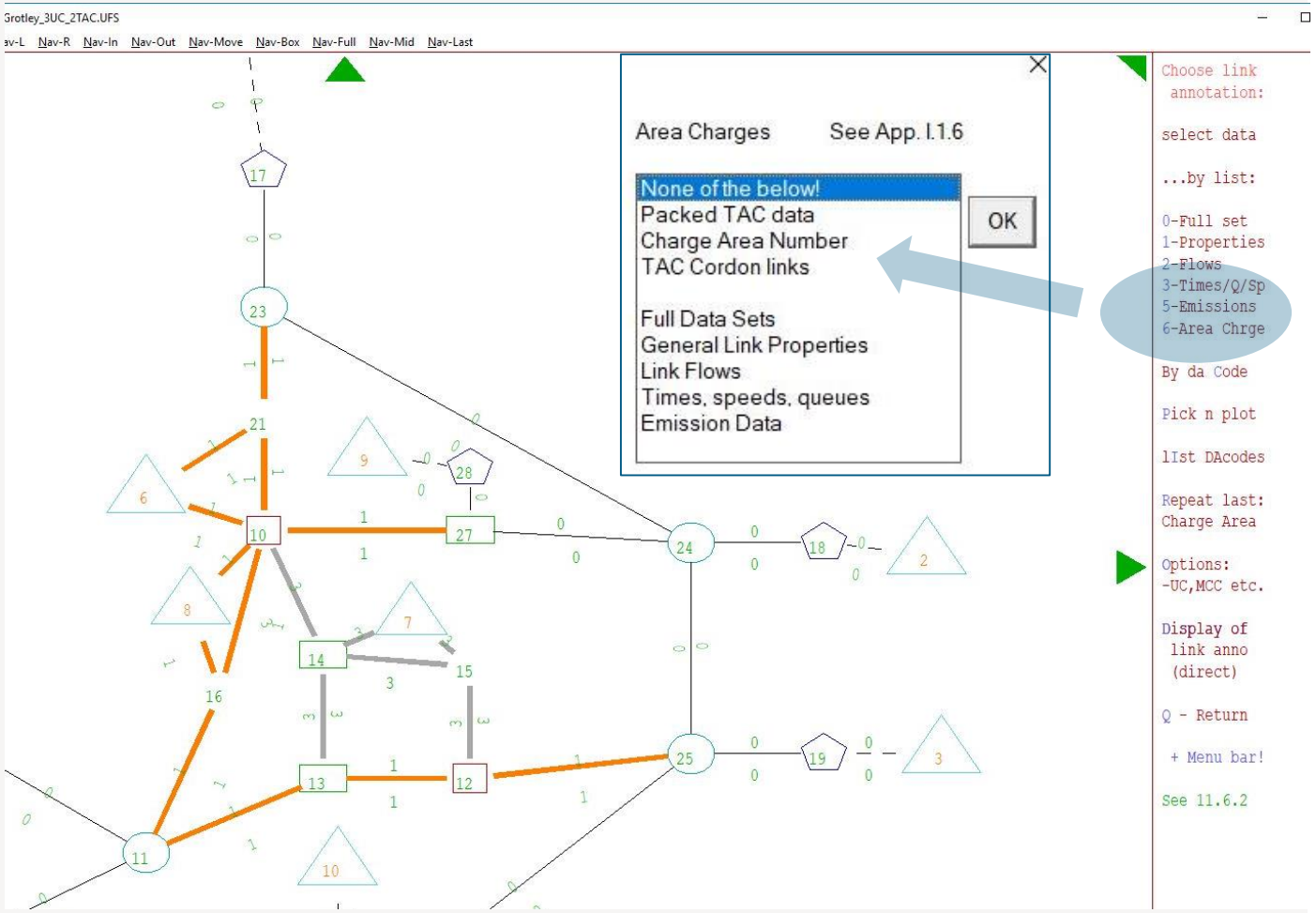
Extract from LPT

```
TOTAL DISCRETIONARY AREA TOLLS=      146993.0 PCU-SEC/HR
            BY USER CLASS:  1 =        5334.5
                            2 =        4525.8
                            3 =      116942.1
                            4 =       12904.0
                            5 =        1509.8
                            6 =        2842.3
                            7 =        2934.3

TOTAL DISCRETIONARY TRIPS    =        4397.6 PCU/HR
            BY USER CLASS:  1 =         153.6
                            2 =         130.6
                            3 =        3477.1
                            4 =         420.7
                            5 =          38.5
                            6 =          90.0
                            7 =          86.9
```

Outputs and Analysis – P1X (i)

New 6. Area Charging Option in *Display Menu*

- Three new link data items within P1X ‘Link Annotation’
  - *Packed TAC data*
  - *Details of Charge Number*
    - *1 if in TAC 1, 2 if in TAC 2, 3 if in both, etc.*
  - *Links on the cordon of a TAZ:*
    - *0 for outside, 1 for TAC 1,*
    - *2 for TAC 2, 3 for both*
- By default, links coloured by Charge Number



Outputs and Analysis – P1X (ii)

New Area Charge Menu

› in P1X under Analysis Options

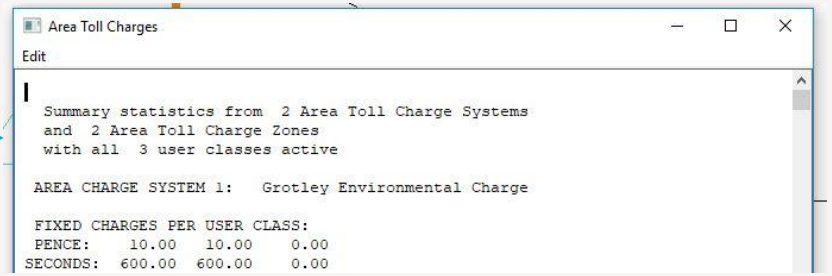
```
 Analysis
 Options:

Select link                >
SLA: Basket                >
Joy ride                   >

Trees etc.
Not with TAC

Area Charges               >
Information                >
ME2 Analysis               >

Full Forest
(vrs Quik F)

Q - Return

 + Menu bar!

See 11.8
```

View Trees

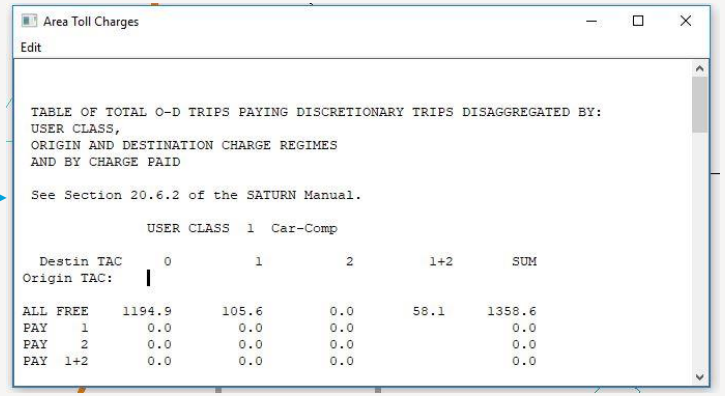
Display links by TAC

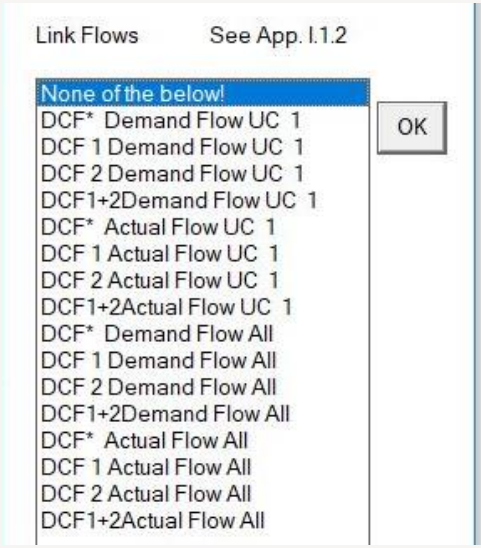
```
Area Charge
  Menu:
 See 20.6.15

Information                >
Tij Tables                 x
DCF Flows                  x

Build trees:

Origin unset               x
Destin unset               x
U.C. =  1                  ?

Sp tree? Yes               (•)

OVerlay                    ( )
 trees? No

Hilite TACS?               x
 ON
Links? Yes                 x
cordoNs? No                x

Q - Return

 + Menu bar!

See 20.6.4
```

Network Data



Discretionary OD Trips by UC and Charge Regime



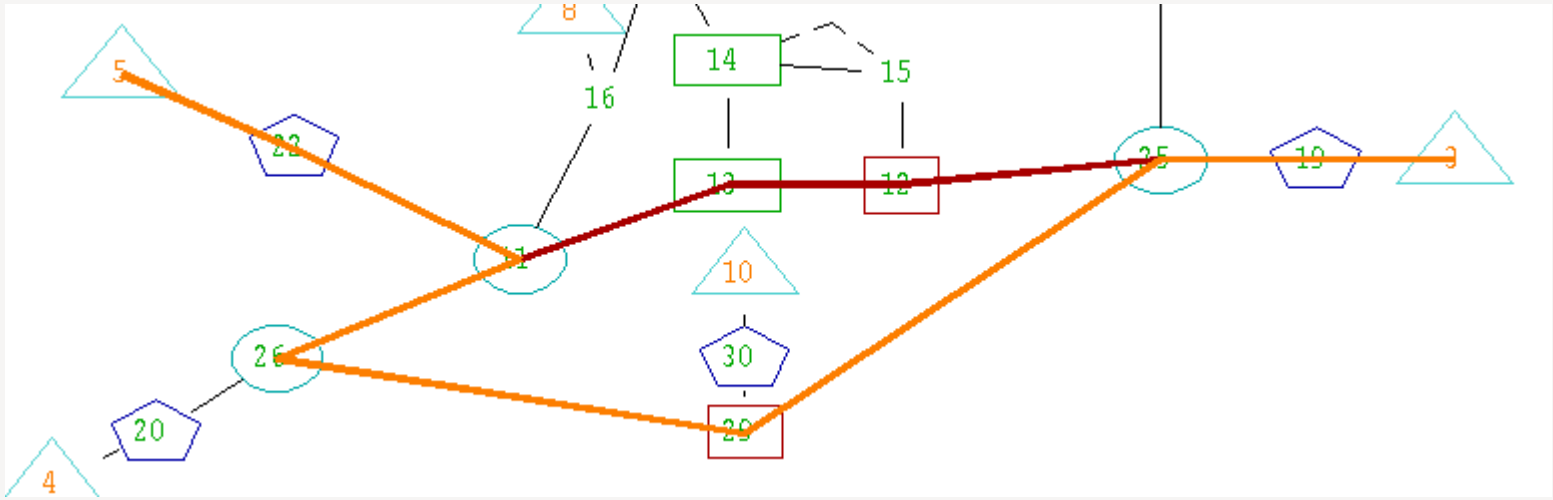


Discretionary Choice Flows by UC and Charge Regime

Outputs and Analysis – P1X (iii)

Individual O-D routes and Forest in P1X

- Individual O-D routes
  - *Option to show all potential minimum cost routes based on whether or not certain TAC charges are paid*



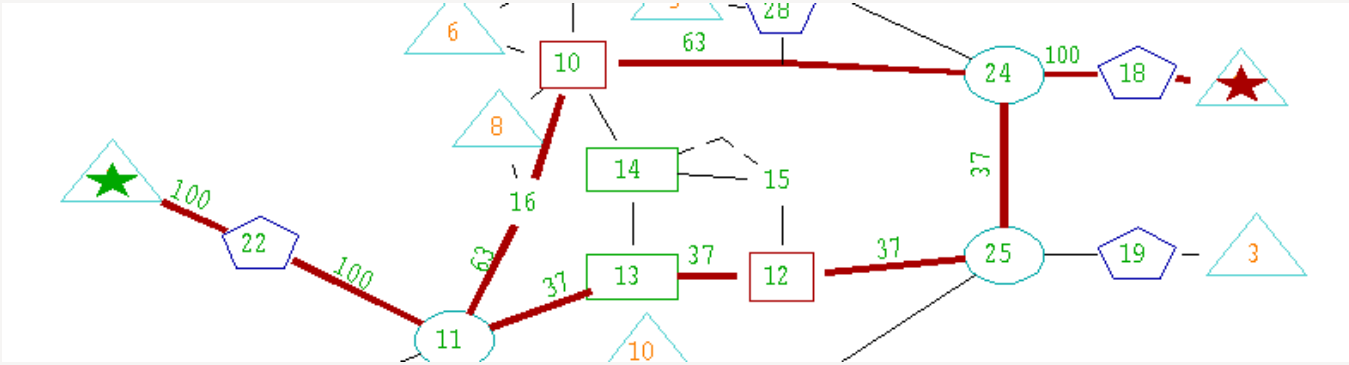

```
TAC routes -
Origin      5
Destin      3
User Class 1
Tij=  158.56
2 Ch. Areas

Toll charges
 in seconds:
 1      6.0
 2      6.0
1+2    12.0

No bans
Pay 2 tolls?
Cost:  108.3
Dist:  644.0
Time:   88.9
Toll:   12.0
Total  120.3

Ban TAC 1
Pay toll 2:
Cost:  108.3
Dist:  644.0
Time:   88.9
Toll:    6.0
Total  114.3

 *Optimum*

Ban TAC 2
Pay toll 1:
Cost:  162.0
Dist: 1220.0
Time:  125.3
Toll:    6.0
Total  168.0

Ban TAC 1&2
Pay no tolls
Cost:  162.0
Dist: 1220.0
Time:  125.3
```

Outputs and Analysis – P1X (iv)

Individual O-D routes and Forest in P1X

O-D Forests

- Option to show all routes generated within an assignment for a specific OD pair.
- Same as existing Forest feature, but in addition shows % of trips which pay in each regime, together with average charge paid.
- NB: existing Forest option under Analysis Menu is disabled for TAC networks




```
Forest for:

Origin      5
Dest.       2
User Cl.    1

Tij=    38.02

Average:
Time =    112
Delay=      7
Dist =    931
Speed= 29.99

Minimum Cost
    145.69

Maximum Cost
    145.76

Average Cost
    145.72

Delta (%) =
      0.019

% TOLL PAID:
TAC 1     0.00
TAC 2   100.00
 1+2      0.00

Tolls Paid:
Pence     0.1
GCost     6.0
```

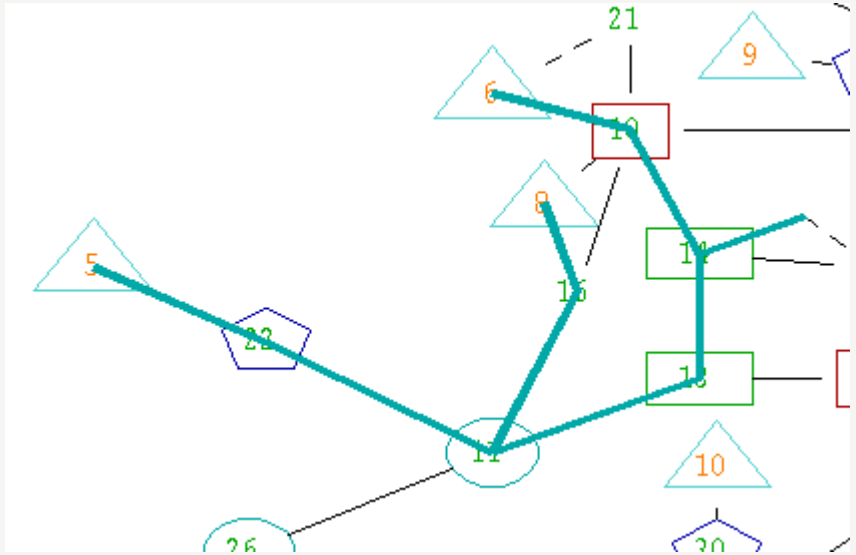
Outputs and Analysis – P1X (v)

Individual O-D routes and Forest in P1X

- Origin based Trees
  - Option to show complete Tree from a selected origin zone to all destination zones
  - Option to show all potential minimum cost routes based on each charging regime available

Select Link Analysis

- Link SLAs available
- Currently being extended for multiple links




```
TAC routes -
Origin     5
Outside TACs
User Class 1
Ch. Areas  2

Repeat with
 a new:
Origin
User Class

TAC trees to
0 - All Dest
1 - Not TACs
2 - TAC 1
3 - TAC 2
4 - TAC 1+2

Normal Trees
5 - All Dest
6 - Not TACs
7 - TAC 1
8 - TAC 2
9 - TAC 1+2

Q - Return

 + Menu bar!
```

Outputs and Analysis – Cost Matrices (ii)

Skimmed Cost Component Matrices (SKIMTAC)

- Standard Skim component matrices for TAC networks can be produced using a batch file SKIMTAC
  - further choice of: distance, time, tolls, penalties or a DA code can be set by a “keyword” on the command line
    - *eg SKIMTAC DIST or SKIMTAC TIME etc*
  - Keyword “ALL” (eg SKIMTAC ALL) skims distance, time, tolls, penalties and **trips** in one go and is recommended
    - *Trips paying the charge*
- produces two sets of matrices
  - disaggregated by regime in a BLOCKED format
  - as a weighted O-D average over the various choices.

New skim option QUICK *N (with a space!)*

- Skims Top N paths by %demand assigned
  - May significantly reduce runtimes - less used / important paths ignored
  - See afternoon session

SATURN 11.5 Development – Next Steps

Beta Release for HAM P4 – Dec'19

- Substantive development work complete – 'mopping up' required:
  - Includes some further (non-TAC) simulation updates
  - Extend P1X-based secondary analysis (eg more SLA options + summary statistics)
- As a SATURN v11.5 Beta Release
  - Available to all users under existing standard User Agreements
    - *Focus shifting towards more general testing*
  - Coincides with TfL HAM P4 launch

First full release - target Mar'20

- Faster assignments by sharing path-builds for User Classes with same PPK/PPM definitions
- Incorporate feedback from beta testing
- Release to all supported users
- New licence level 'X?' to accommodate HAM P4 LoHAM (5750 zones, 16UCs, 2TACs)

Update SATGPU for 11.5 & Area Charging - TBC

TfL HAM P4 Development