“**An efficient solution to toll choices involving multiple toll booths and / or multiple tolling strategies”**

Current approaches to toll road demand forecasting:

- Toll Delay Penalty (TDP) models

- Behavioural Route Choice (BRC or ‘logit’) models

BEHAVIOURAL ROUTE CHOICE (BRC OR ‘LOGIT’) MODELS

The payment of a toll is treated as a purchase of a range of road travel benefits

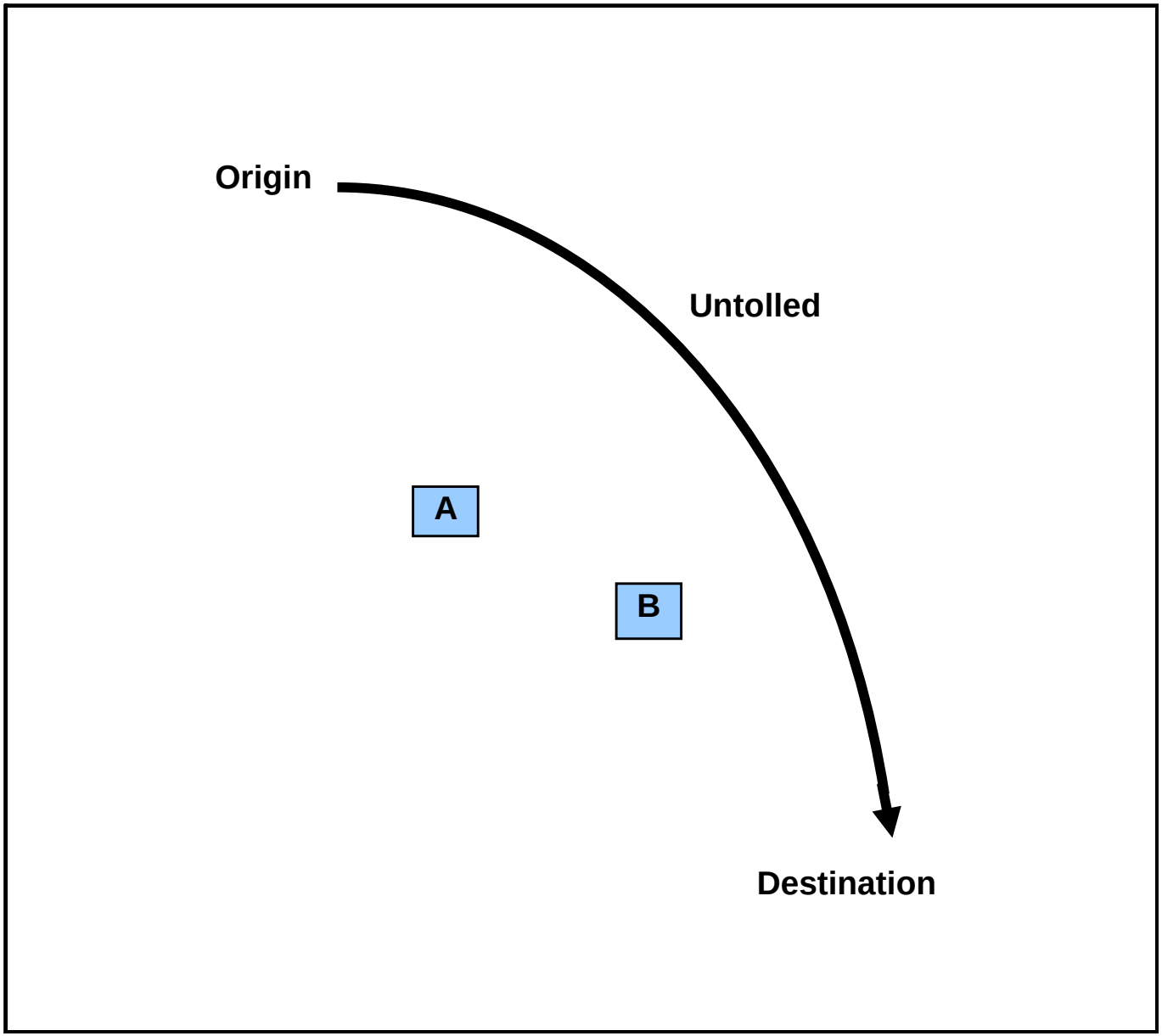
The willingness of potential toll road users to pay a toll is driven by a range of relative utilities, with the value of time being only one component of choice.

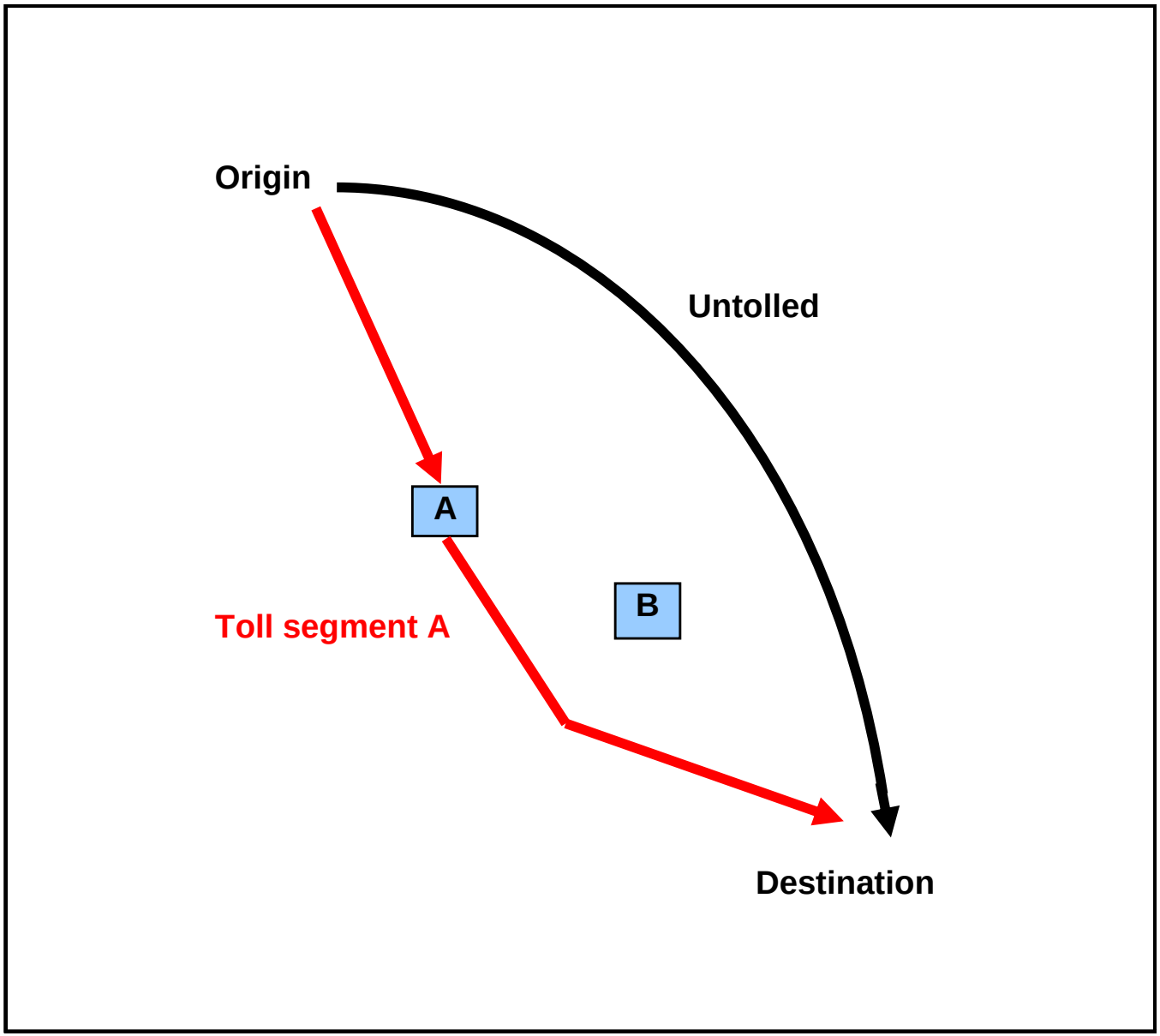
Pluses?
Can be calibrated to observed toll road user behaviour (RPSP surveys)

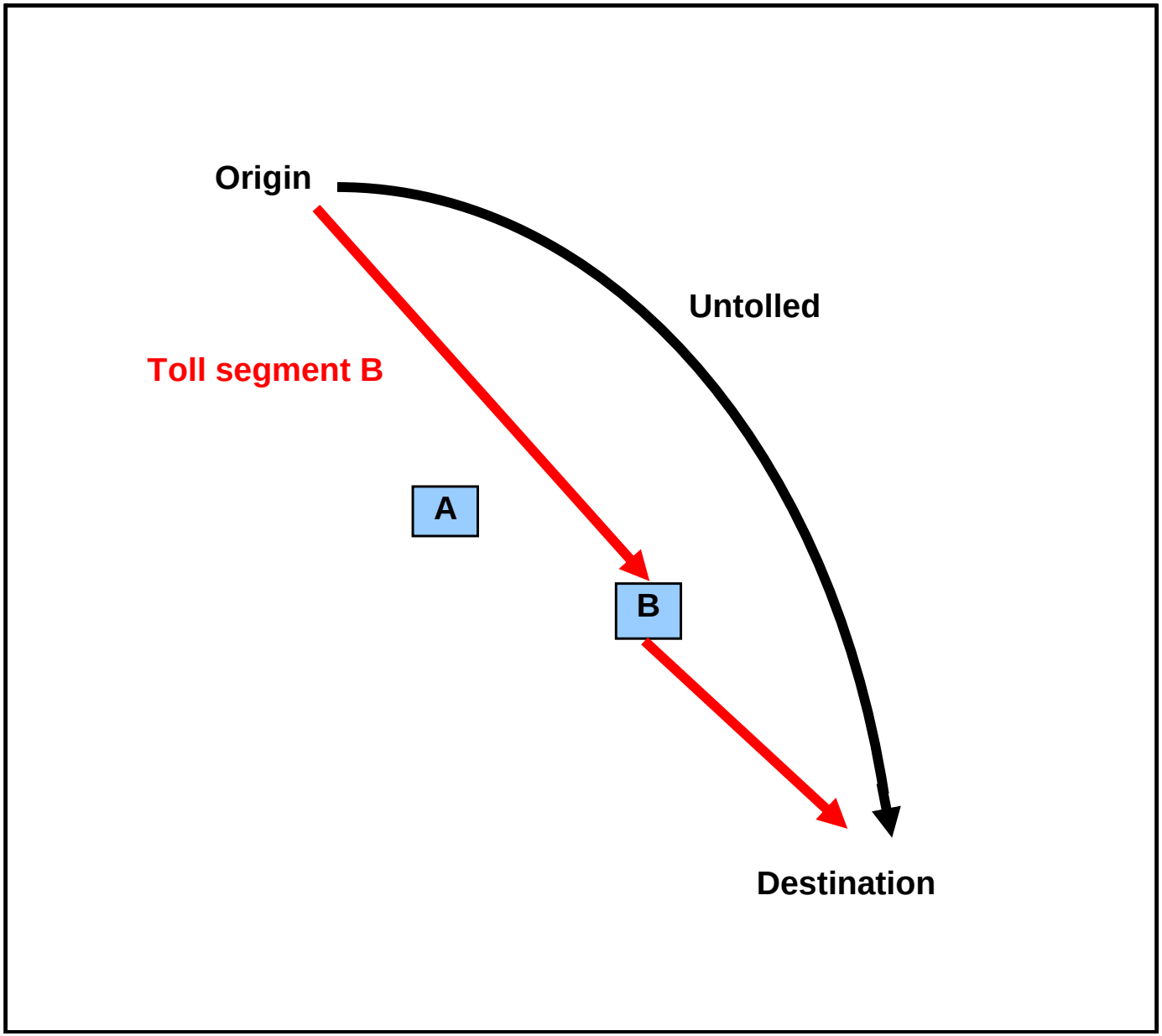
Minuses?
Arbitrary definitions of potential toll users

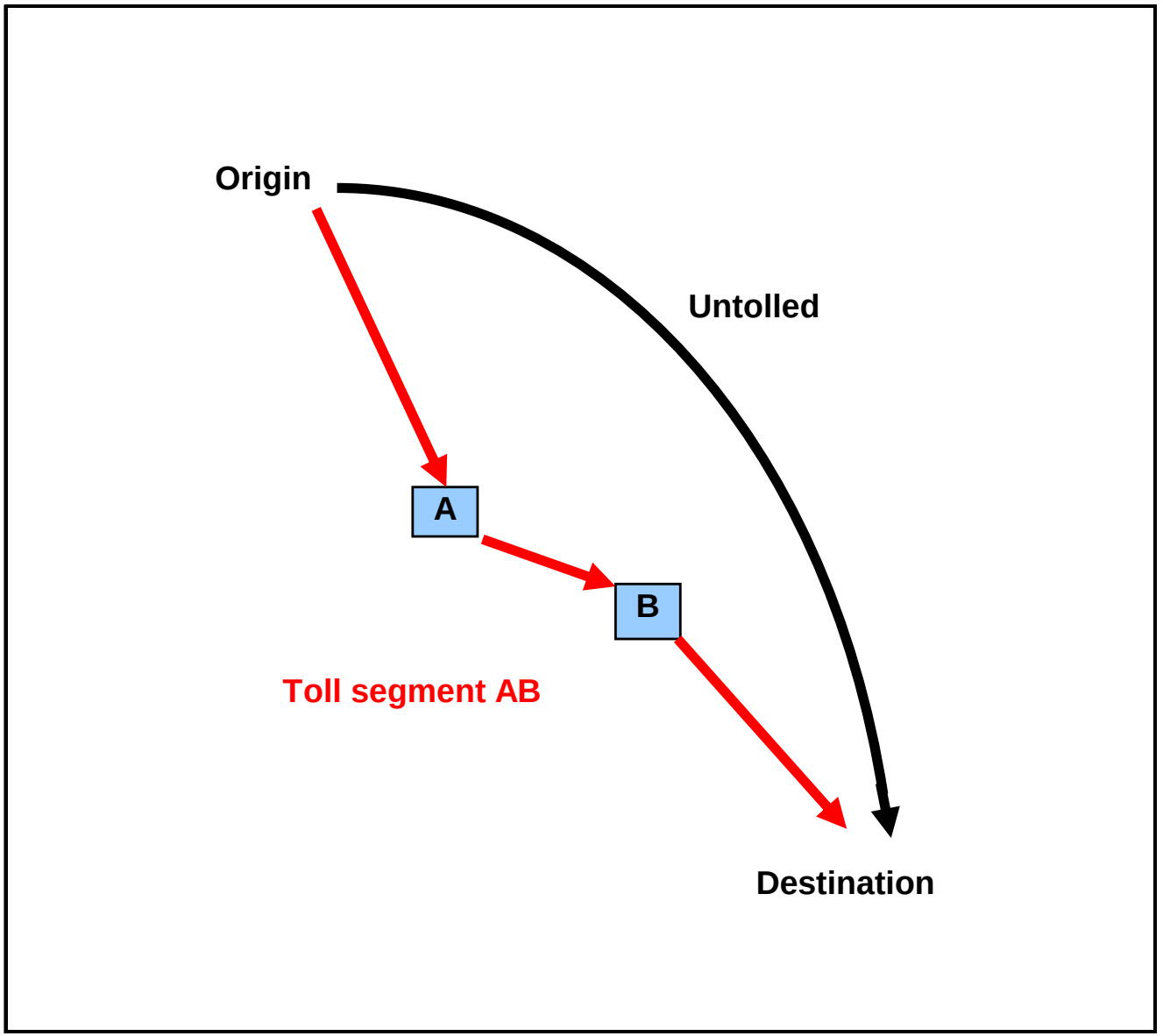
Complexity with multiple toll booths and/or multiple tolling strategies

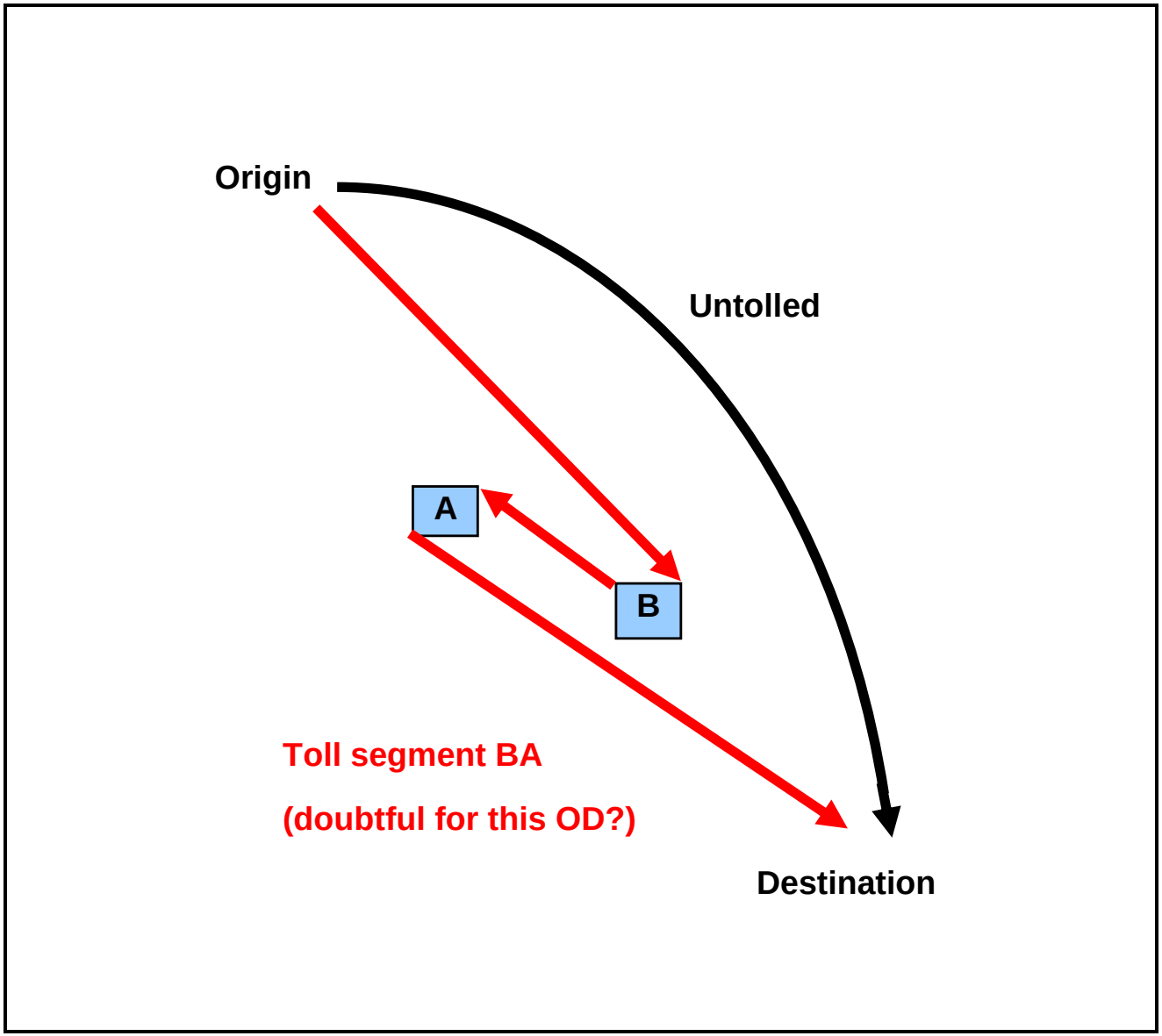
General convergence and run-time issues

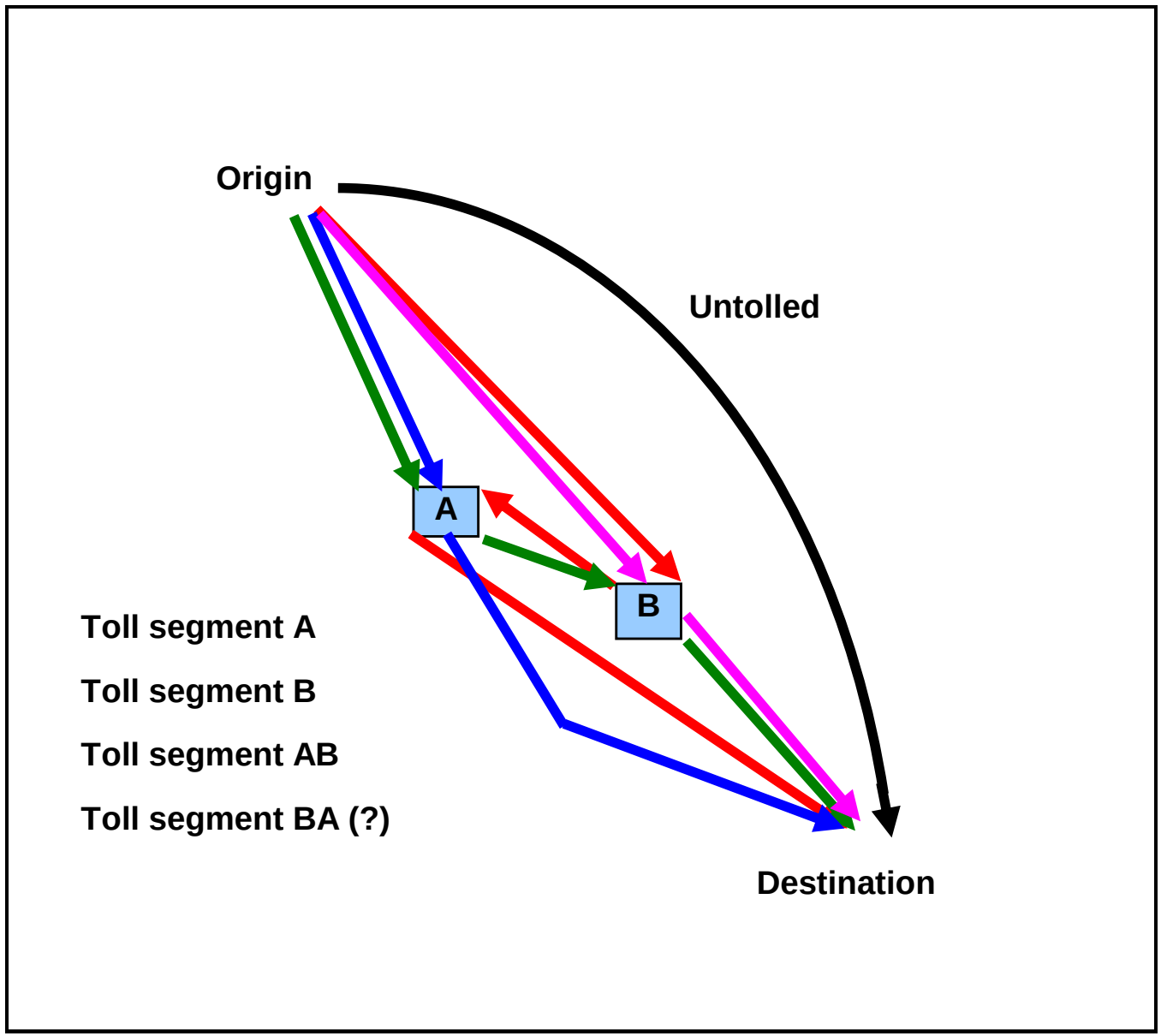

Origin
Untolled
A
B
Destination


Origin
Untolled
A
B
Toll segment A
Destination


Origin
Untolled
Toll segment B
A
B
Destination


Origin
Untolled
A
B
Toll segment AB
Destination


Origin
Untolled
A
B
Toll segment BA
(doubtful for this OD?)
Destination


Origin
Untolled
A
B
Toll segment A
Toll segment B
Toll segment AB
Toll segment BA (?)
Destination

UTILITIES

Utility UN = a1 + a2 . Time_UN

Utility A = a1 + a2 . Time_A + a3 . Toll_A

Utility B = a1 + a2 . Time_B + a3 . Toll_B

Utility AB = a1 + a2 . Time_AB + a3 . Toll_AB

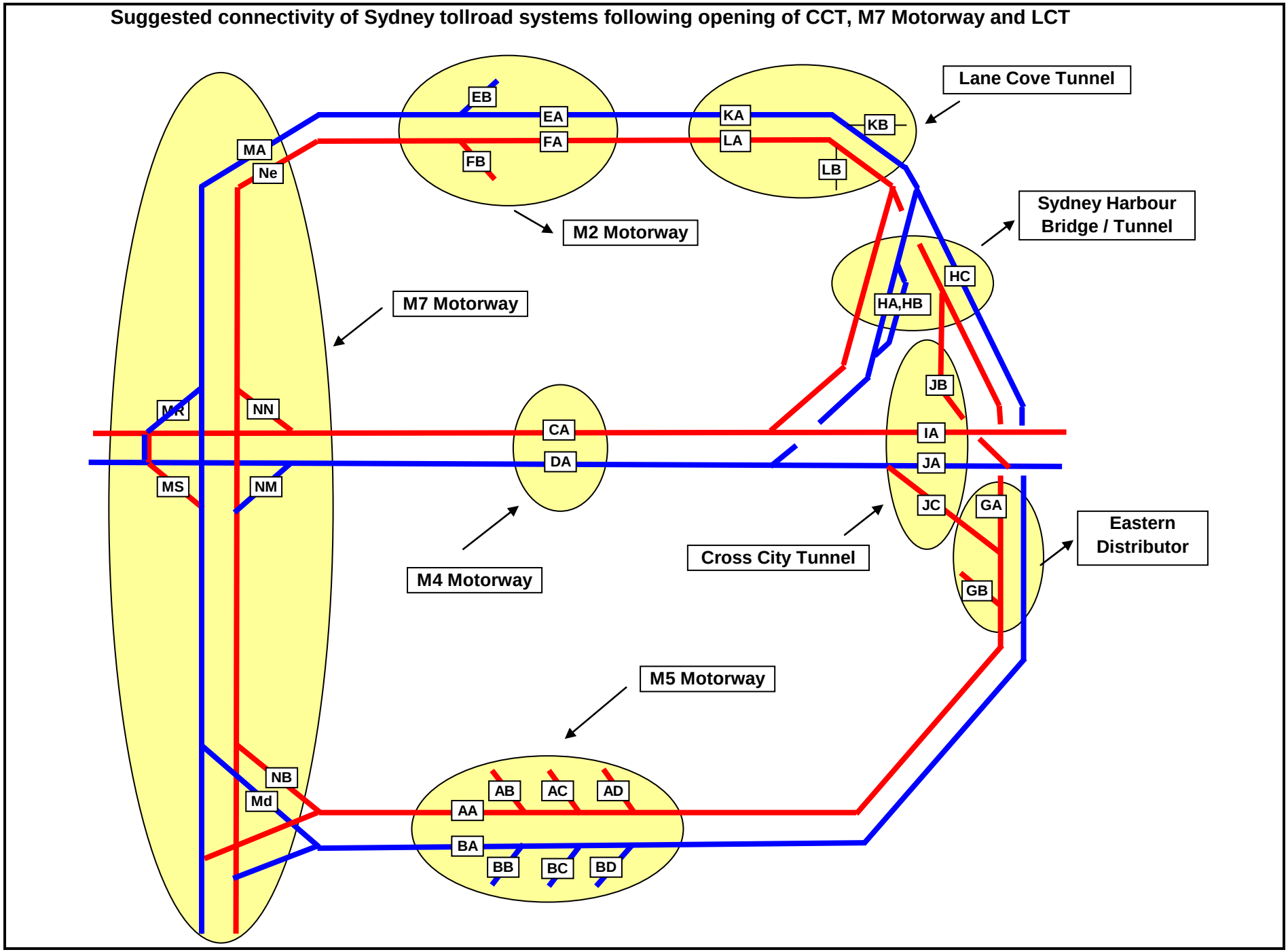
Utility BA = a1 + a2 . Time_BA + a3 . Toll_BA

Calculating the tolls (A, B, AB, BA) is relatively easy

Calculating the times (A, B, AB, BA) is messy and time-consuming (OD matrices)
- network techniques such as toll link ‘flags’ or ‘switches’, select links etc

Hard enough with 4 toll segments – what about 300+ (Sydney since Westlink M7)

Suggested connectivity of Sydney tollroad systems following opening of CCT, M7 Motorway and LCT



THE SYDNEY TOLL ROAD NETWORK - CURRENT TRENDS

More toll booths

Pre-M7	19
Post-M7	77

More ‘valid’ toll segments

Pre-M7	35
Post-M7	300+ (about half are M7 ramp-to-ramp)

More ‘valid’ toll segments in the toll choice for each OD pair

Pre-M7	2.0 (cutoff = 0 min)
Post-M7	5.0 (cutoff = 0 min)

A NEW BRC APPROACH

Potential toll segments
For ‘n’ toll booths and up to three toll booths in a single trip, there are

n + n2 + n3 toll segments

eg for 10 toll booths, there are 1110 potential toll segments

Valid toll segments
Logic test to remove obvious (eg AA, ABA, AAA, BAA)

Input a list of valid toll segments

User-defined **toll connectivity matrix**

A NEW BRC APPROACH

A ‘dummy’ zone represents each toll booth

Allows each OD variable (eg Travel time, StopStart time, Variability time, Reliability time) to be derived from a single matrix, for each valid toll segment, ‘on the fly’ or in memory

The size of this single matrix is the number of centroids PLUS the number of toll booths

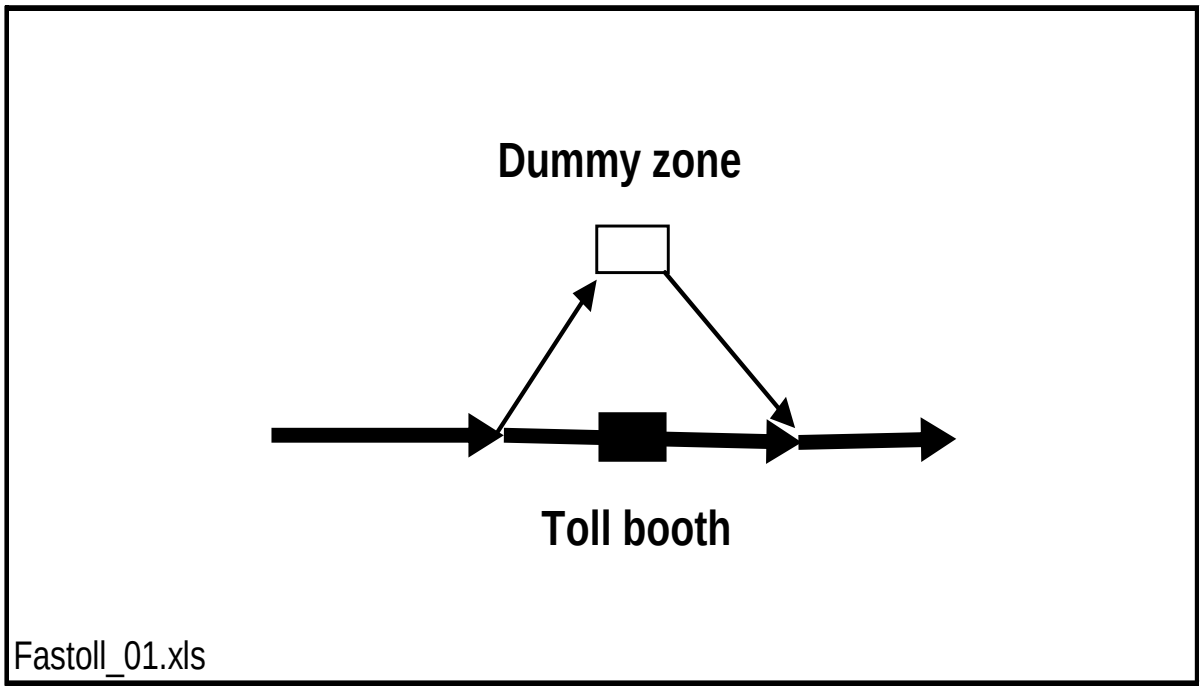
Removes the need for toll ‘flags’ or toll ‘switches’

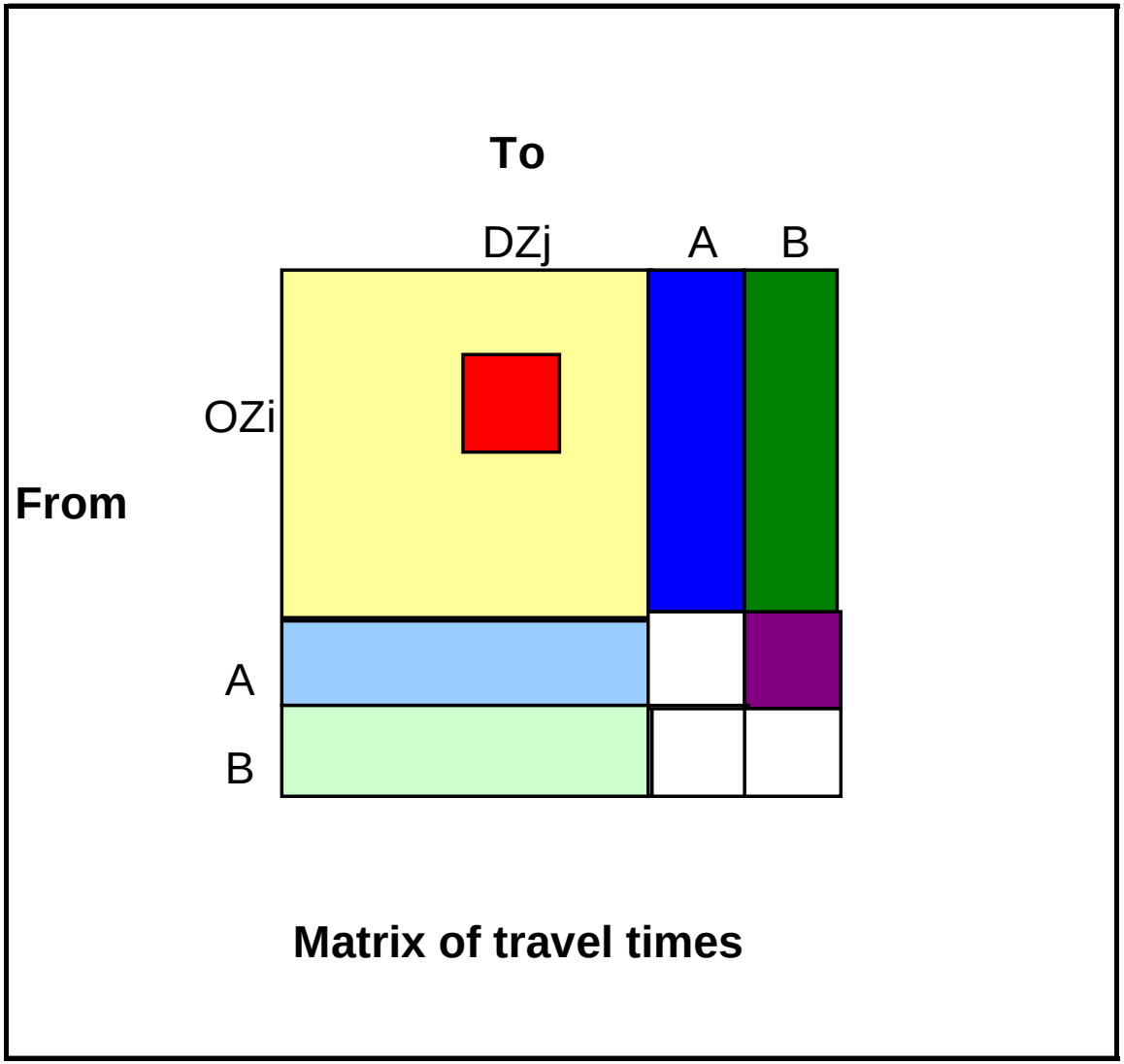
Uses standard matrix algebra for adding vectors and scalars

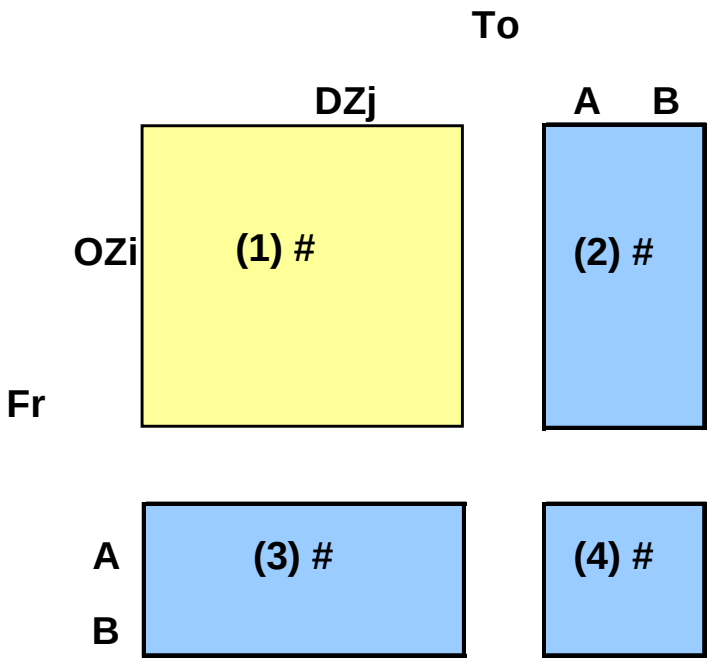
The ‘dummy’ zone network construction (ie nodes and links) are easily integrated into a user’s existing transport software (eg EMME2, Voyager, TransCad etc).

A NEW BRC APPROACH

A ‘dummy’ zone represents each toll booth




To
DZj
A
B
From
OZi
A
B
Matrix of travel times



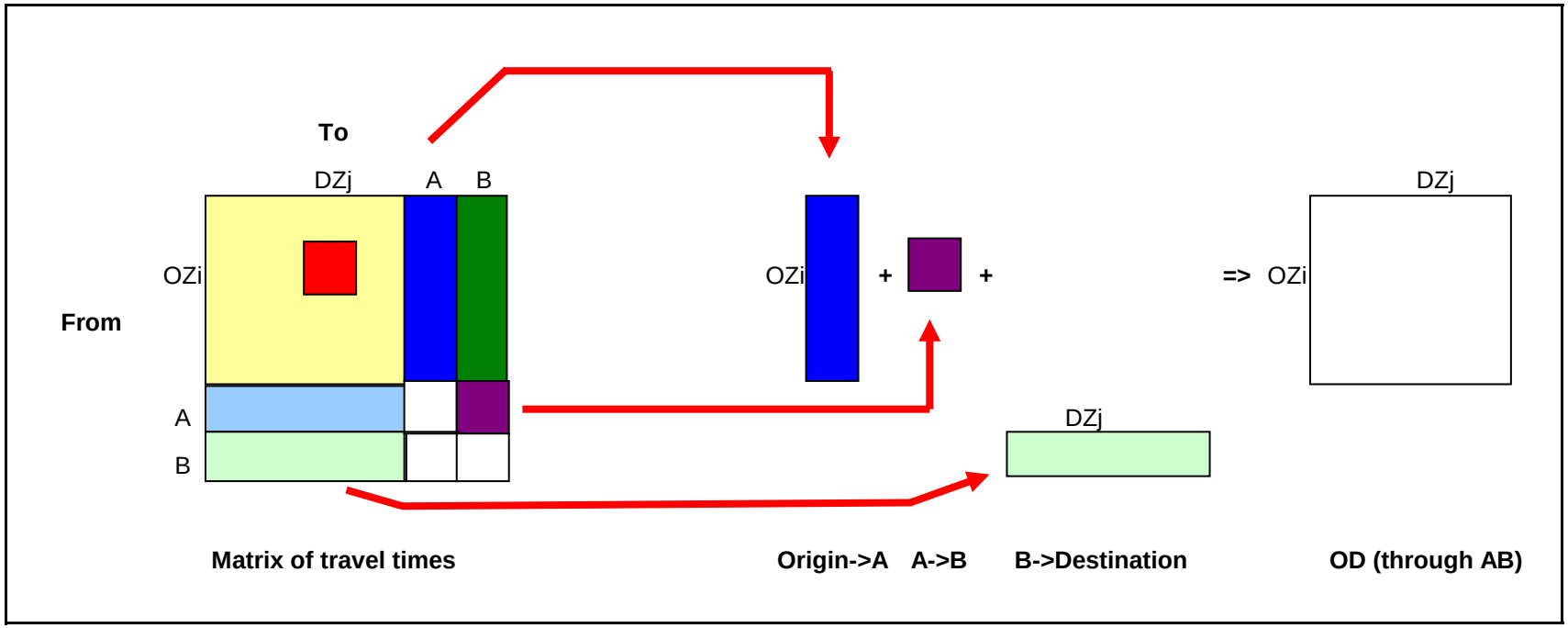
(1) From OZ to DZ

(2) From OZ to Toll booths

(3) From Toll booths to DZ

(4) From Toll booth to Toll booth

\# *Without passing through an intermediate tollbooth*


To
DZj
A
B
From
OZi
A
B
Matrix of travel times
OZi
+
+
Origin->A
A->B
DZj
B->Destination
=>
OZi
DZj
OD (through AB)

A NEW BRC APPROACH

Untolled OD times
Tolled OD times (Toll segments A, B, AB, BA)

Define toll catchments by comparing untolled and tolled times

eg For toll segment A, accept an OD if

Tolled time_A – 'Cutoff' – Untolled time < 0 etc

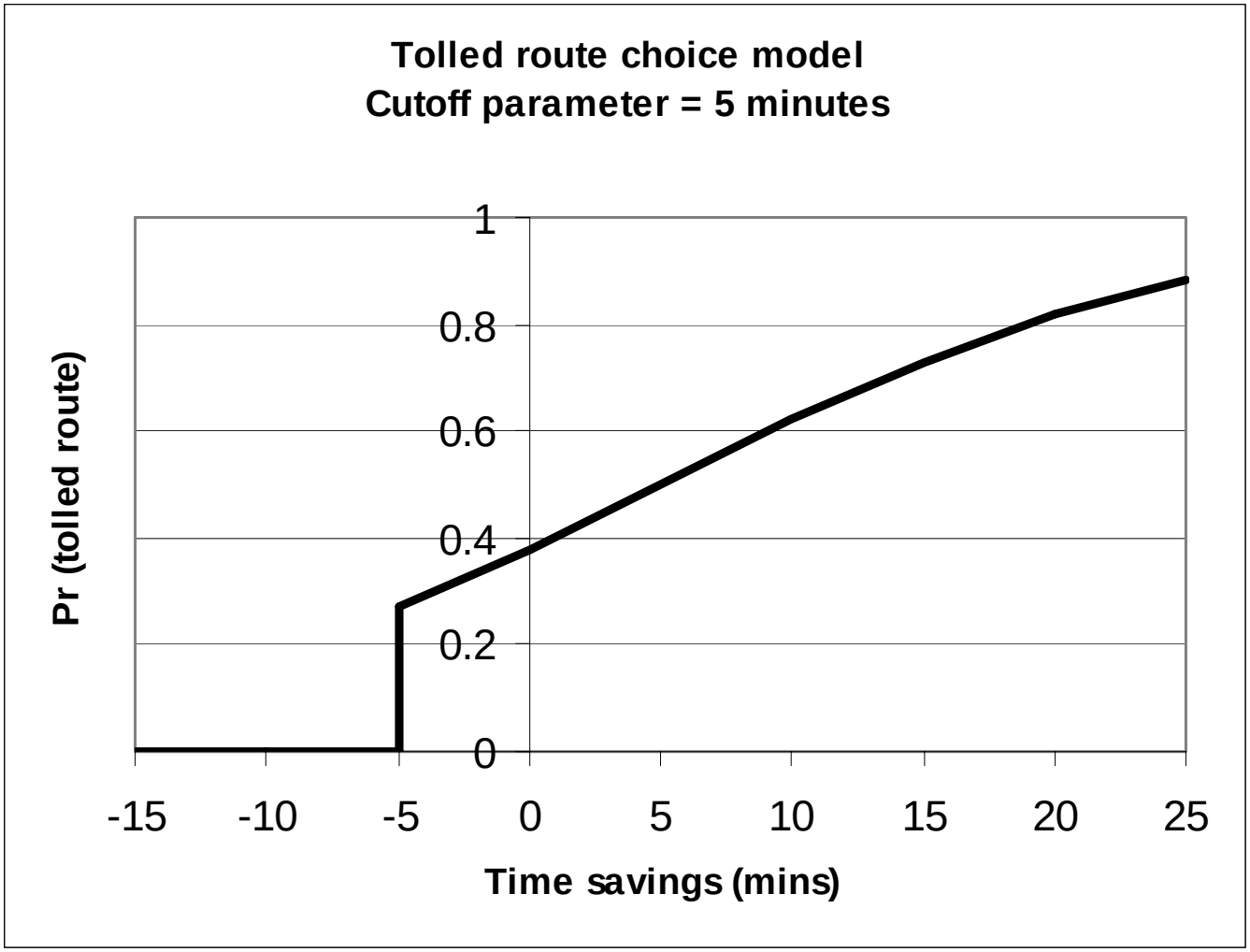
Toll segments are SPARSE – why process tolled ODs that fail?

[Public transport matrices are also generally sparse eg Bus-Rail]

Don't need to build toll segments using toll 'flags' or 'switches'

Matrix-based rather than network-based

Depending on the 'Cutoff'
Catchment ODs increase or decrease
Toll segment BA may fail for the example OD


Tolled route choice model
Cutoff parameter = 5 minutes
Pr (tolled route)
1
0.8
0.6
0.4
0.2
0
-15
-10
-5
0
5
10
15
20
25
Time savings (mins)

A NEW BRC APPROACH

Toll segments are SPARSE
The Sydney demand matrix has 1,000,000 (1000 zones) or 8M

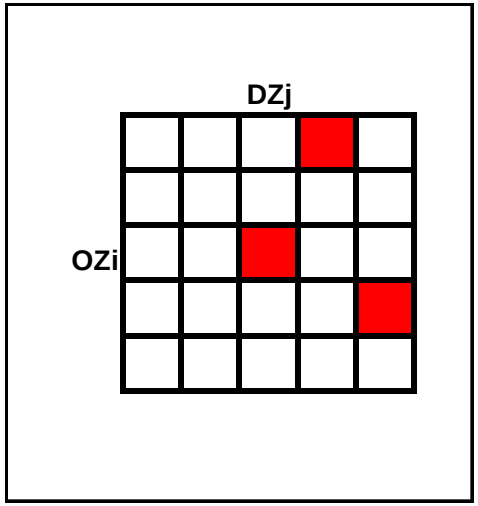
The largest of the 300+ toll segments is only 12%

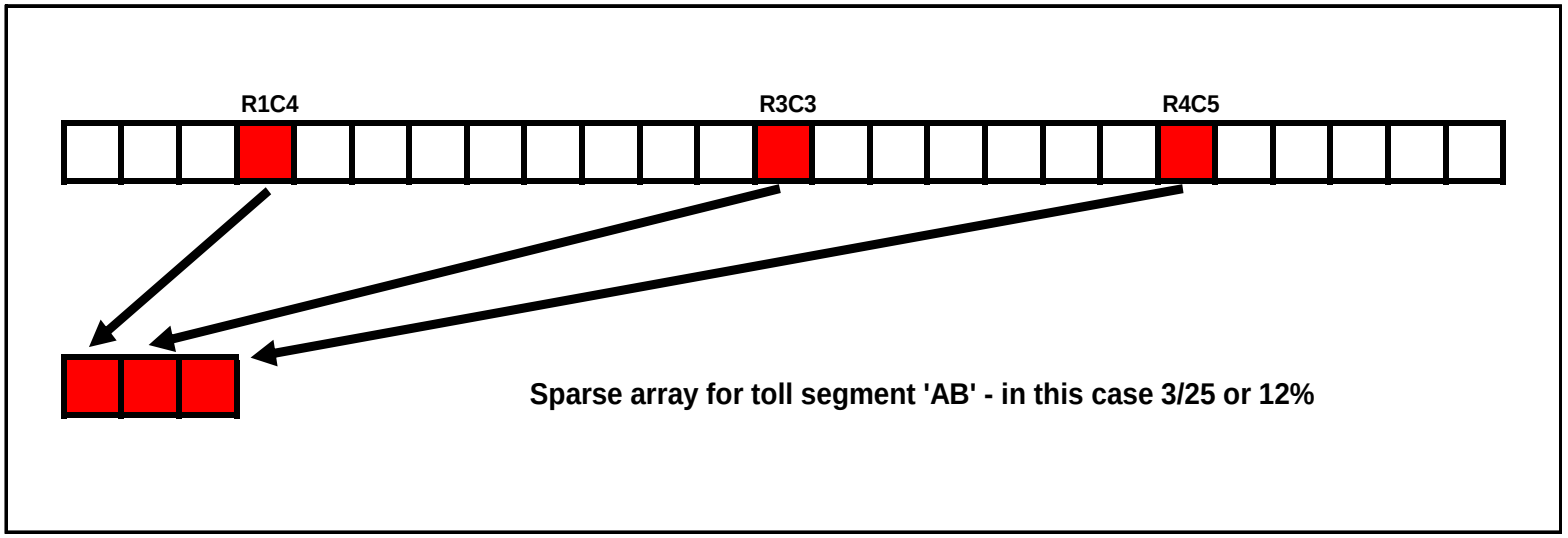
Remaining toll segments from 1-12%

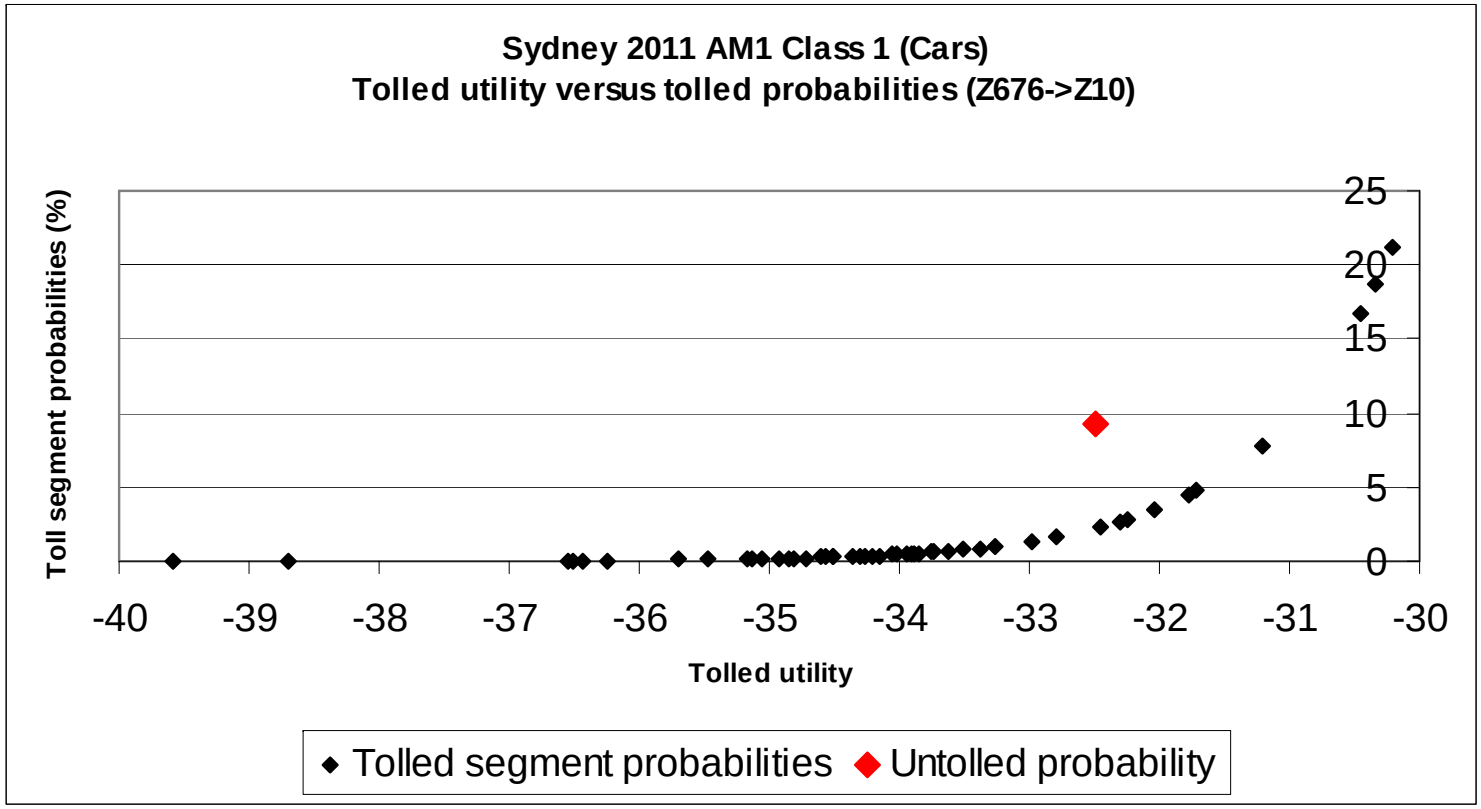
The new BRC model uses sophisticated matrix indexing to ensure that only the valid OD pairs of each valid toll segment are processed, whilst retaining full matrix functionality.

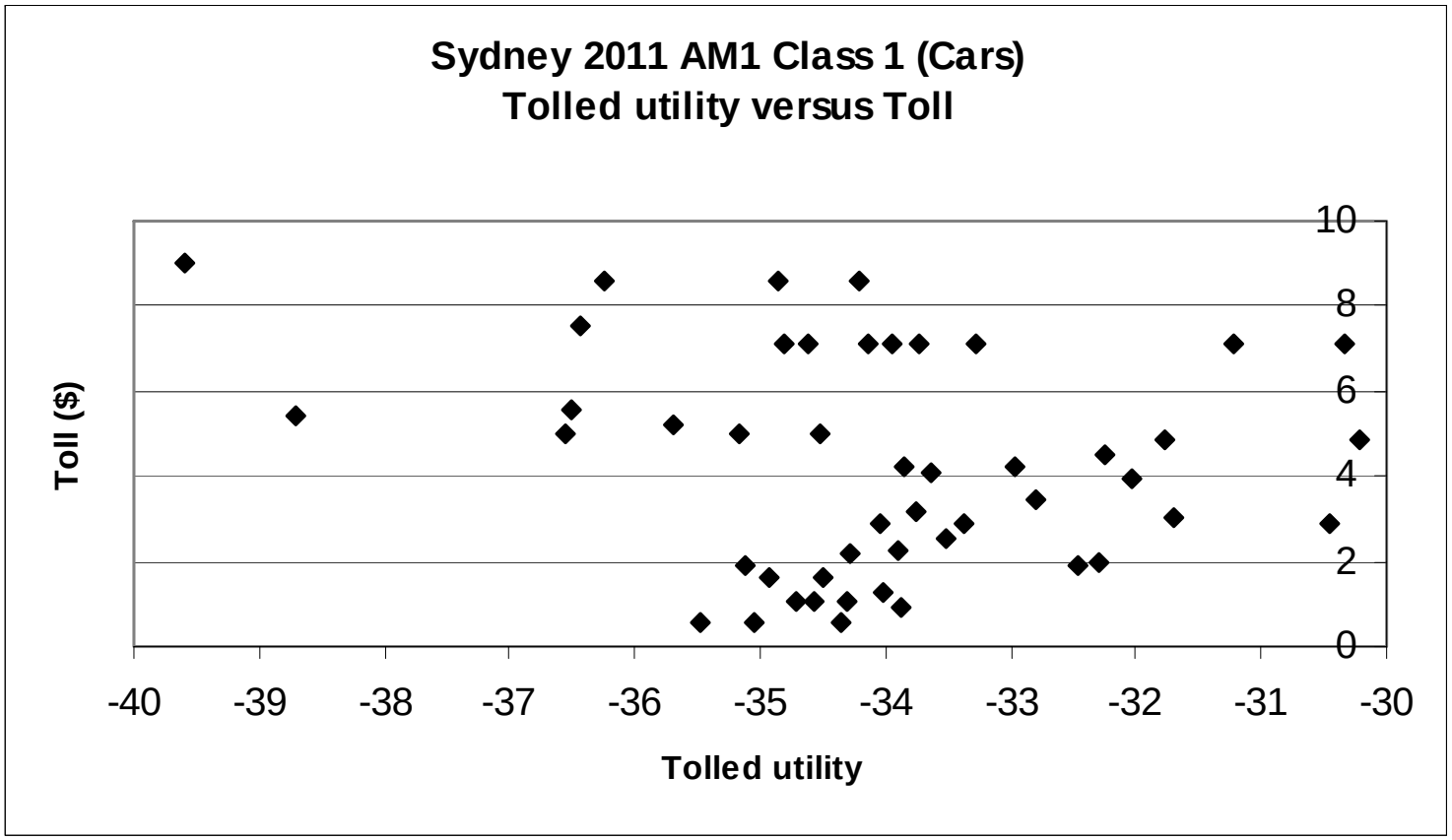
The process is undertaken wholly in memory and is limited only by available computer memory (1.5G), easily sufficient for 300+ toll segments and two toll classes (say car and truck)

A NEW BRC APPROACH
eg Toll segment A






Sydney 2011 AM1 Class 1 (Cars)
Tolled utility versus tolled probabilities (Z676->Z10)
Toll segment probabilities (%)
25
20
15
10
5
0
-40
-39
-38
-37
-36
-35
-34
-33
-32
-31
-30
Tolled utility
Tolled segment probabilities
Untolled probability


Sydney 2011 AM1 Class 1 (Cars)
Tolled utility versus Toll
Toll ($)
10
8
6
4
2
0
-40
-39
-38
-37
-36
-35
-34
-33
-32
-31
-30
Tolled utility

A NEW BRC APPROACH

Trip threshold

The use of a trip threshold after the first model iteration can significantly reduce the number of toll segments to be considered in later iterations, by skipping those toll segments where the total tolled trips (summed across all toll classes) are less than the specified trip threshold.

Number of toll segments versus model run-time

A NEW BRC APPROACH

Preparing a single demand matrix for assignment

Disaggregate the tolled trips into component ‘legs’
Sum across all toll segments
Add the untolled demands
Sum across all toll classes

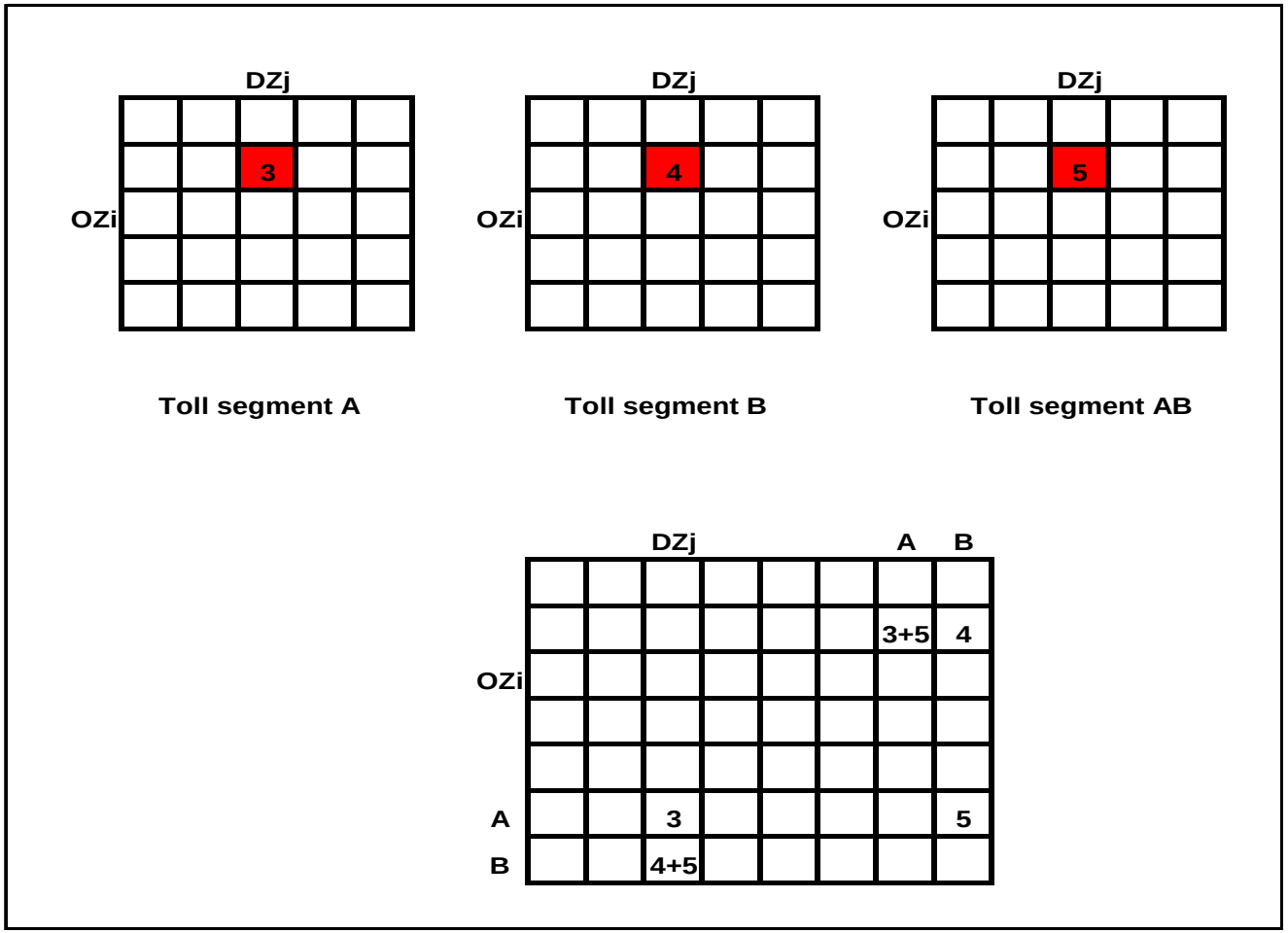
Ensures that a computationally efficient single-class equilibrium assignment can be performed (all link tolls banned).

The model converges readily because ALL the tolled trips must travel through their designated toll booths (or at least through the adjacent dummy zone)

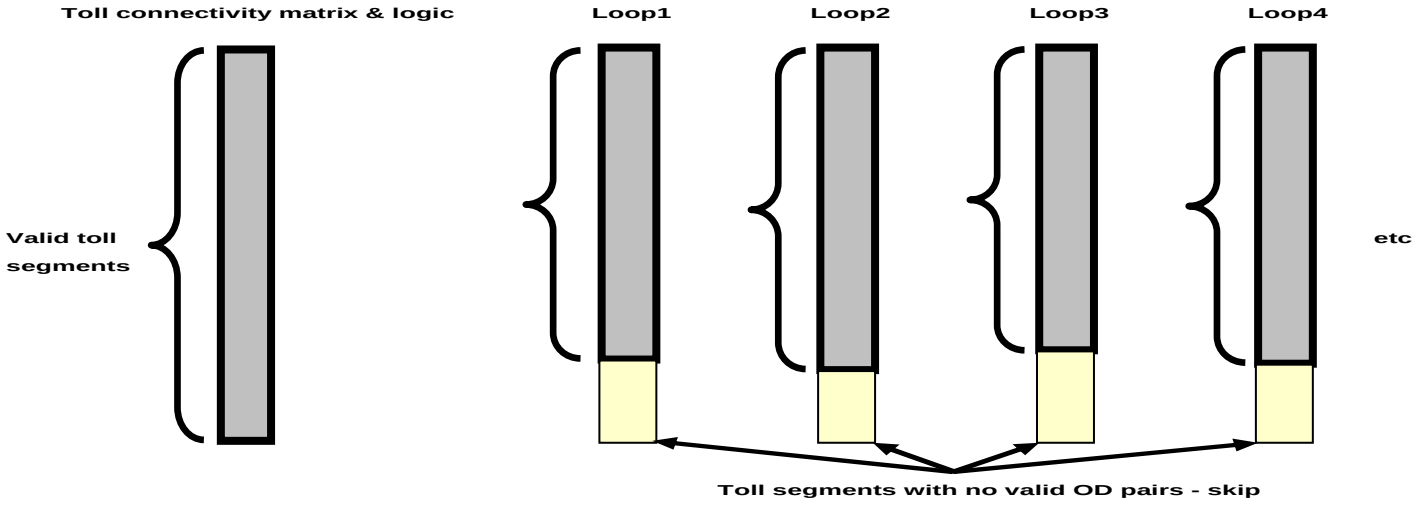
For reporting and/or analysis purposes, multi-class assignments can still be undertaken eg untolled/tolled

A NEW BRC APPROACH (*FASTOLL*)

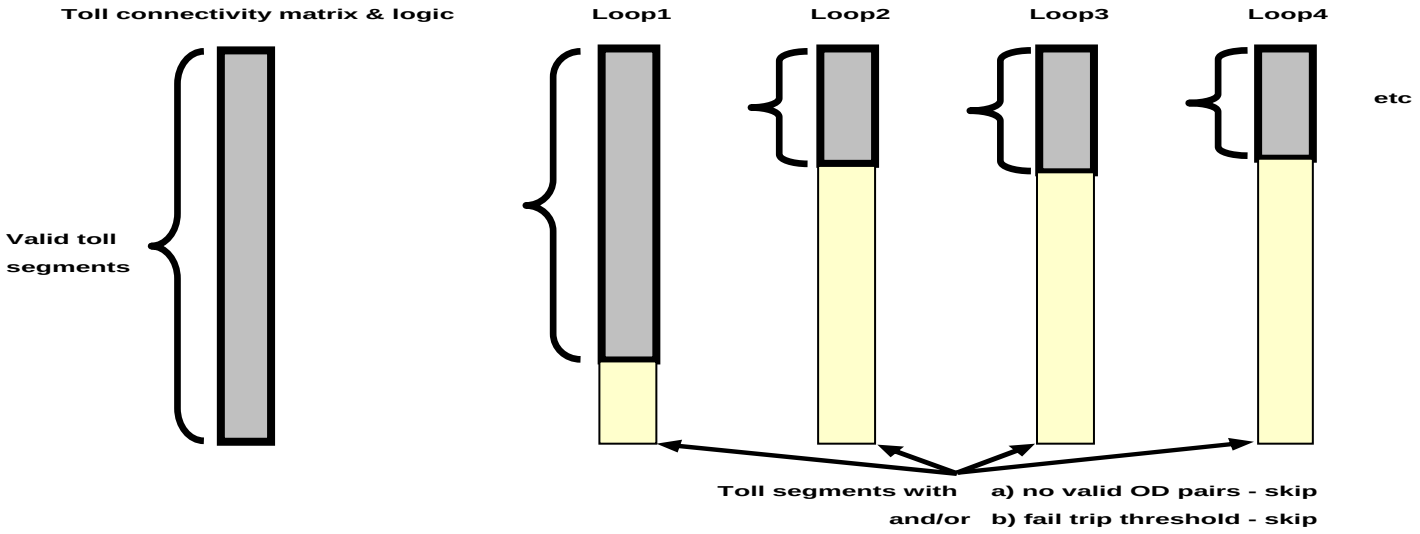
Preparing a single demand matrix for assignment



Without a trip threshold:



With a trip threshold:



Source: Fastoll_01.xls

A NEW BRC APPROACH (*FASTOLL*)

Summary of key features:

BRC models – convergence, runtimes, arbitrary definitions

Valid toll segments (logic, list and/or toll connectivity matrix)
Each toll booth is represented by a 'dummy' zone. For each toll segment, travel times can be extracted from a single matrix 'on the fly'
An acceptance condition (ie cutoff) defines, for each valid toll segment, the valid OD pairs (the cutoff equals amount of negative time savings) – toll segment ODs are SPARSE
Sophisticated matrix indexing is used to ensure only valid ODs are processed in memory, whilst retaining full matrix functionality
Trip threshold to skip minor toll segments – saves runtime
Disaggregating tolled trips into component 'legs', summing across all toll segments and adding untolled trips, ensures that a computationally efficient single class equilibrium assignment can be performed.

FASTOLL - a new BRC approach

Toll demand forecasting module

Integrates seamlessly with user's existing software (EMME2, Voyager, TransCad). Existing software used for equilibrium assignment only

Spreadsheet-based inputs

Implemented as an Application Program in MaxMan (MAtriX MANager)

Demonstration available