

Our development spreadsheet outputs trip end files, which are then fed into a CUBE Voyager full demand model to produce finalised UFM SATURN files. The values in the trip end files are based on base trip rates, anticipated growth (from TEMPRO projections), and additional trips beginning and ending at new developments. Developing a York Local Plan model for 2033 which provides a realistic representation of the impact of developments has taken six approaches:

1. TEMPRO capped:

- TEMPRO mode sets trip ends at all zones to comply with TEMPRO projections.
- The process of TEMPRO constraining may effectively reduce the trip ends to/from the zone of a new development, if the addition of the development's associated trips brings the total number of trips to/from that zone above the number projected by TEMPRO.
- This results in the number of trips to/from the development appearing to be lower in the resulting SATURN model than calculated in the development spreadsheet.
- The result of this is that TEMPRO capping can result in an unrealistic model when effects of specific zones/developments are the main focus of a model.
- TEMPRO capping, though required for WebTAG compliance, therefore produces a model which may be considered realistic only on a large-scale, strategic level.

2. Unconstrained:

- Unconstrained mode applies no constraint factors to the trips calculated to result from the addition of developments.
- However, producing unconstrained trip ends, unlike TEMPRO capping, does not apply background growth to zones with no specific additional developments to account for factors such as population growth.
- Since substantial growth in trip rates is anticipated in all zones by 2033, an unconstrained model therefore does not provide a realistic representation of how the network might operate in 2033.

3. TEMPRO capped/strategic sites unconstrained:

- In an attempt to capture the effects of both background growth (provided by TEMPRO capping) and the full calculated trip rates at major sites (provided by unconstrained mode), this was the first hybrid model.
- Unconstrained output trip ends were taken for strategic sites' zones (the largest and most severely affected by TEMPRO capping), and combined with TEMPRO capped output trip ends for all other zones to produce hybrid trip end files.
- When these trip ends were run through the CUBE Voyager full demand model, the results were the same as those produced by the fully TEMPRO capped model. Because the details of the full demand model assignment are convoluted, the reason that this produces the same result as TEMPRO capping is not easy to trace. It is currently believed that because the majority of the zones remained capped, the flow at the opposite end of each intended trip to/from a strategic site remained at a lower level than can sustain the full number of trips in the development spreadsheet, and that over the course of the full demand model's multiple iterations the majority of the addition trips effectively dissipated.

4. Modified TEMPRO capped:

- The TEMPRO capped model is taken as a starting point, since background growth factors have been correctly applied to this version.
- In order to force the trip ends at zones of strategic developments to equal those prescribed by the development spreadsheet, the trip matrix is rebuilt, based on the output TEMPRO capped trip matrices.
- First, the zones of strategic developments are identified.
- New origin and destination totals are assigned for each of these zones, equal to the number of departures and arrivals respectively prescribed by the development spreadsheet:
  - $R_{Ni}$  = new row  $i$  total (zone  $i$  development's total departures)
  - $C_{Nj}$  = new column  $j$  total (zone  $j$  development's total arrivals)
- Matrix elements which have strategic site zones as both their origin and destination assigned values. This is done in such a way that the proportions of an element's value to its (new) row and column totals is as close as possible to the same ratio in the original (TEMPRO capped) matrix. By doing this, the new elements are effectively scaled to the new row and column totals. Note that each of the following is only applied to the rows and columns for level 1 of the matrix (user class 1 – commuting cars):
  - $E_{Nij}$  = value of new matrix element in row  $i$ , column  $j$
  - $E_{Tij}$  = value of TEMPRO capped matrix element in row  $i$ , column  $j$
  - $R_{Tj}$  = total of row  $i$  of TEMPRO capped matrix (total zone  $i$  origins)
  - $C_{Tj}$  = total of column  $j$  of TEMPRO capped matrix (total zone  $j$  destinations)
  - $E_{Nij} = E_{Tij} \times \frac{R_{Ni}}{R_{Ti}} \times \frac{C_{Nj}}{C_{Tj}}$
- The row and column totals with the strategic O-D elements ( $E_{Nij}$  above) subtracted are then calculated for each strategic site zone. This gives the remaining number of trips to be allocated to each such zone's row and column. The corresponding totals from the TEMPRO capped matrix are also found:
  - $R_{NRi}$  = remaining row  $i$  total (for new matrix)
  - $R_{TRi}$  = corresponding row  $i$  total (from TEMPRO matrix)
  - $C_{NRj}$  = remaining column  $j$  total (for new matrix)
  - $C_{TRj}$  = corresponding column  $j$  total (from TEMPRO matrix)
  - $R_{NRi} = R_{Ni} - \sum_j E_{Nij}$
  - $R_{TRi} = R_{Ti} - \sum_j E_{Tij}$
  - $C_{NRj} = C_{Nj} - \sum_i E_{Nij}$
  - $C_{TRj} = C_{Tj} - \sum_i E_{Tij}$
- Matrix elements which have a strategic zone as either their origin or destination (but not both) are then assigned values. This is done in such a way that the row and column totals for strategic development zones equal the departures and arrivals prescribed by the development spreadsheet. While doing this, the ratios between these values are kept the same as they were in the original (TEMPRO capped) matrix:
  - If the element is in the row (but not column) of a strategic zone, its value becomes:

$$- E_{Nij} = E_{Tij} \times \frac{R_{NRi}}{R_{TRi}}$$

If it is in the column (but not row) of a strategic zone, its value becomes:

$$- E_{Nij} = E_{Tij} \times \frac{C_{NRi}}{C_{TRi}}$$

- The sum of all elements  $E_{Nij}$  assigned so far (i.e., the elements of the new matrix whose row, or column, or both correspond to strategic zones) is subtracted from the sum of all elements of the TEMPRO capped matrix, leaving the total remaining trips to be assigned:
    - $S_{NR}$  = total remaining trips to be assigned
    - $S_T$  = total trips in the entire TEMPRO capped matrix
    - $S_{NR} = S_T - \sum_{i,j} E_{Nij}$
  - The remaining matrix elements are assigned values. These are the elements whose row and column are not strategic development zones. This is done such that the ratios between the values of the unassigned elements remain the same as they were in the TEMPRO capped matrix, and the resulting matrix total is the same as the TEMPRO capped matrix total – effectively the old values are scaled to make up the new matrix total:
 
$$- E_{Nij} = E_{Tij} \times \frac{S_{NR}}{S_T}$$
  - Although the row and column totals for the strategic zones within the matrix file equal those from the development spreadsheet, and the matrix total is the same as that of the TEMPRO capped model, the results observed in the SATURN model after assignment ended up somewhat different than intended. However, this version's outputs are closer to the development spreadsheet values than those of any of the previous approaches.
5. Furnessed TEMPRO capped:
- The factors of difference between the TEMPRO capped model's arrivals and departures and those prescribed by the development spreadsheet are identified.
  - These factors (where they are greater than 1) are then applied using SATURN's MX module and the matrix is then Furnessed (to equalise total origins and destinations) to produce a new matrix file.
  - The new matrix file is assigned to the network to produce a new model.
  - This method produced the closest match to the development spreadsheet values, but the matches are still not exact.
6. Iteratively Furnessed TEMPRO capped:
- The TEMPRO capped SATURN model's demand flows for strategic development sites are extracted, and compared to the flows prescribed by the development spreadsheet, to calculate a factor, for each site, by which the SATURN flow would have to be multiplied to equal the development spreadsheet flow.
  - These factors are applied to the strategic zones using SATURN's MX module and the matrix is Furnessed to produce a new matrix file.
  - The new matrix is assigned to the network to produce a new model.
  - The new model has strategic zone flows closer to those in the development spreadsheet than the original model, but there is still a significant difference.

- The previous steps are repeated until the strategic zones’ flows have sufficiently converged with those in the development spreadsheet.
- In cases where a strategic zone’s flow does not move substantially closer to its intended value from one iteration to the next, the factor applied to that zone during Furnessing is amplified (increased if greater than 1, or decreased if less than 1) in the following iteration. Generally, if a flow appears reluctant to change as requested in a given iteration, it will be similarly resistant in the next iteration. This amplification is therefore applied to compensate, and accelerate convergence.

The results are 50 iterations using approach 6 are as follows:

Approach 6 Results: 50 Iterations		AM					
		Arrivals			Departures		
Reference	Zone	Target	Result	% of Target	Target	Result	% of Target
ST5 (employment)	34	723	721	100	58	63	108
ST32	106	23	23	100	99	99	100
ST8	221	83	83	100	270	271	100
ST33	223	8	8	100	24	24	100
ST7	323	74	74	100	240	241	100
ST4	325	18	18	100	60	60	100
ST9	327	89	89	100	290	291	100
ST2	328	23	23	100	74	75	100
ST15	329	432	431	100	1405	1406	100
ST36	408	48	48	100	156	156	100
ST14	411	153	154	100	497	499	100
ST5 (residential)	412	92	92	100	298	297	100
ST16	501	32	32	100	103	103	100
ST31	524	21	21	100	67	66	100
ST1	631	103	103	100	335	336	100
ST17 (residential)	632	74	74	100	241	241	100
ST17 (employment)	633	408	407	100	63	67	106
ST27	634	269	268	100	22	22	100
ST26	635	182	181	100	30	30	100
ST35	811	61	61	100	197	197	100

Approach 6 Results: 50 Iterations		PM					
		Arrivals			Departures		
Reference	Zone	Target	Result	% of Target	Target	Result	% of Target
ST5 (employment)	34	62	62	100	576	576	100
ST32	106	70	70	100	31	31	100
ST8	221	189	189	100	92	92	100
ST33	223	17	17	100	8	8	100
ST7	323	167	167	100	82	82	100
ST4	325	42	42	100	20	20	100

ST9	327	202	203	100	99	99	100
ST2	328	52	52	100	25	25	100
ST15	329	980	977	100	479	480	100
ST36	408	109	109	100	53	61	114
ST14	411	347	346	100	170	169	100
ST5 (residential)	412	208	209	100	102	101	100
ST16	501	72	72	100	35	35	100
ST31	524	46	46	100	23	23	100
ST1	631	234	235	100	114	114	100
ST17 (residential)	632	168	169	100	82	82	100
ST17 (employment)	633	60	60	100	344	343	100
ST27	634	23	23	100	214	213	100
ST26	635	28	28	100	154	155	100
ST35	811	138	138	100	67	68	100

The arrivals and departures for the majority of zones in both peaks are equal or almost equal to the numbers calculated by the development spreadsheet. The only exceptions are ST5 (employment)'s (zone 34's) departures in the AM peak, which end up at 63 but should be 58, and ST36's (zone 408's) departures in the PM peak, which end up at 61 but should be 53.

In both cases, these flows appear to have reached a constraint of the model which further Furnessing cannot exceed – zone 34's AM departures are 63 from iteration 20 onwards, while zone 408's PM departures are 61 from iteration 9 onwards. These limitations appear to arise regardless of the method or extent of factor amplification applied to attempt to accelerate convergence (e.g. linear, geometric, dynamic based on iteration history, etc.).