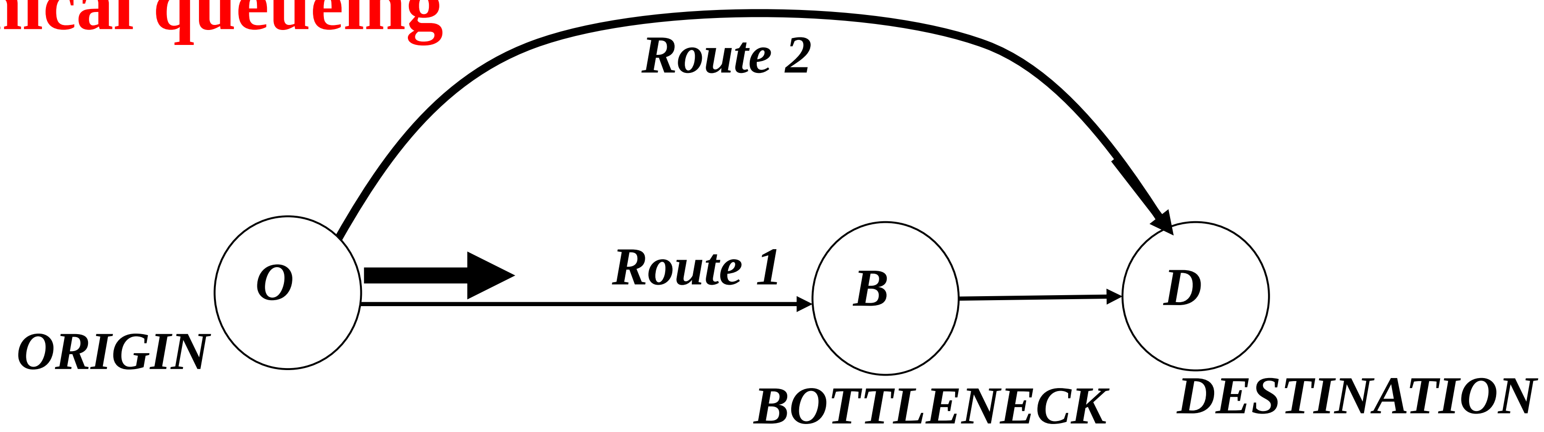
MATTS: University of Delft, 2018

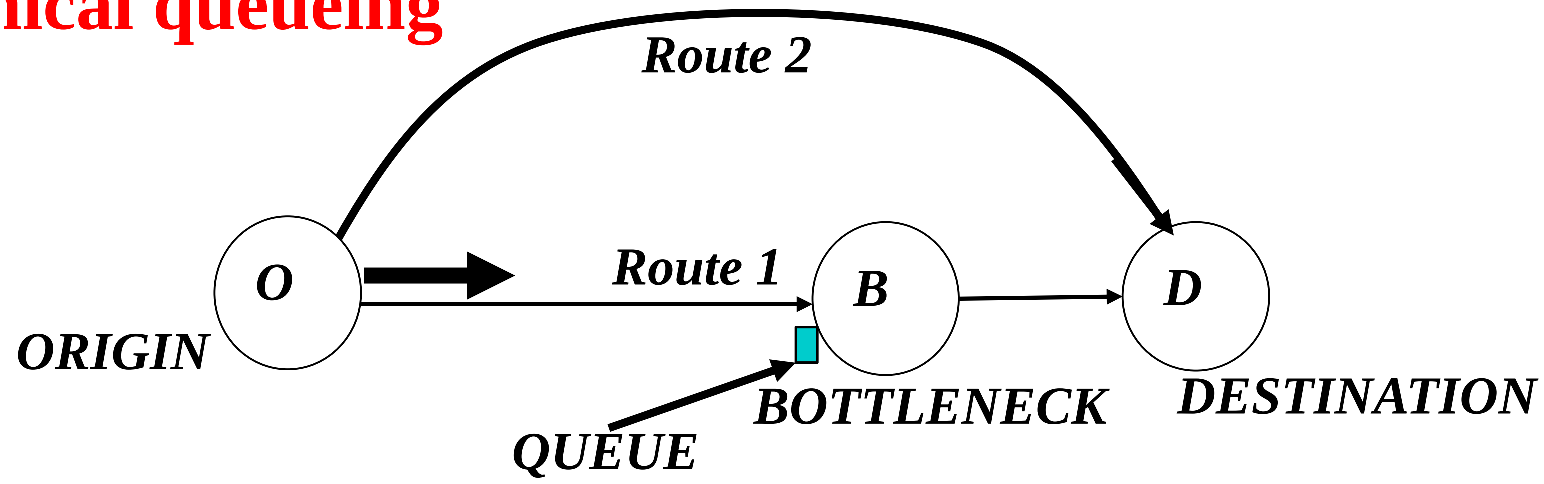
Dynamical queueing, dynamical route choice, responsive traffic control and control systems which maximise network throughput

Michael J. Smith, Takamasa Iryo, Richard Mounce, Marco Rinaldi, and Francesco Viti
Universities:
York, Kobe, Aberdeen, Luxembourg

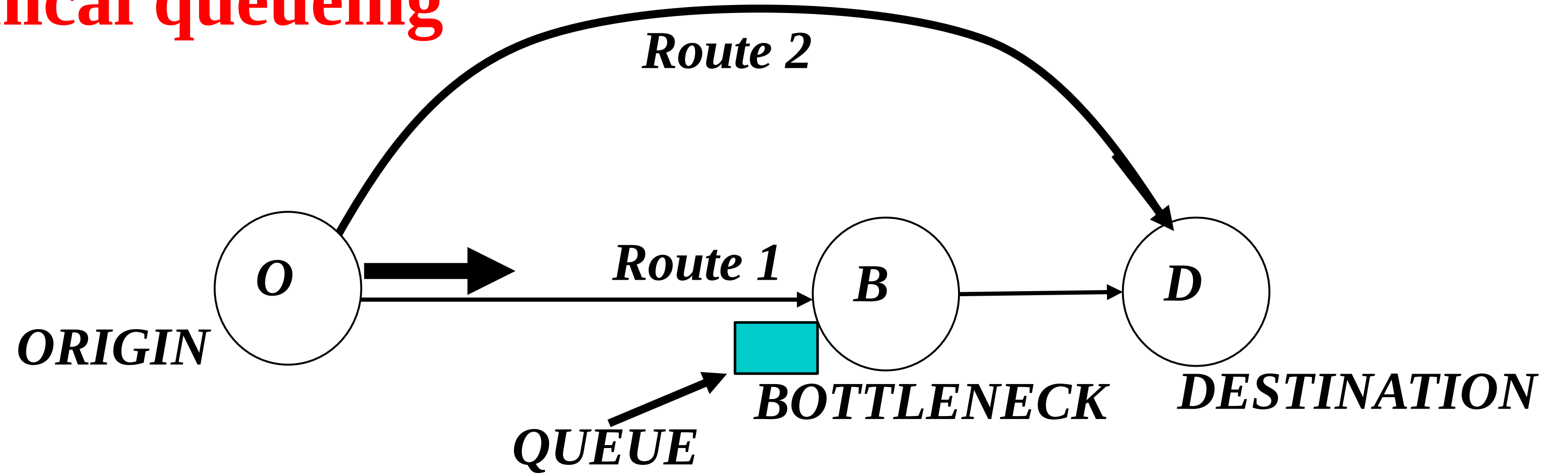
Dynamical queueing



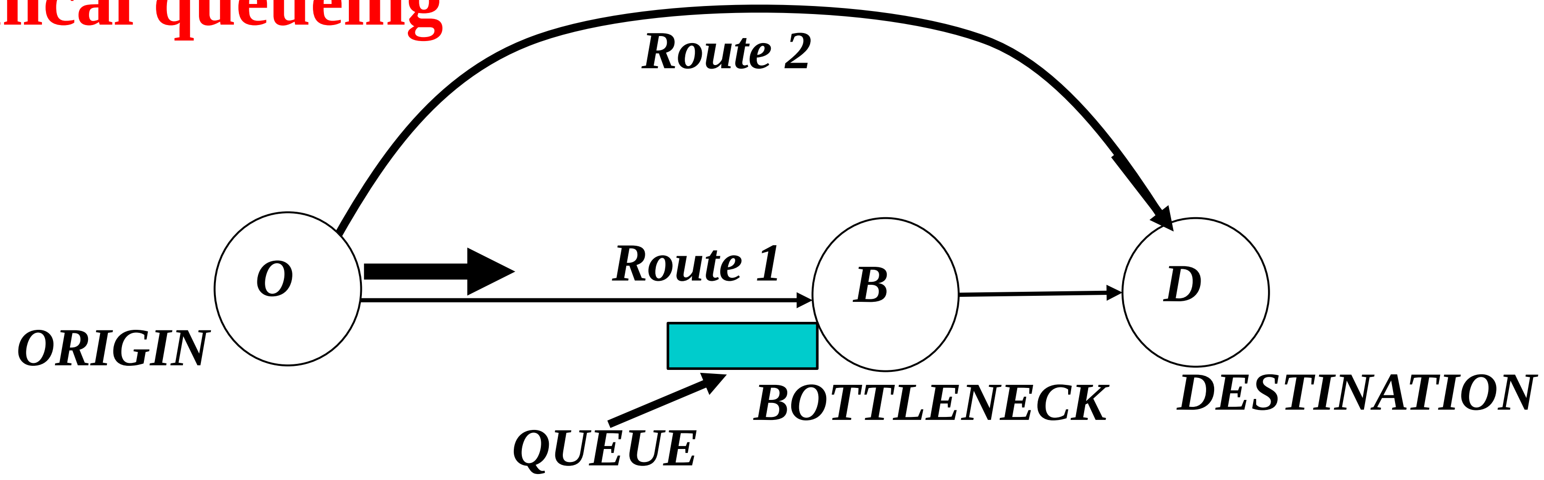
Dynamical queueing



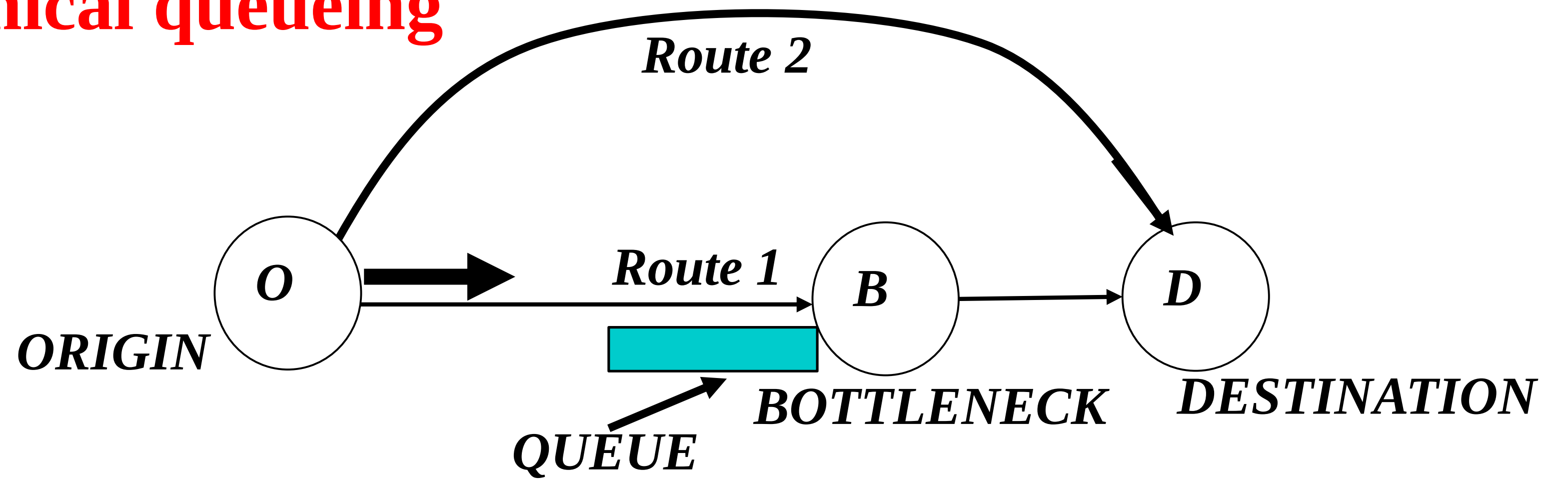
Dynamical queueing



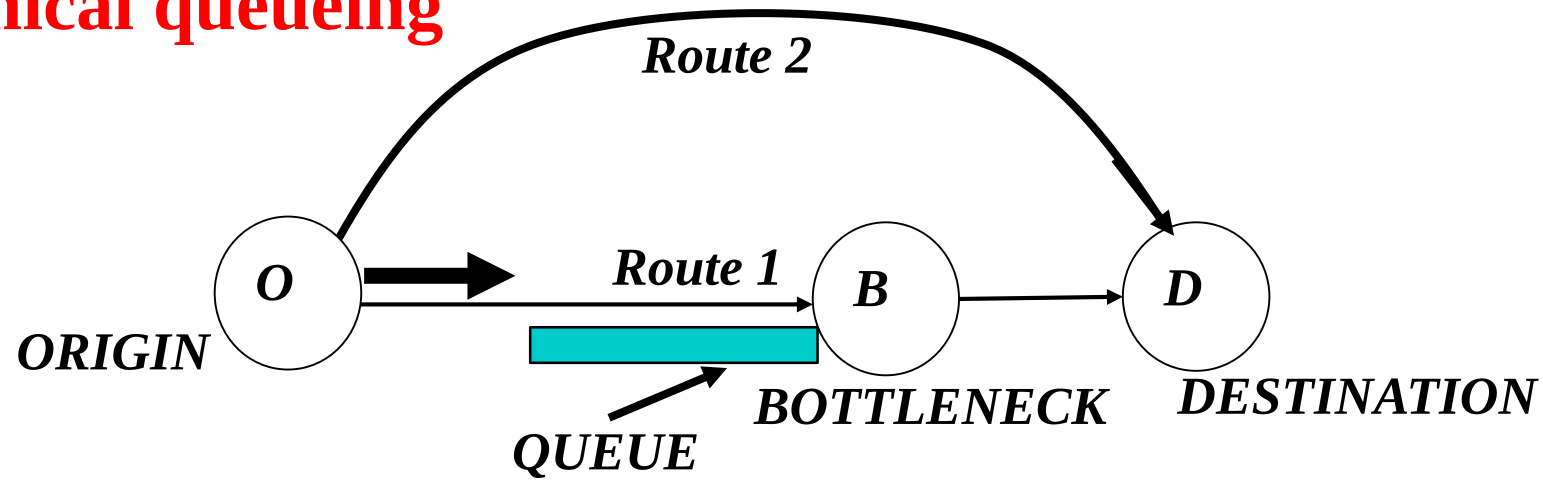
Dynamical queueing



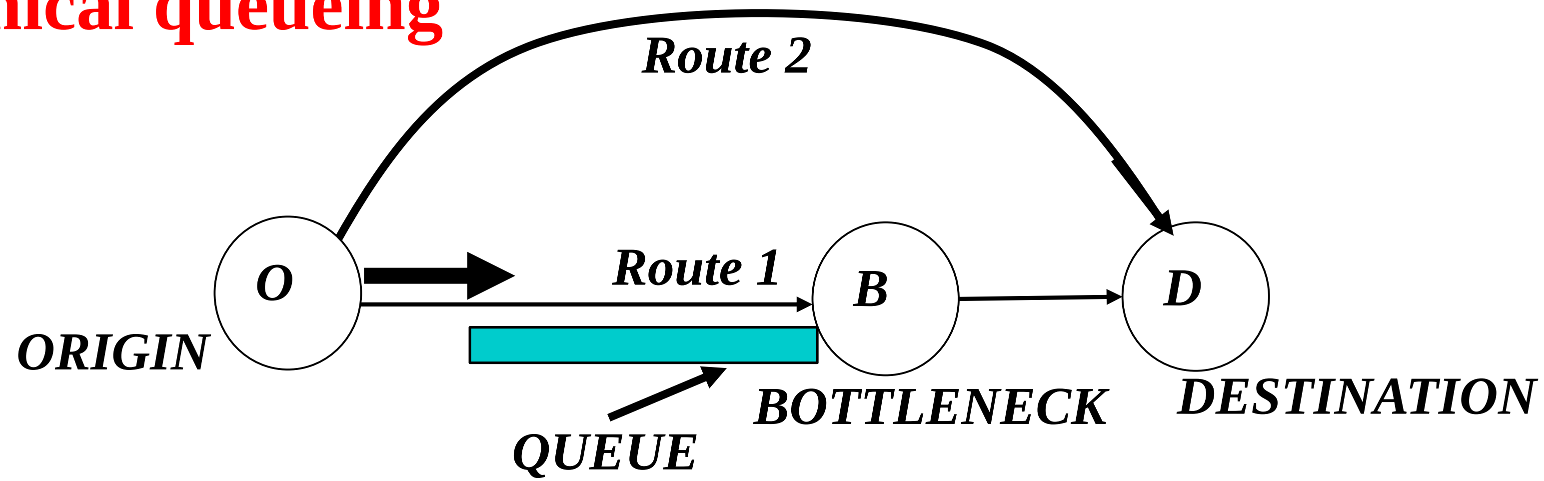
Dynamical queueing



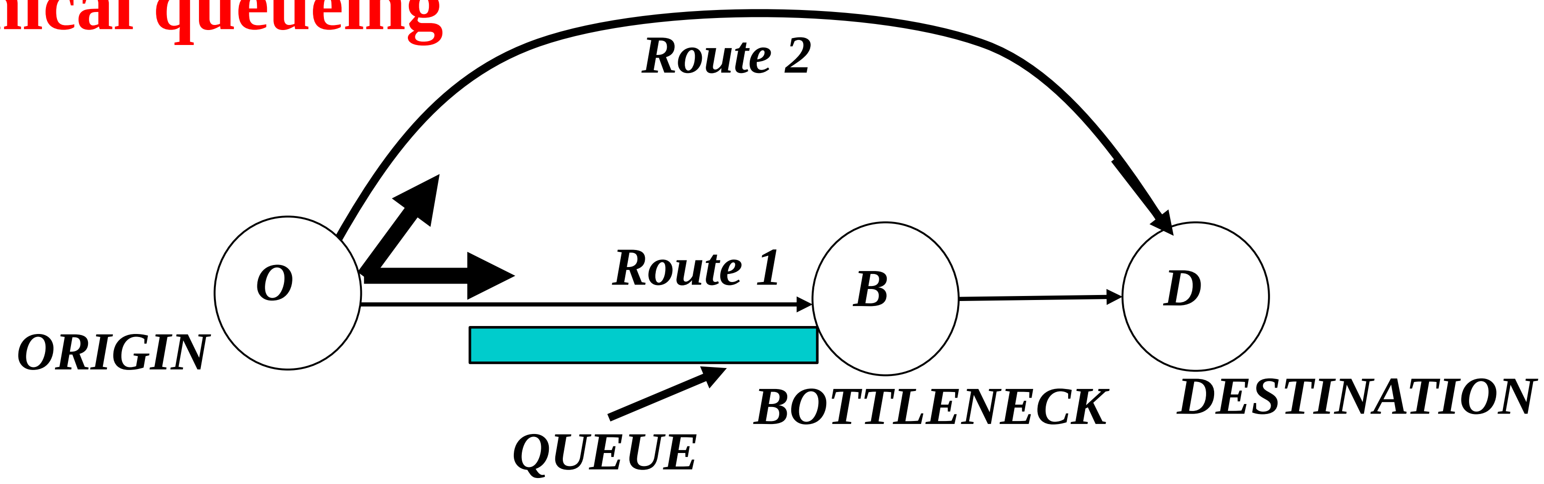
Dynamical queueing



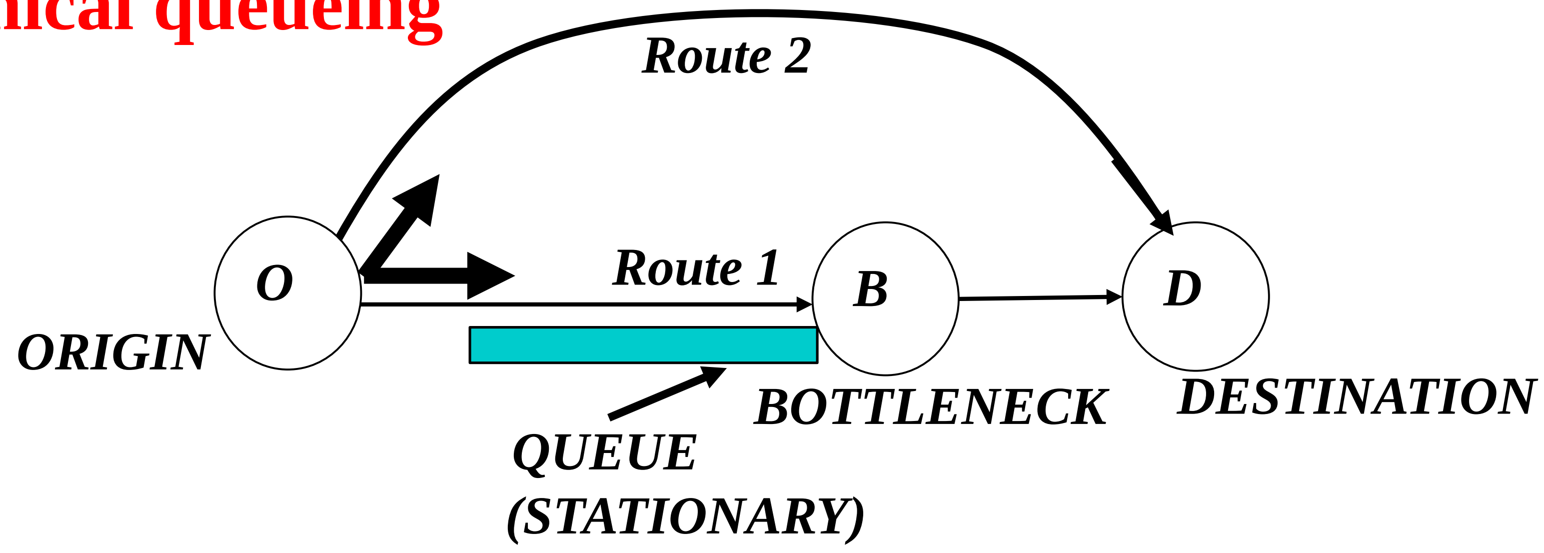
Dynamical queueing



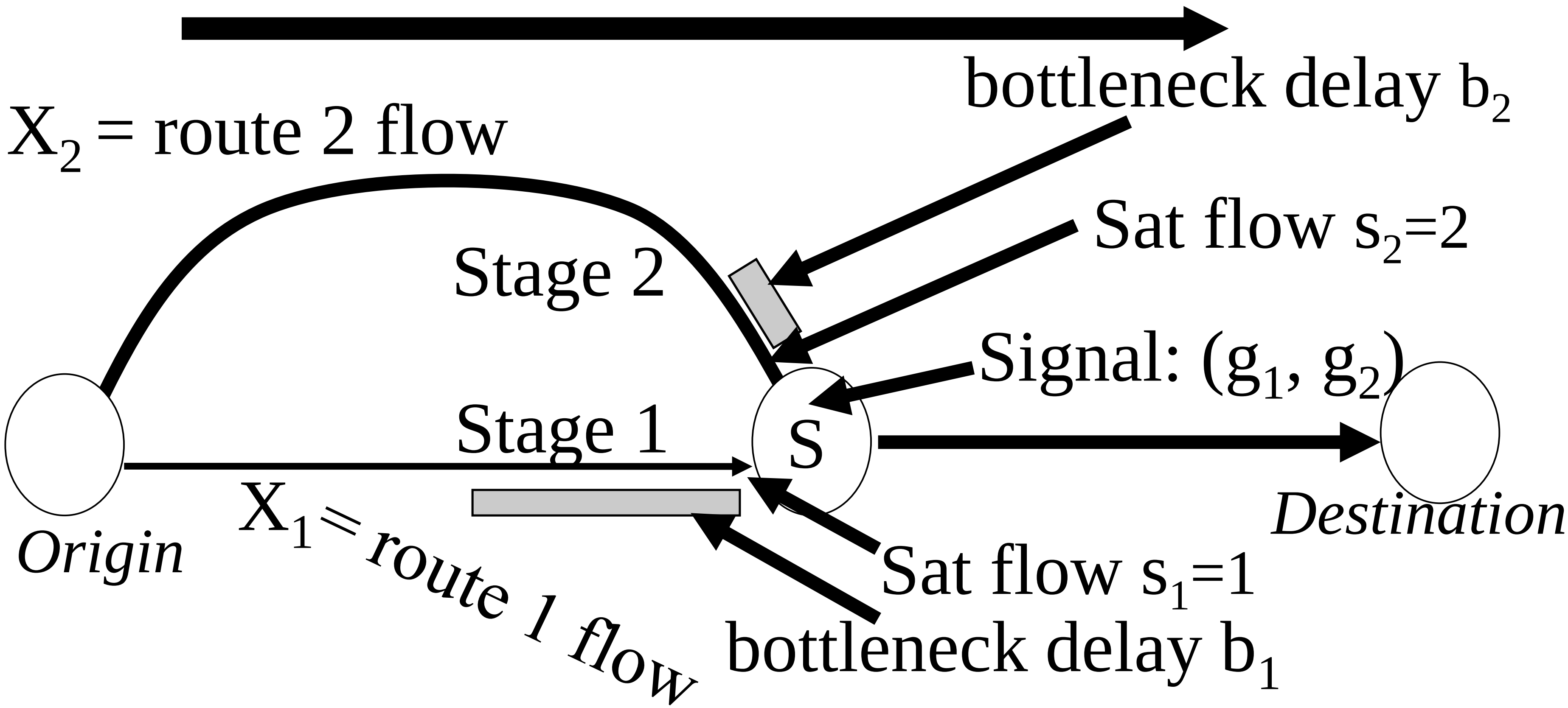
Dynamical queueing



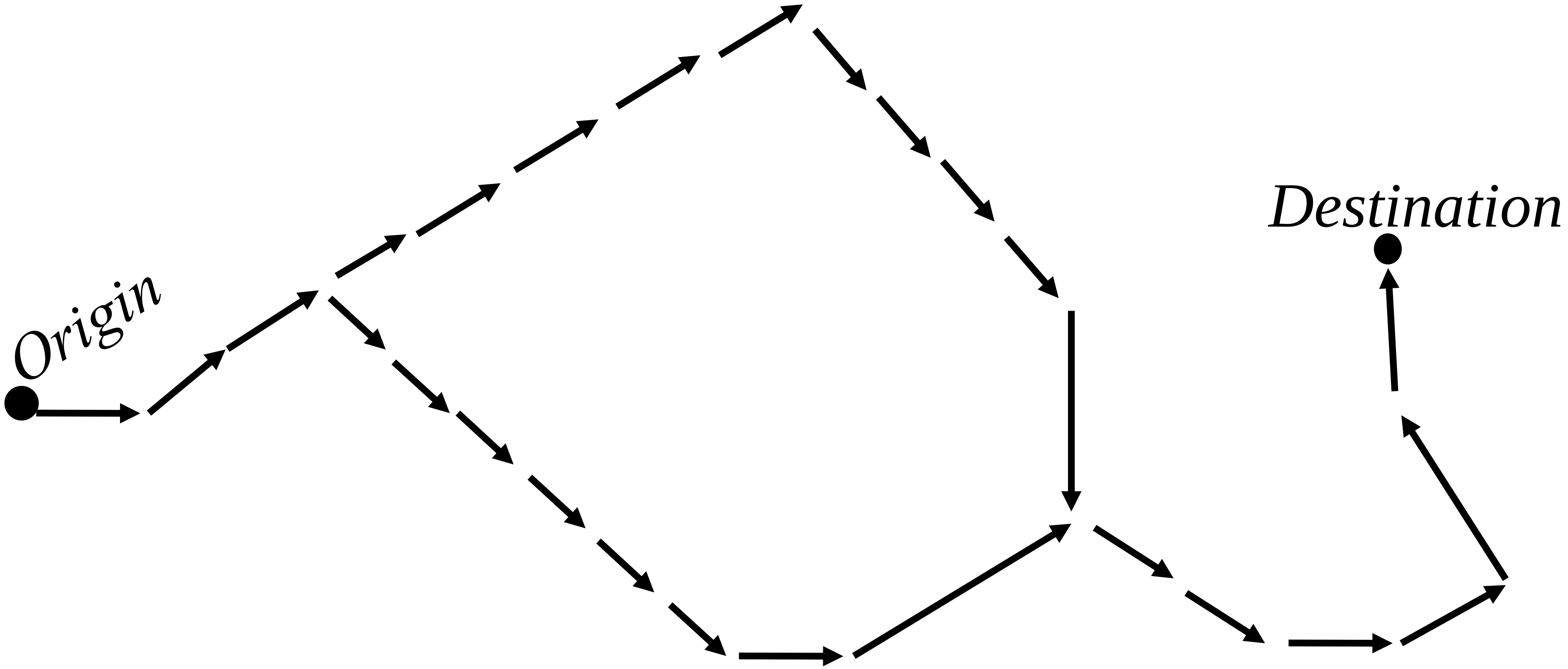
Dynamical queueing



SMALL Network



SMALL Network is not unrealistic



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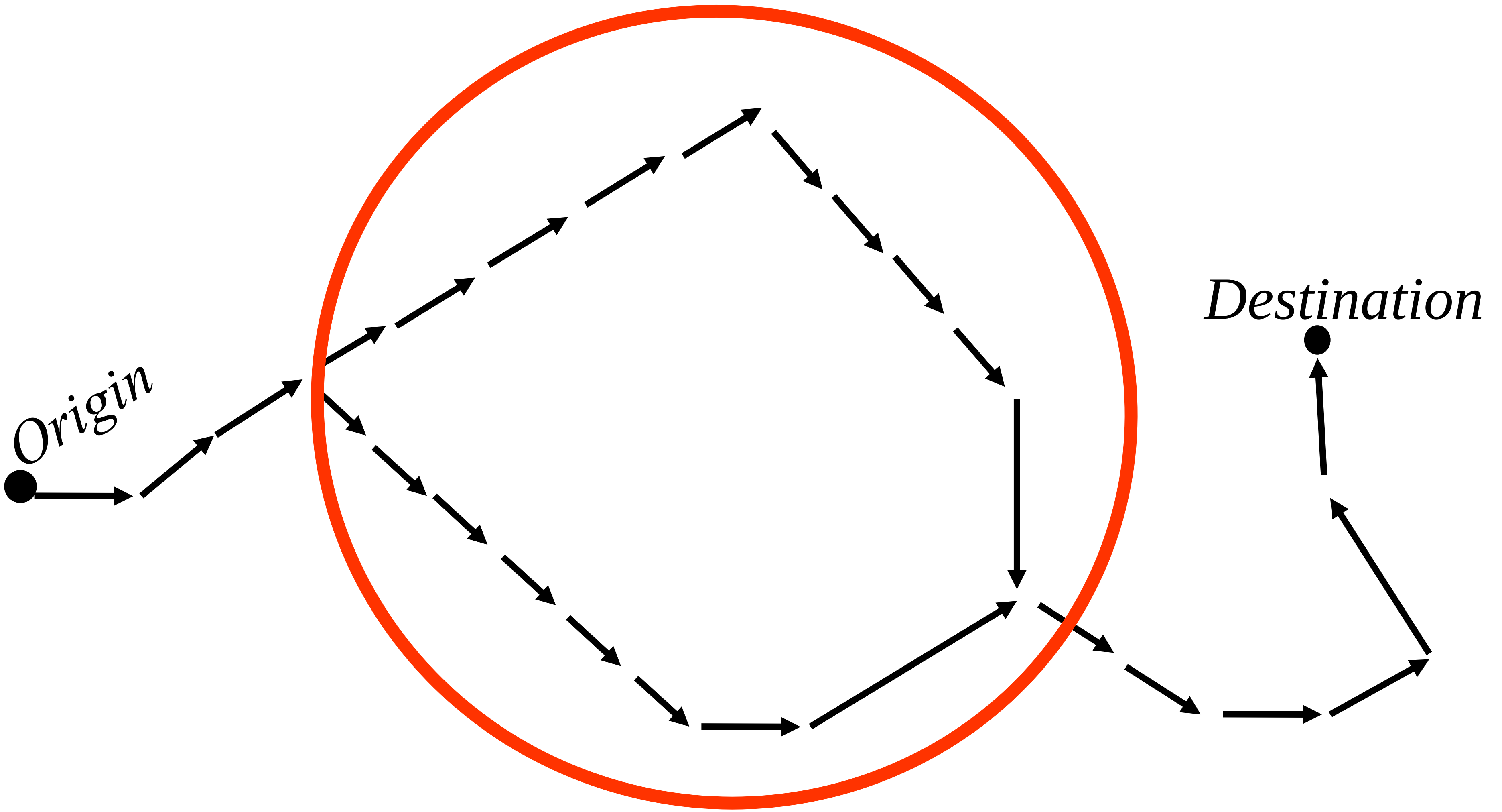
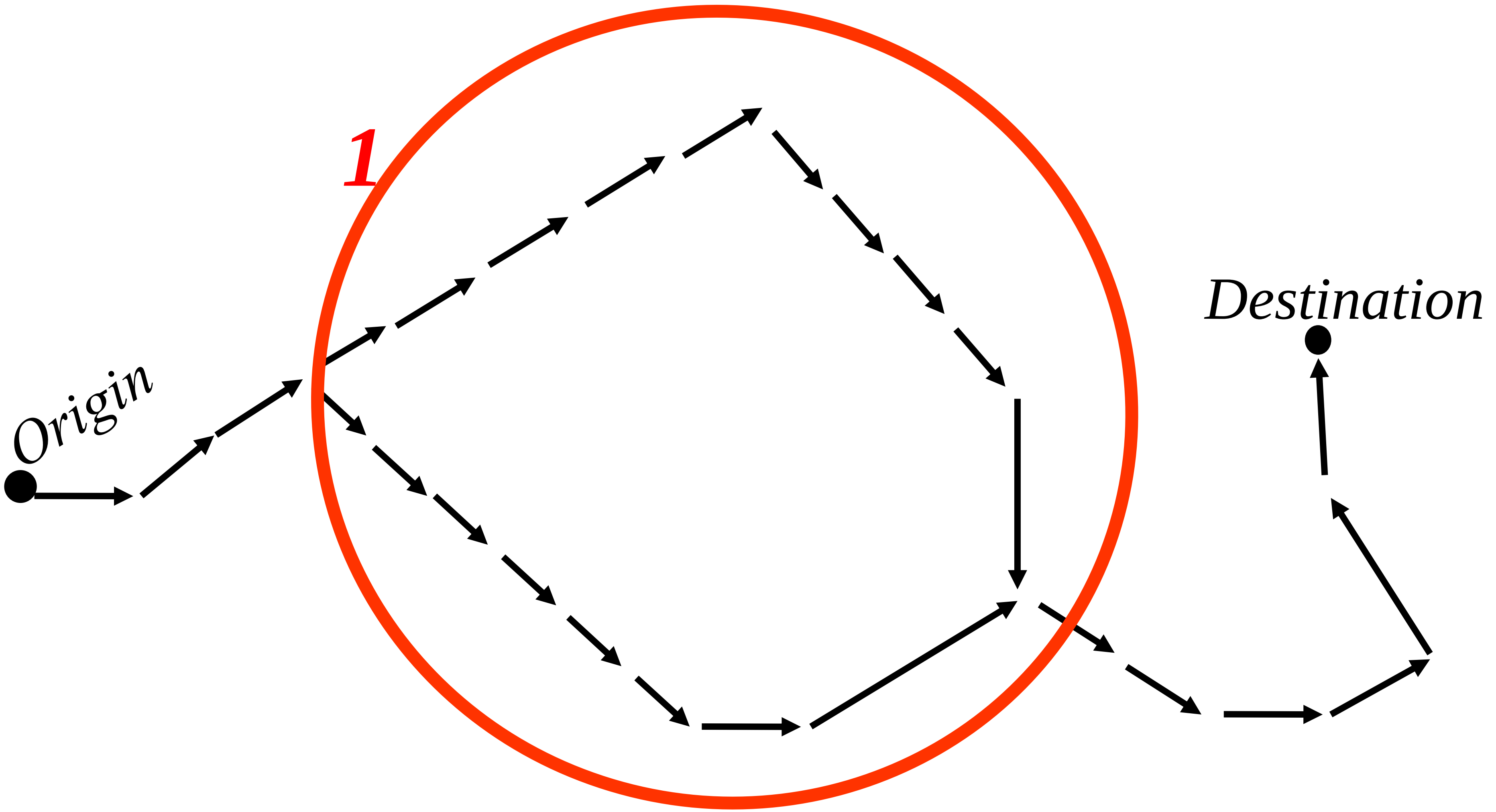
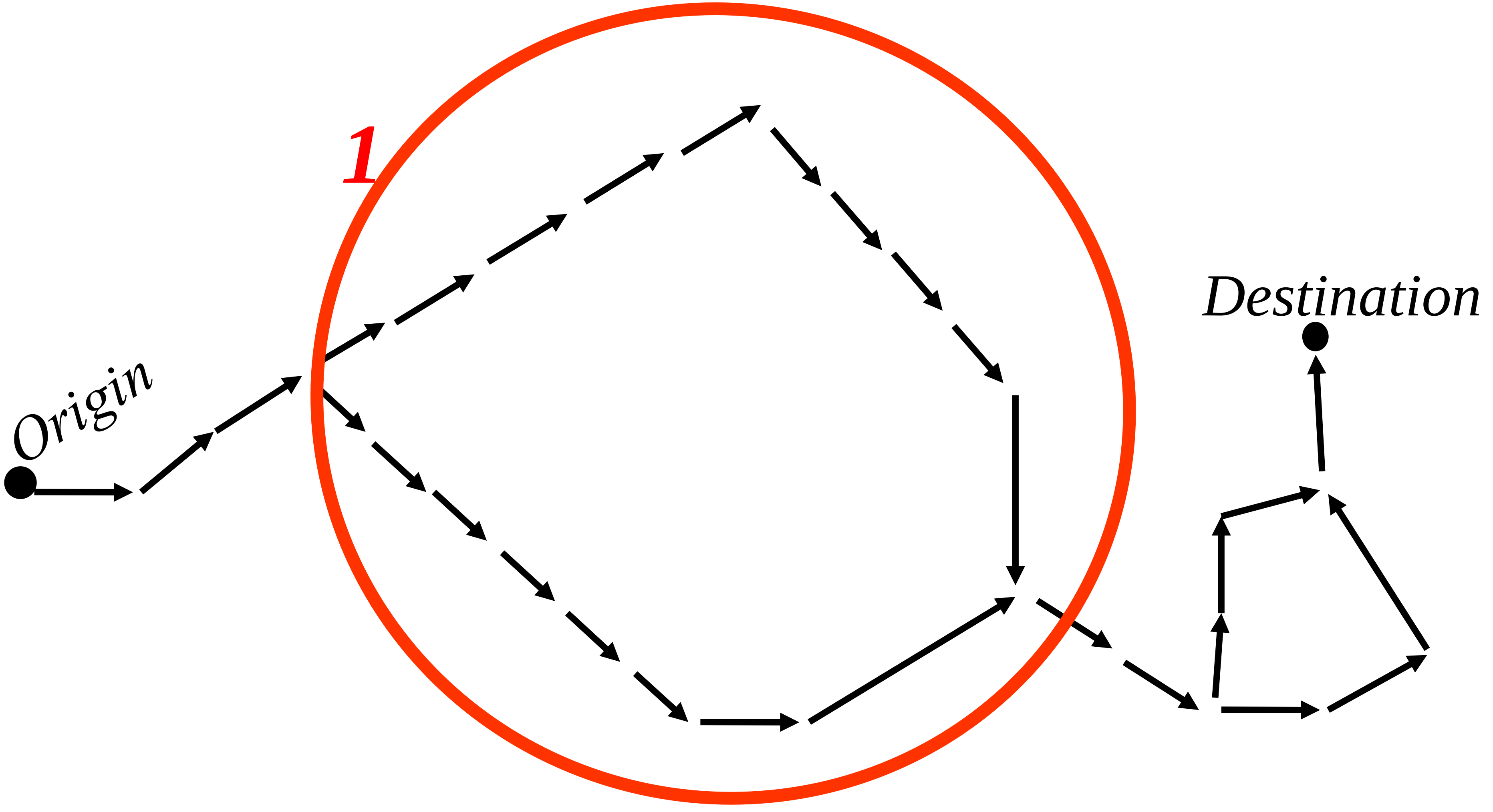


***SMALL Network* is not unrealistic**



SMALL Network is not unrealistic



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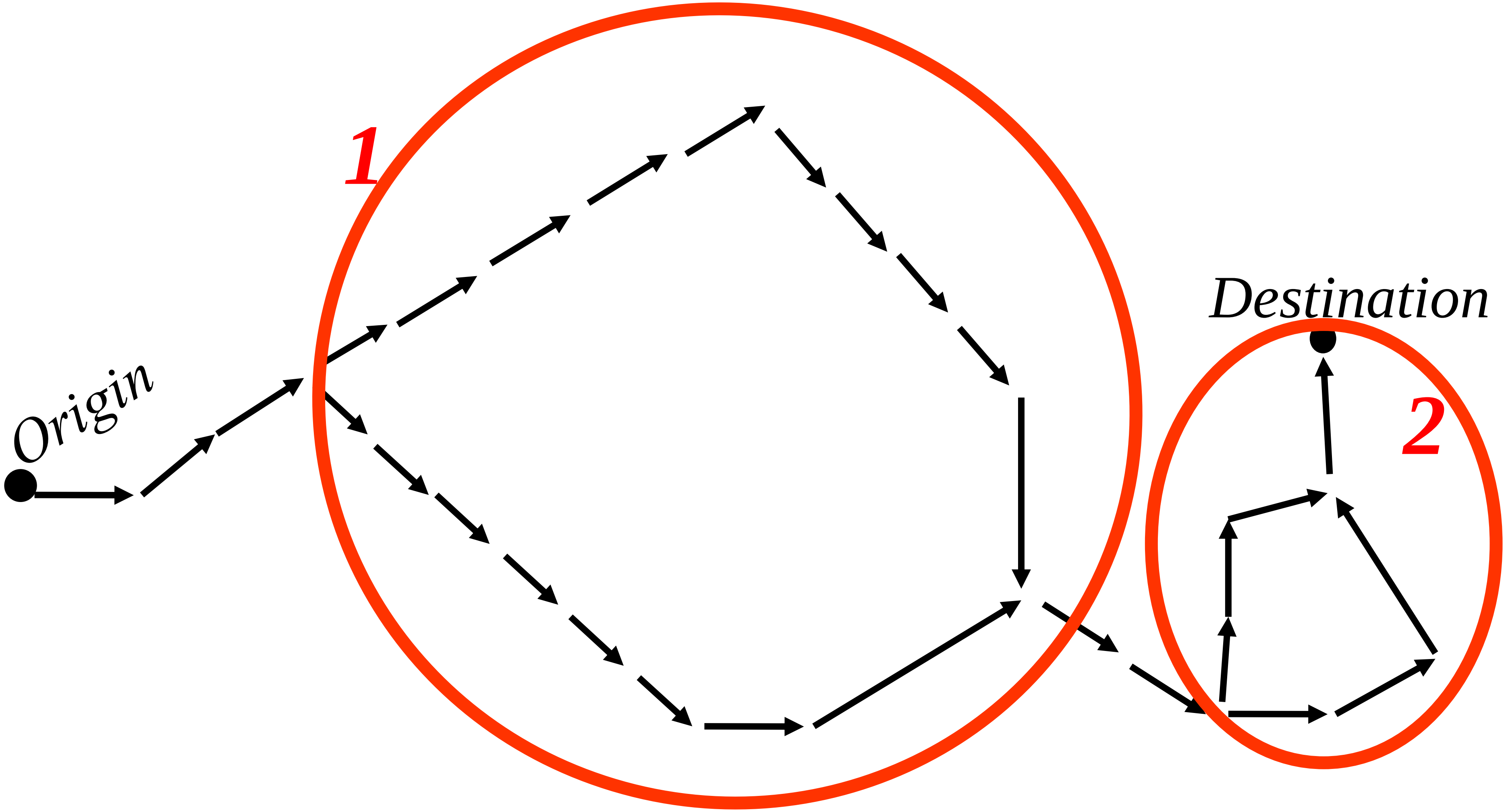
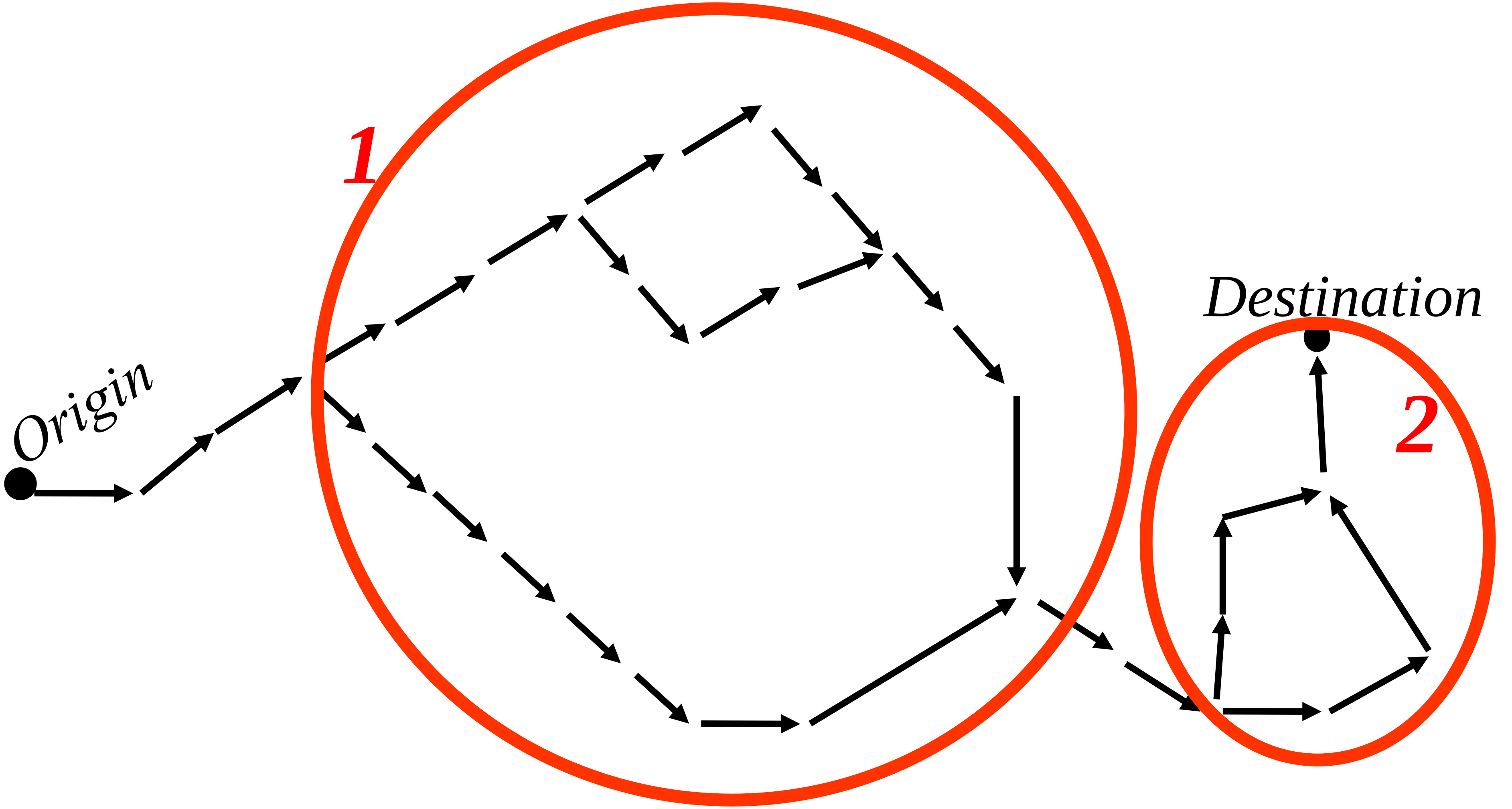


SMALL Network is not unrealistic



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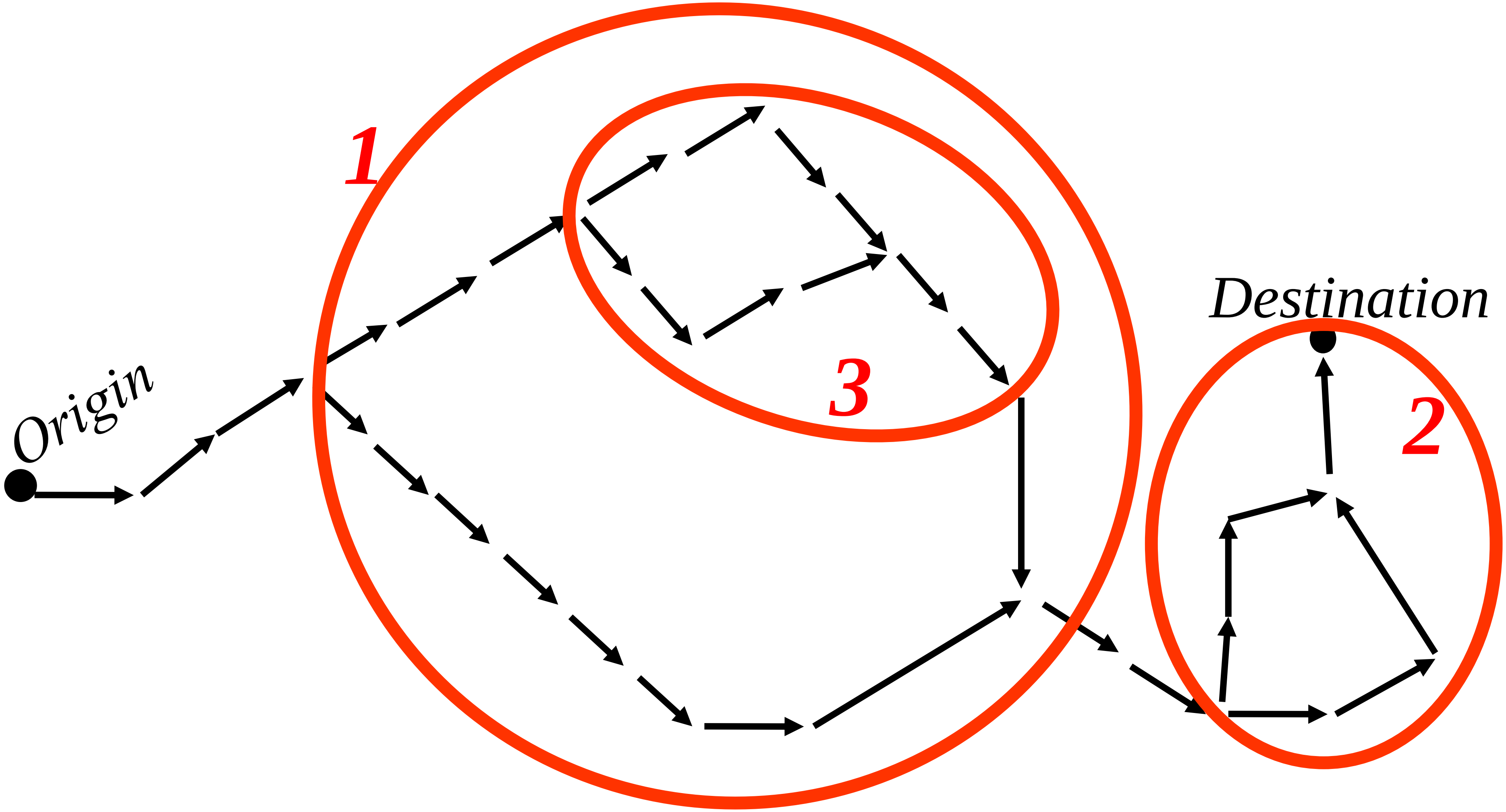


Summary

The talk considers:

- *A spatial queueing model (representing the space taken up by queues)*
- *Traffic signal control and route choice.*
- *Throughput maximising control when demand exceeds capacity*

- *P0 control and pricing results for the City of York.*

Summary

The talk considers:

- *A spatial queueing model (representing the space taken up by queues)*
  DONE
- *Traffic signal control and route choice.*
- *Throughput maximising control when demand exceeds capacity*

- *P0 control and pricing results for the City of York.*

AIM

TO REDUCE CONGESTION / POLLUTION IN CITIES

AIM

TO REDUCE CONGESTION / POLLUTION IN CITIES

IN PART AUTOMATICALLY

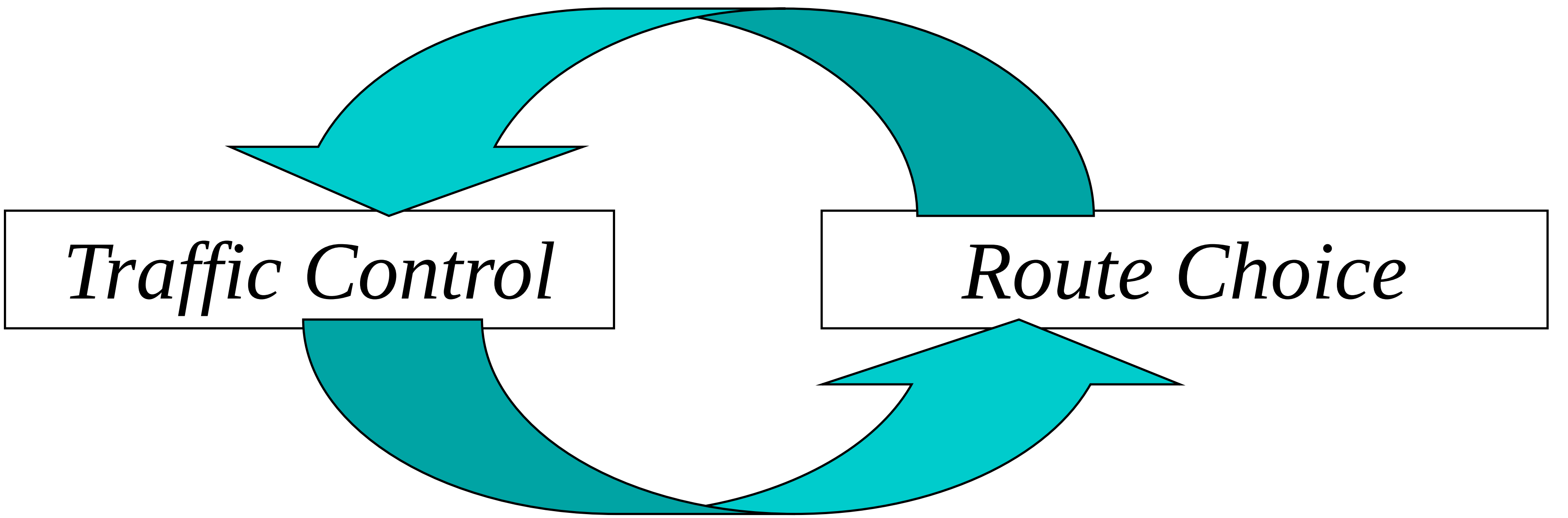
Previous Work

Modelling Signal Control and Route Choice:

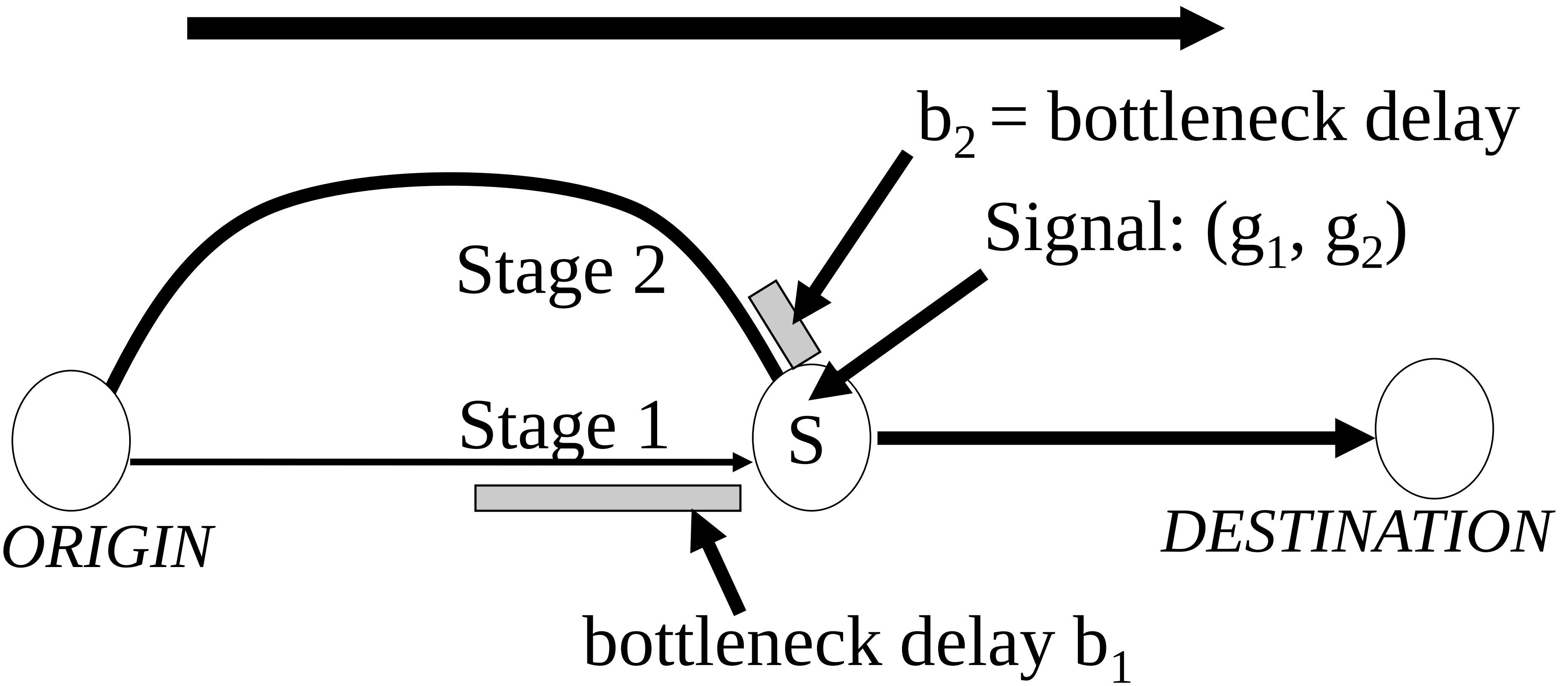
Allsop, Dickson, Gartner, Akcelik, Maher, Van Vliet, Van Vuren, Smith, Van Zuylen, Meneguzzer, Gentile, Noekel, Taale, Cantarella, Mounce, Watling, Ke Han, Himpe, Viti, Schlaich, Haupt, Tampere, Huang, Rinaldi,

⋮

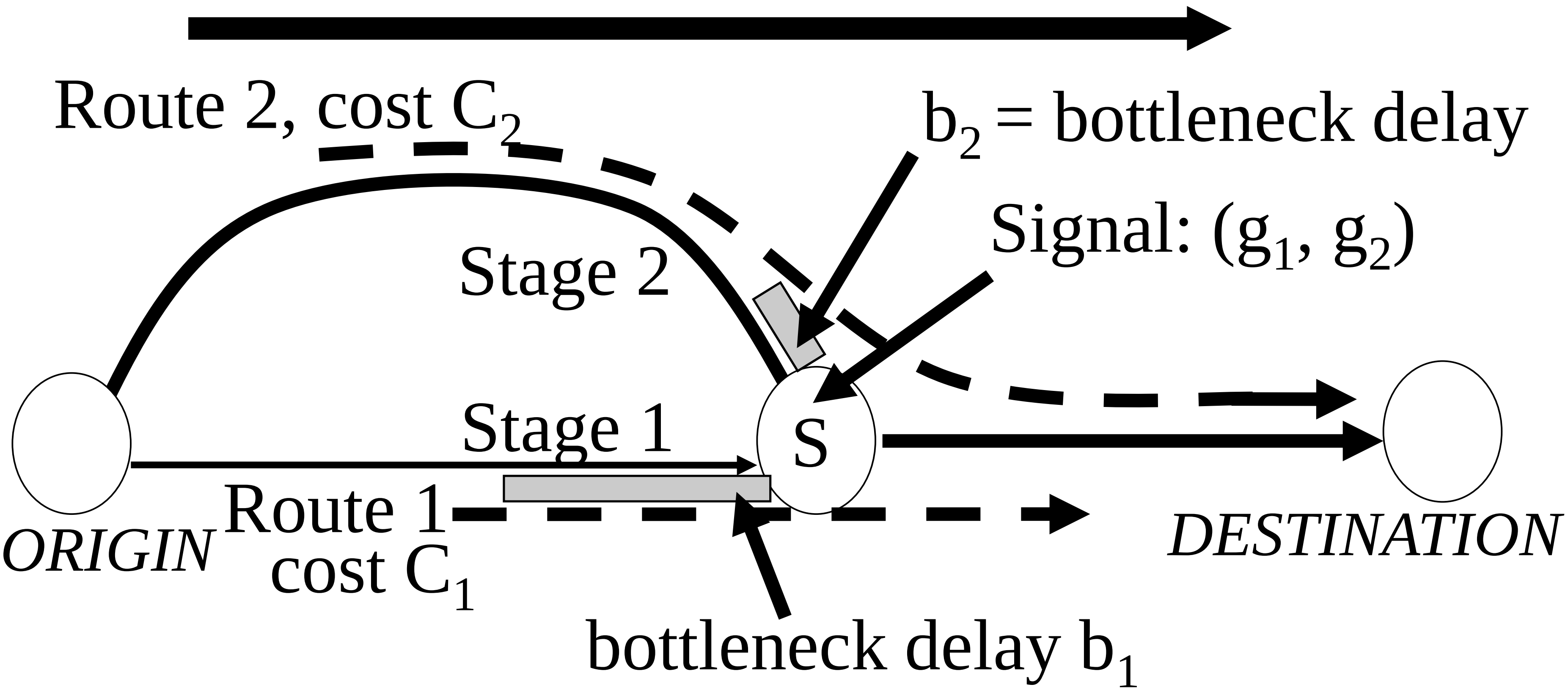
Traffic Control and Route Choice



NETWORK WITH ROUTE AND GREEN-TIME CHOICES



NETWORK WITH ROUTE AND GREEN-TIME CHOICES



Control and Route-flow Variables

Controls:

Green-time vector **g**:

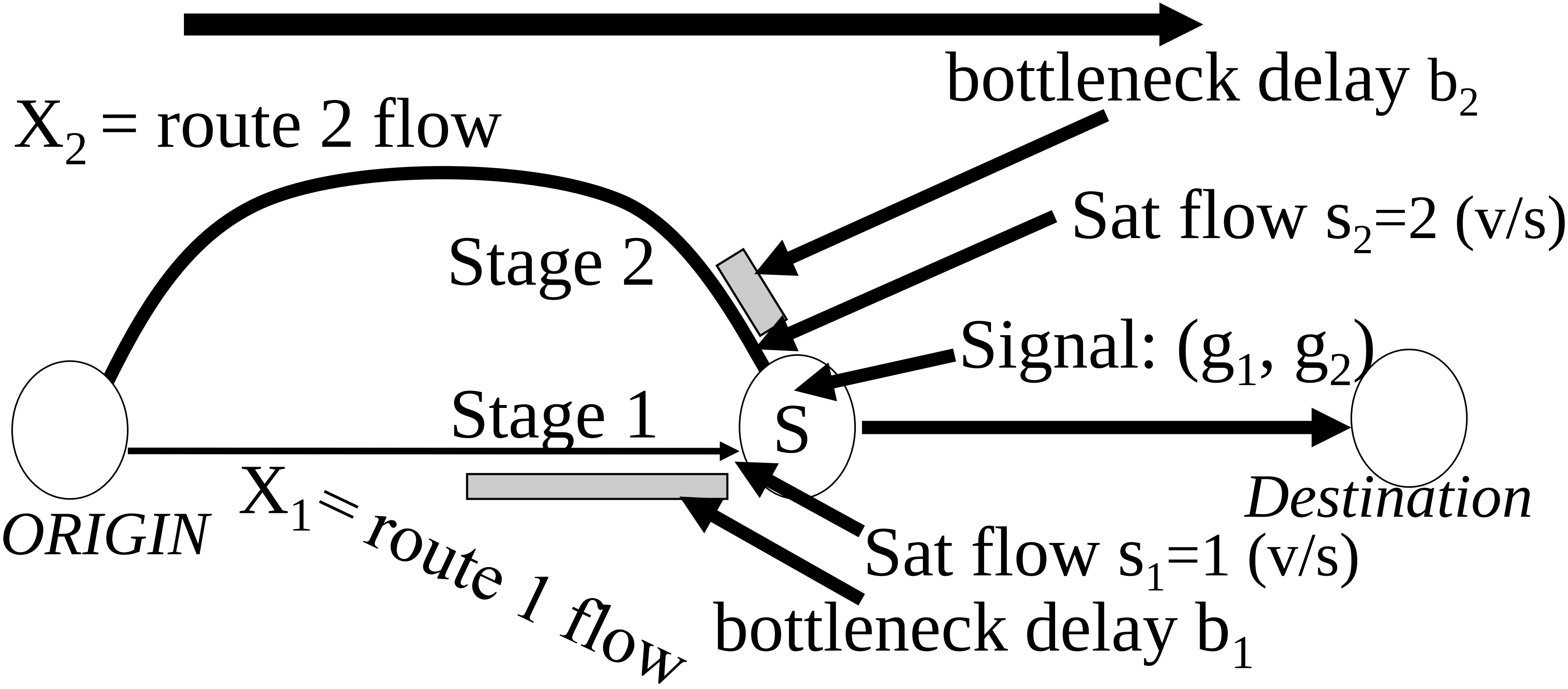
$$g_1 + g_2 = 1.$$

Route-flows:

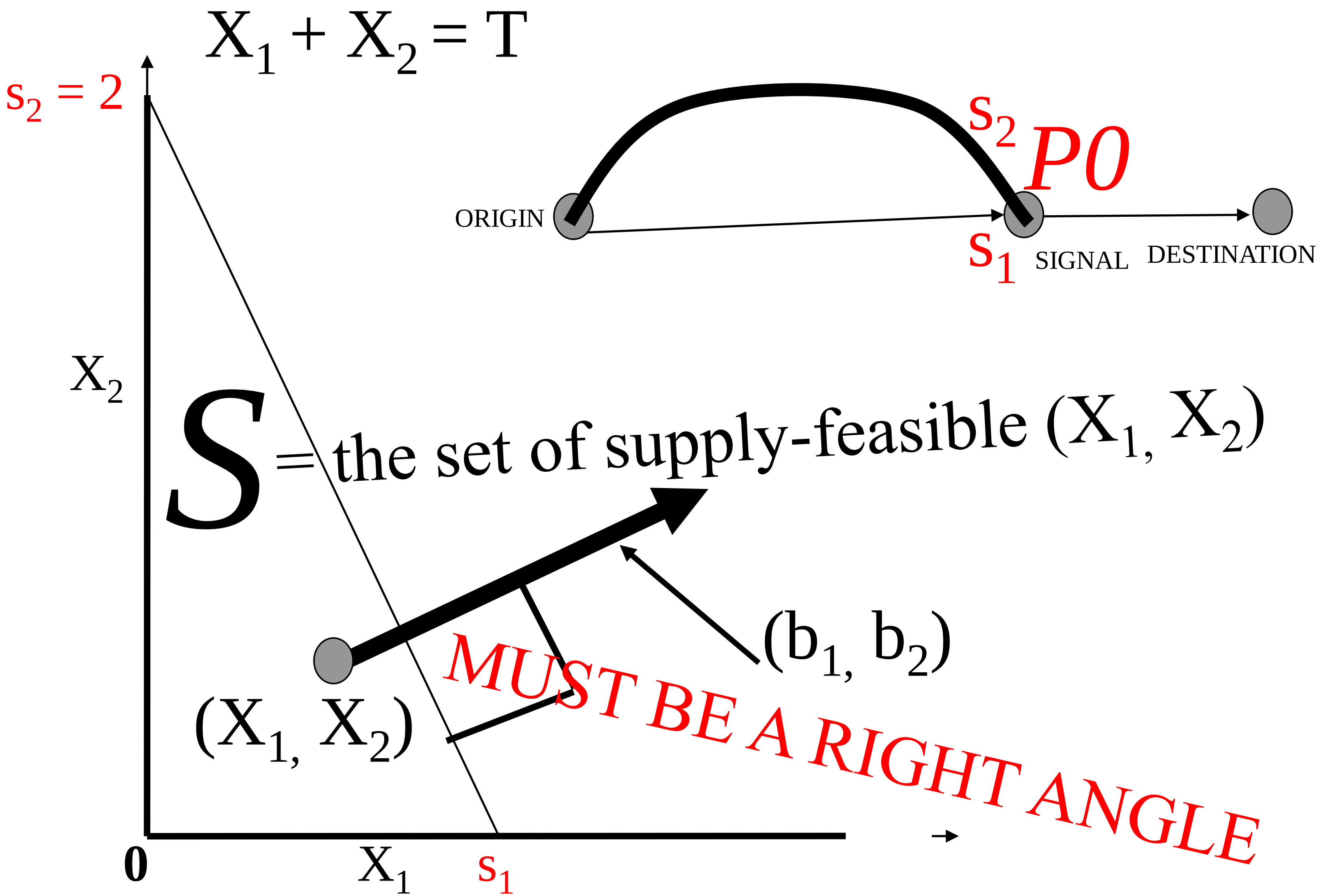
Route-flow vector **X**;

$$X_1 + X_2 = \text{given steady demand } T.$$

SMALL Network

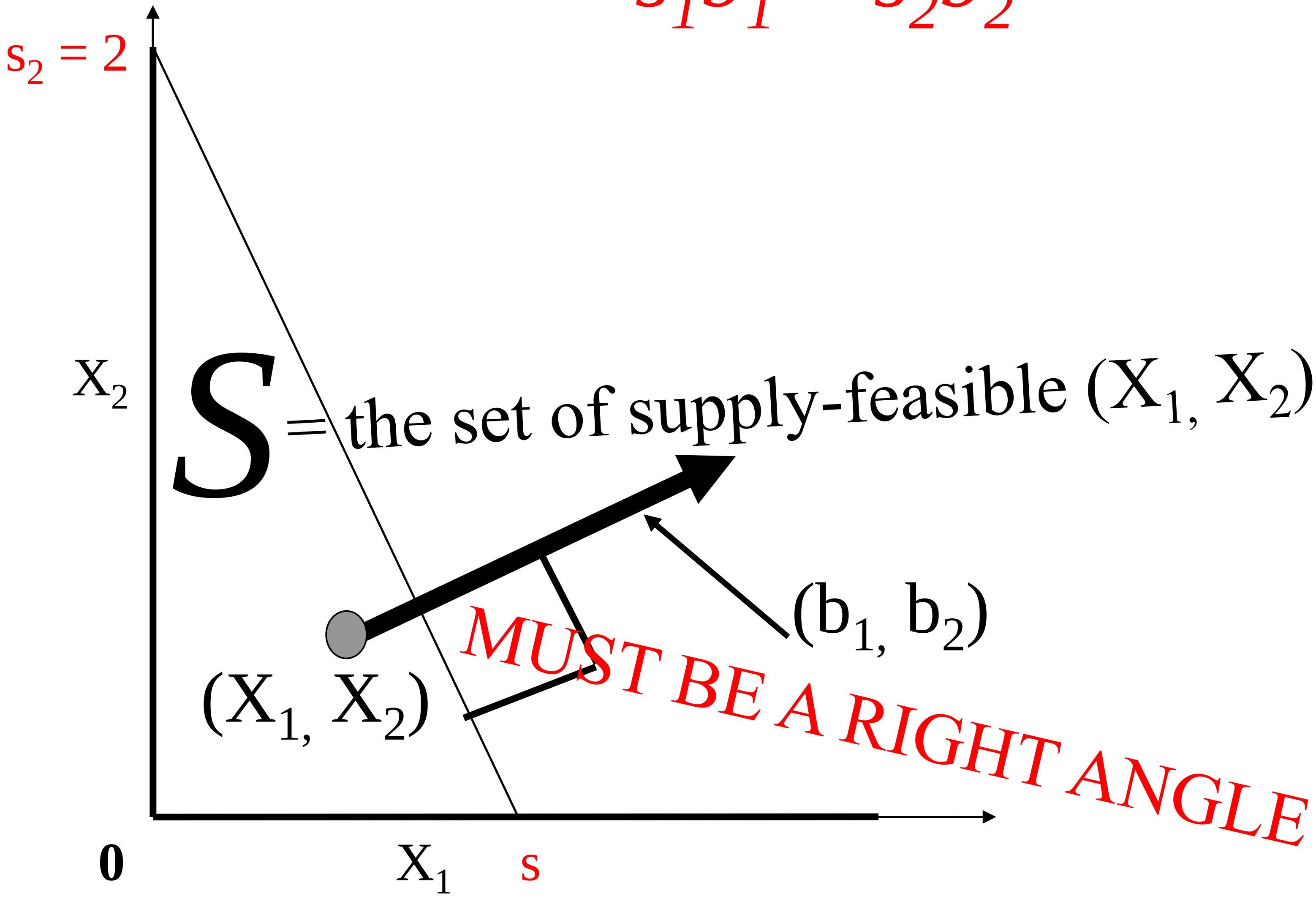


*P0: Choose greens so **b** is "normal" to S.*

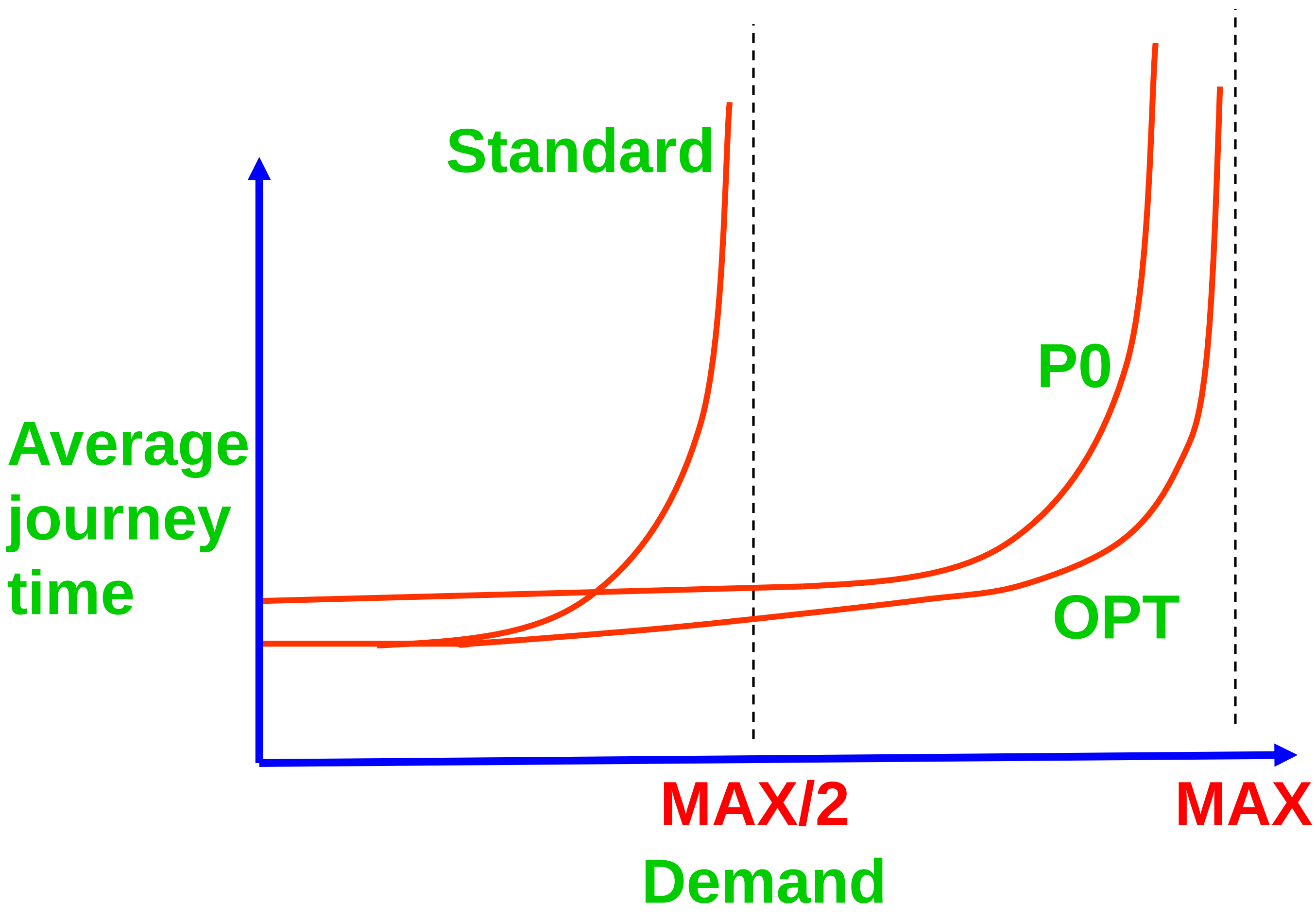


P0: Choose greens so **b** *is "normal" to S.*

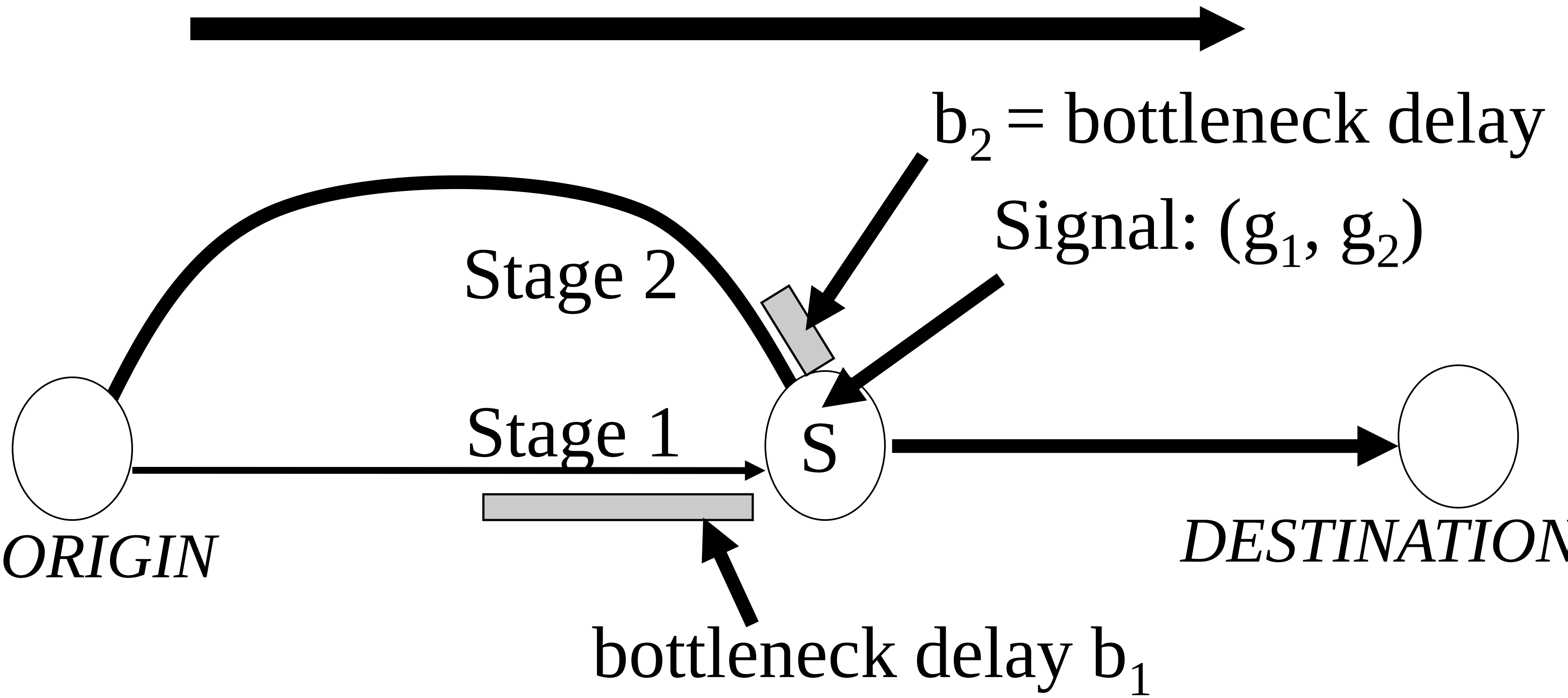
$$s_1 b_1 = s_2 b_2$$



STANDARD POLICIES HALVE THE CAPACITY OF THIS NETWORK



NETWORK WITH ROUTE AND GREEN-TIME CHOICES



Equilibrium flow and P_0 green-time

EXACT P_0 Control Policy:

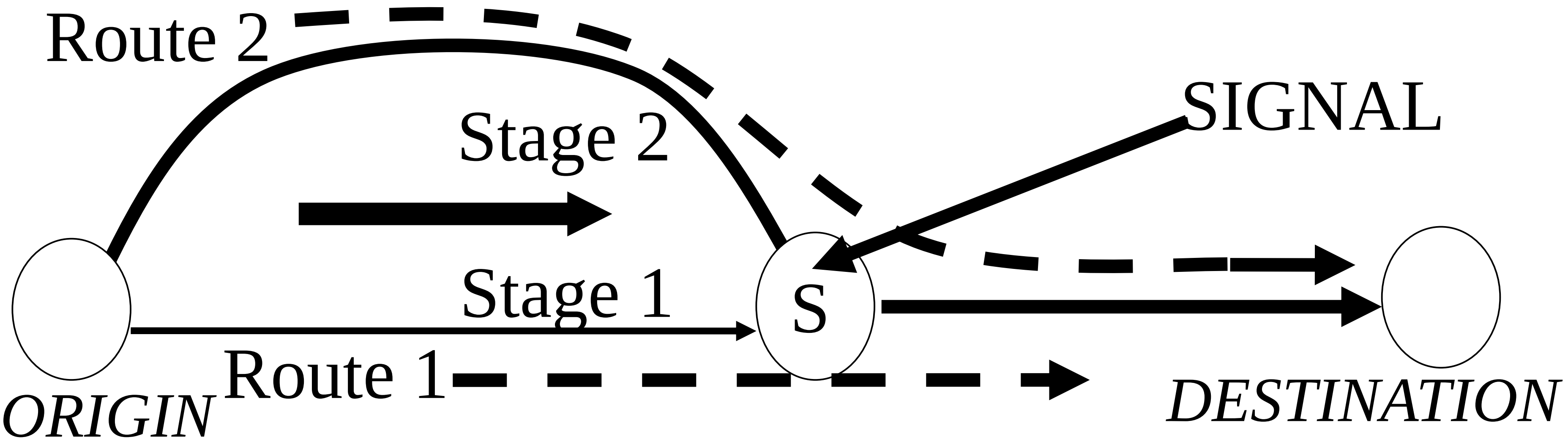
green-time **g** satisfies $s_1 b_1 = s_2 b_2$

EXACT route-choice equilibrium:

route-flow **X** satisfies $C_1 + b_1 = C_2 + b_2$

What if these conditions do not hold?

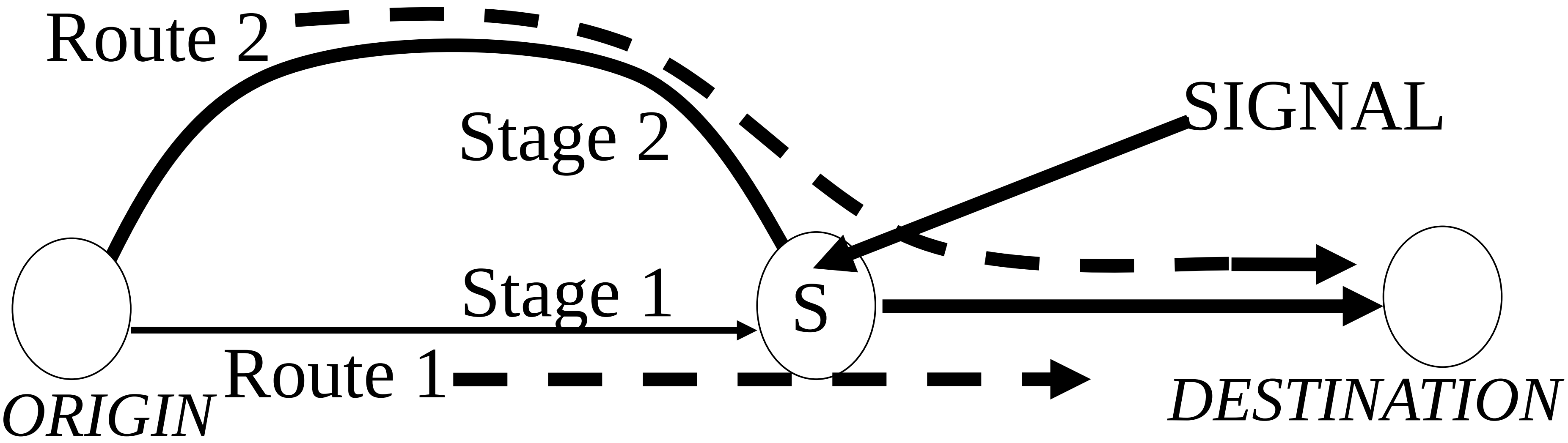
ROUTE AND GREEN-TIME SWAPS



ROUTE AND GREEN-TIME SWAPS

Travel cost along route 1 = C_1+b_1

Travel cost along route 2 = C_2+b_2



ROUTE AND GREEN-TIME SWAPS

Travel cost along route 1 = C_1+b_1

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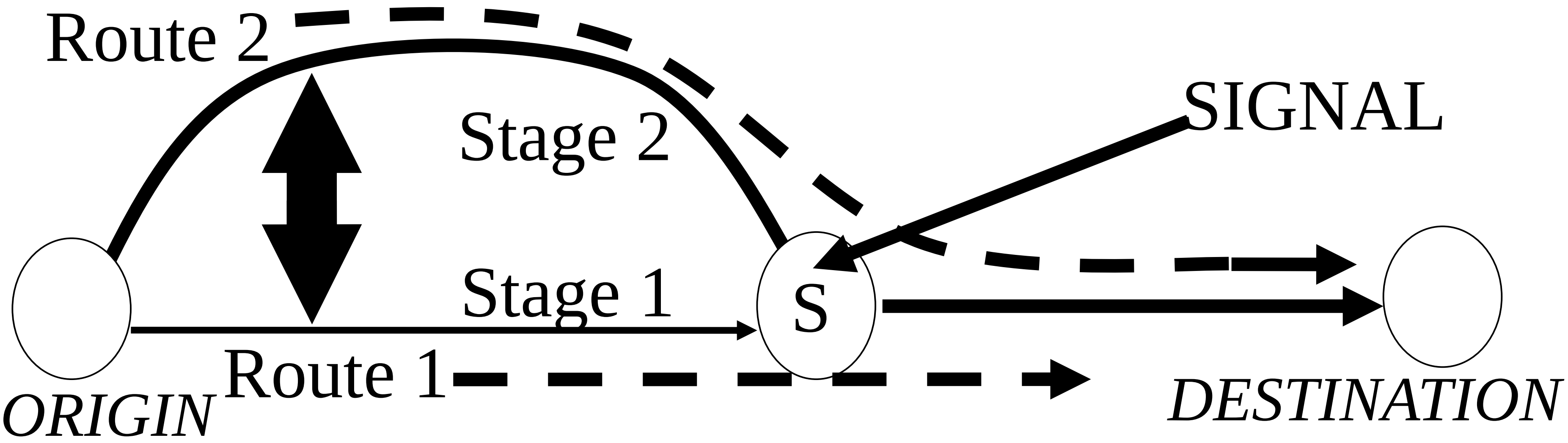
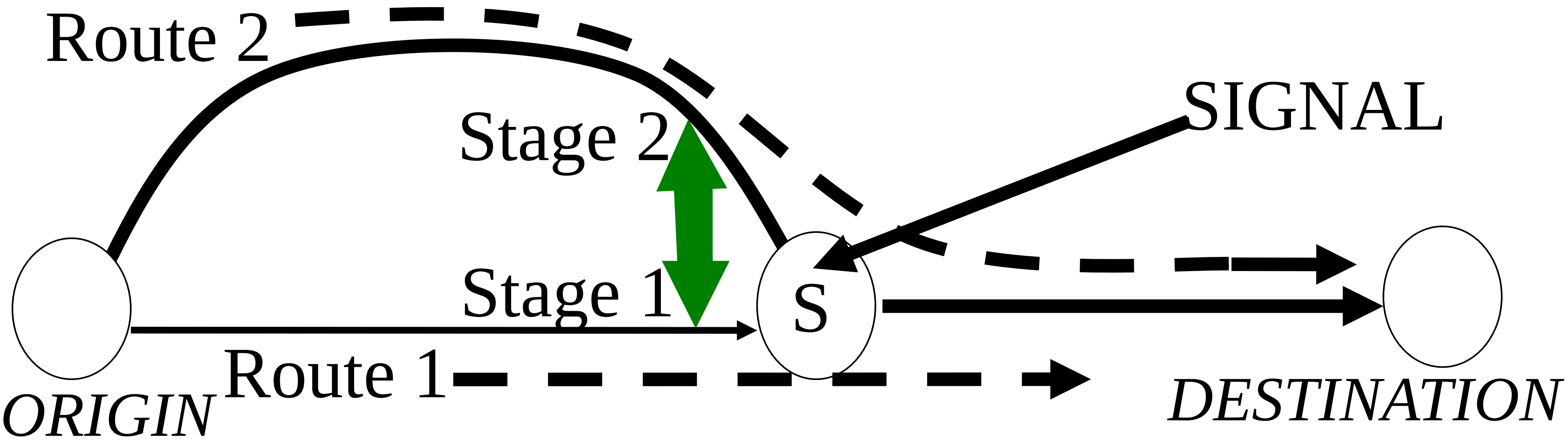


ROUTE AND GREEN-TIME SWAPS

Pressure on stage 1 = $s_1 b_1$

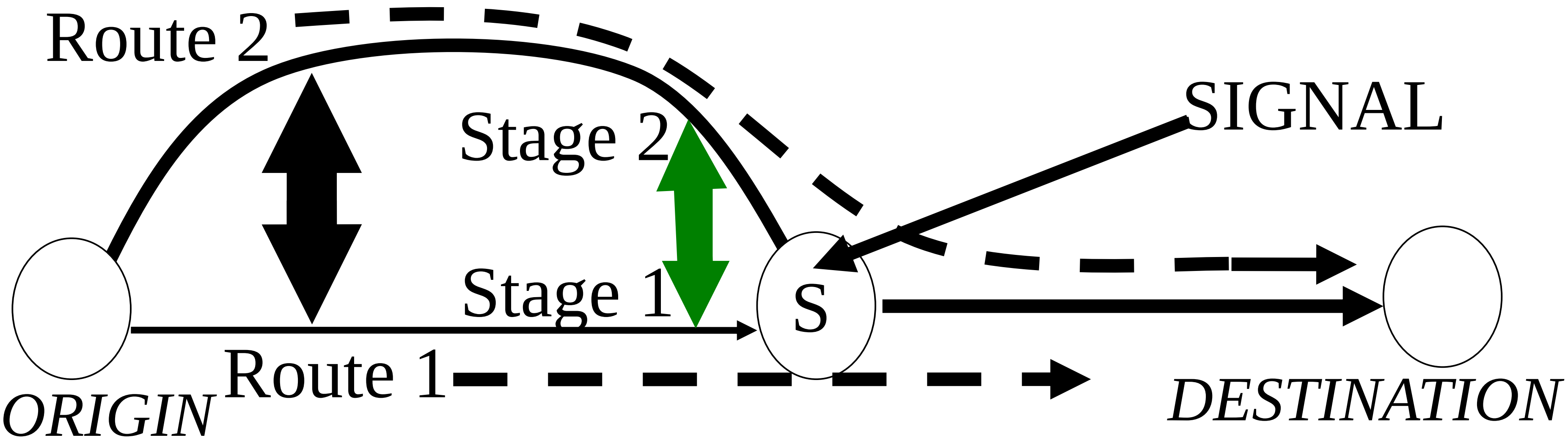
Pressure on stage 2 = $s_2 b_2$



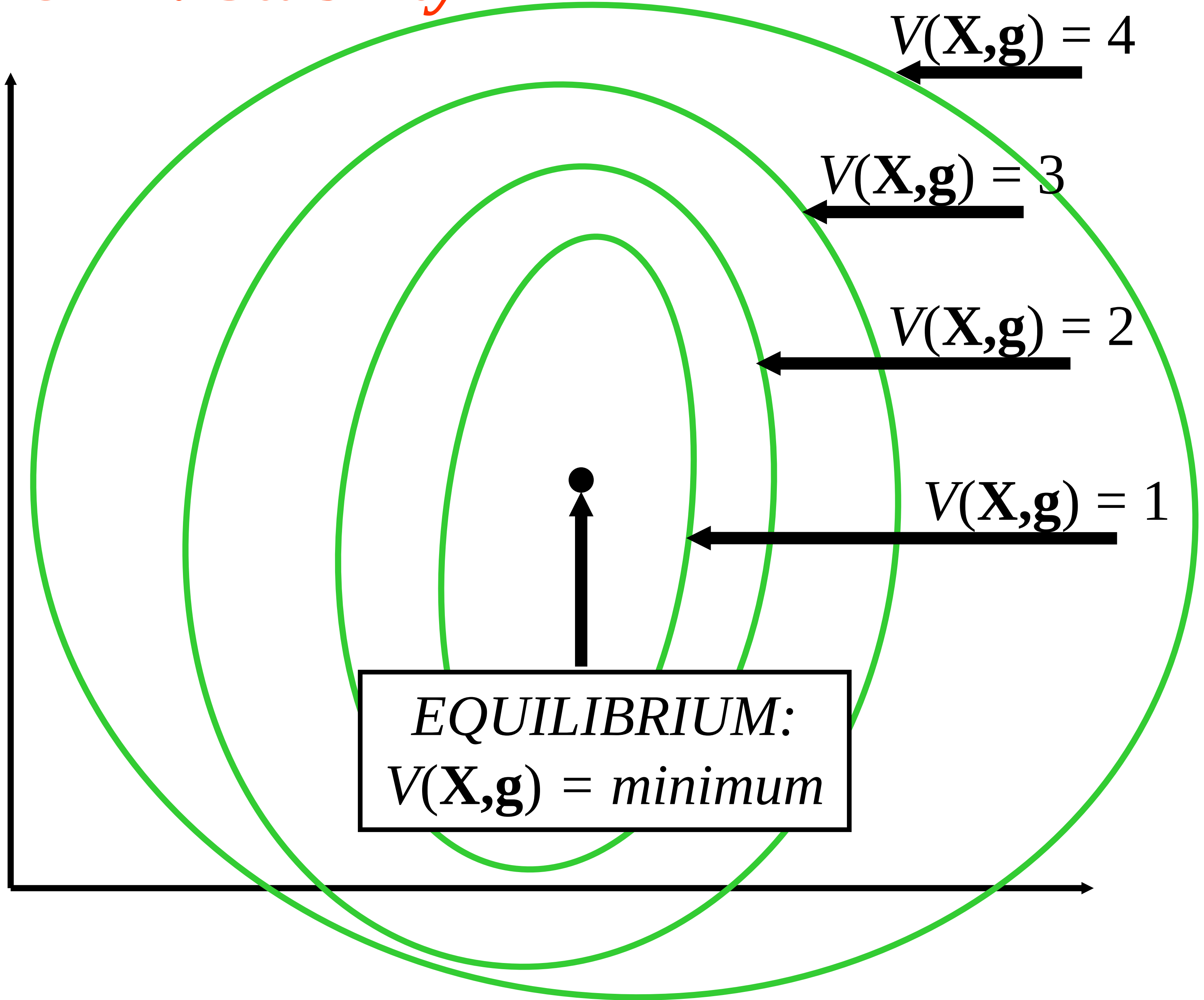
ROUTE AND GREEN-TIME SWAPS

$[C_1+b_1] - [C_2+b_2]$ controls black arrow

s_1b_1 - s_2b_2 controls green arrow



*** HOPE: Stability ***



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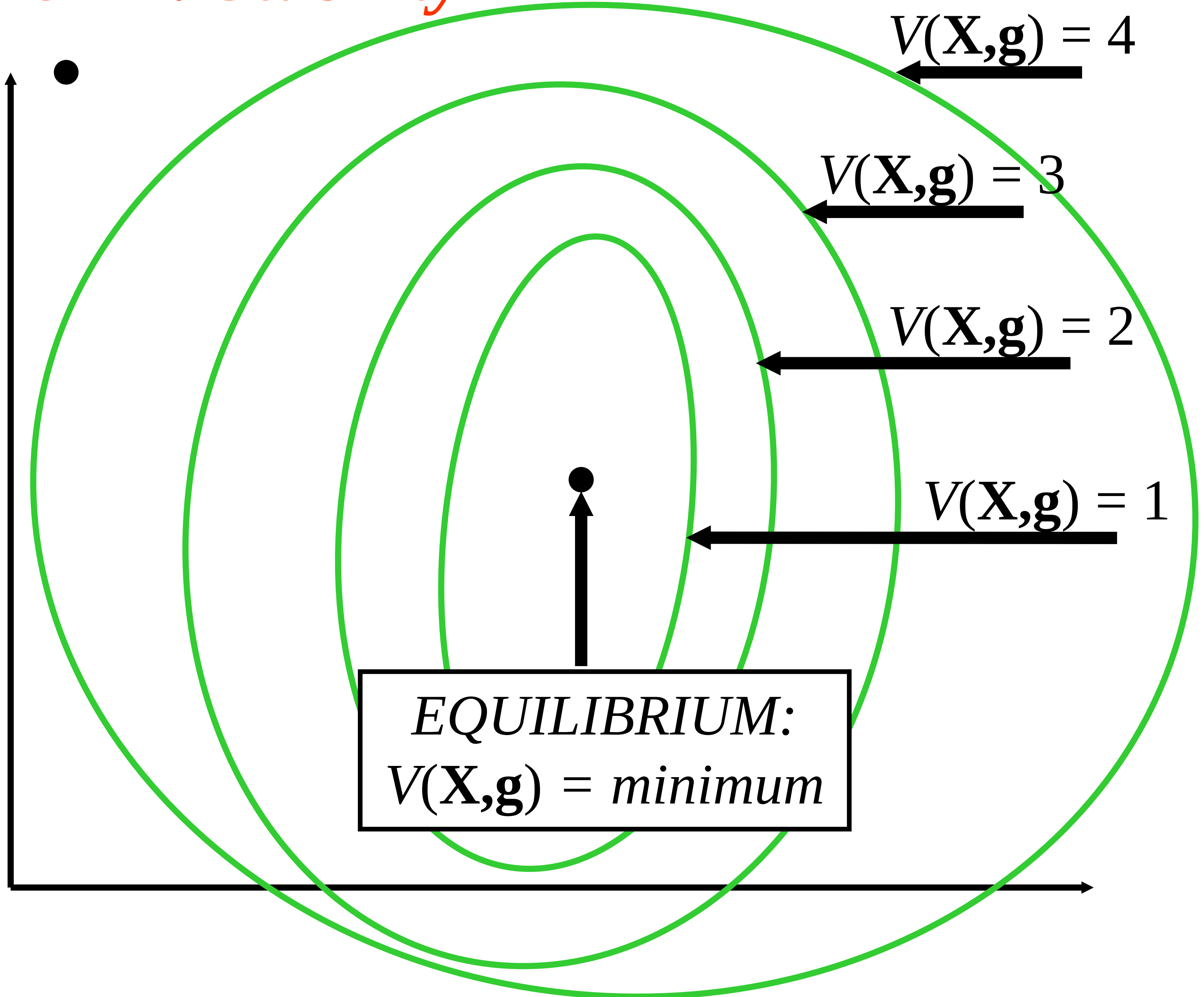

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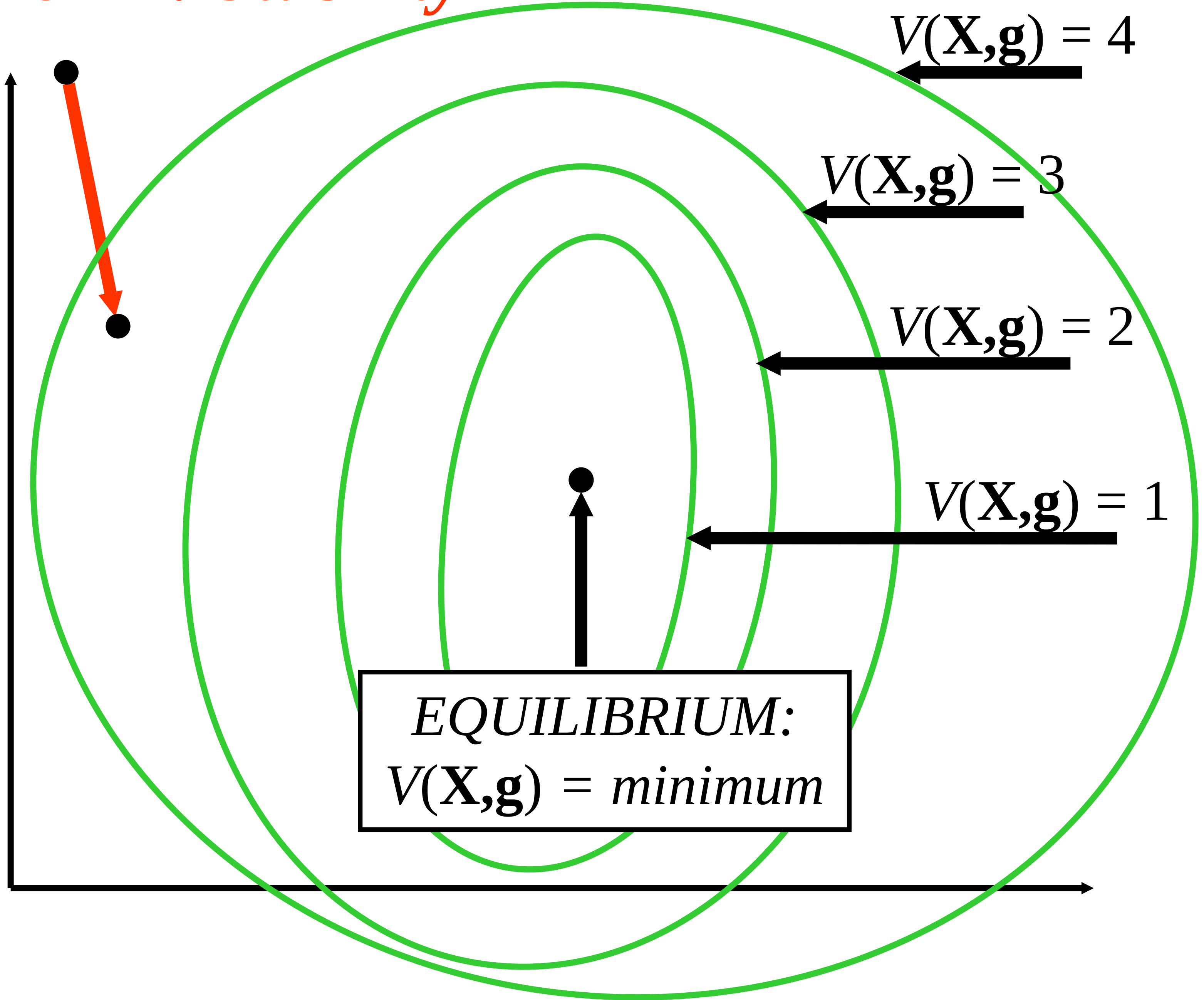

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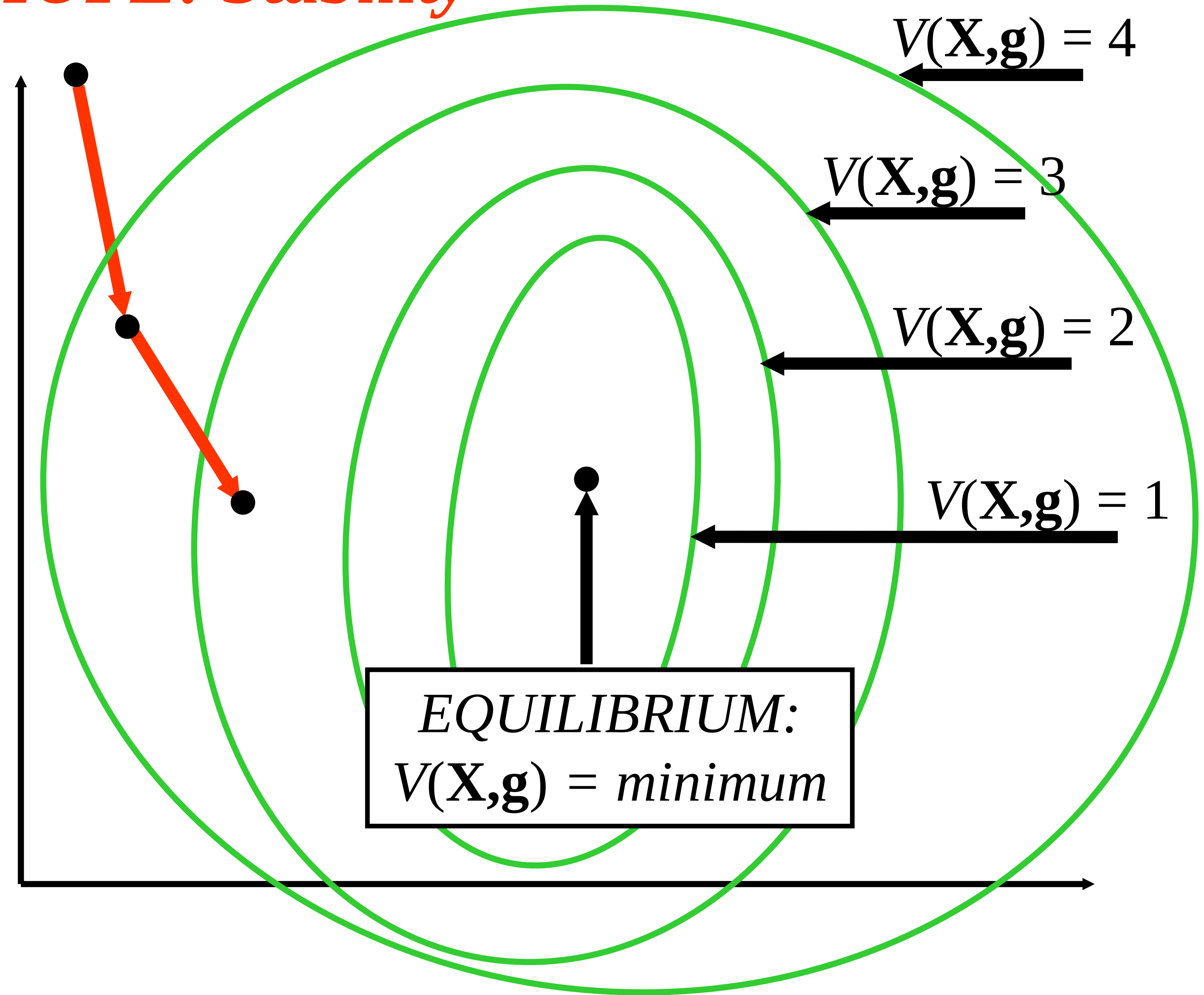

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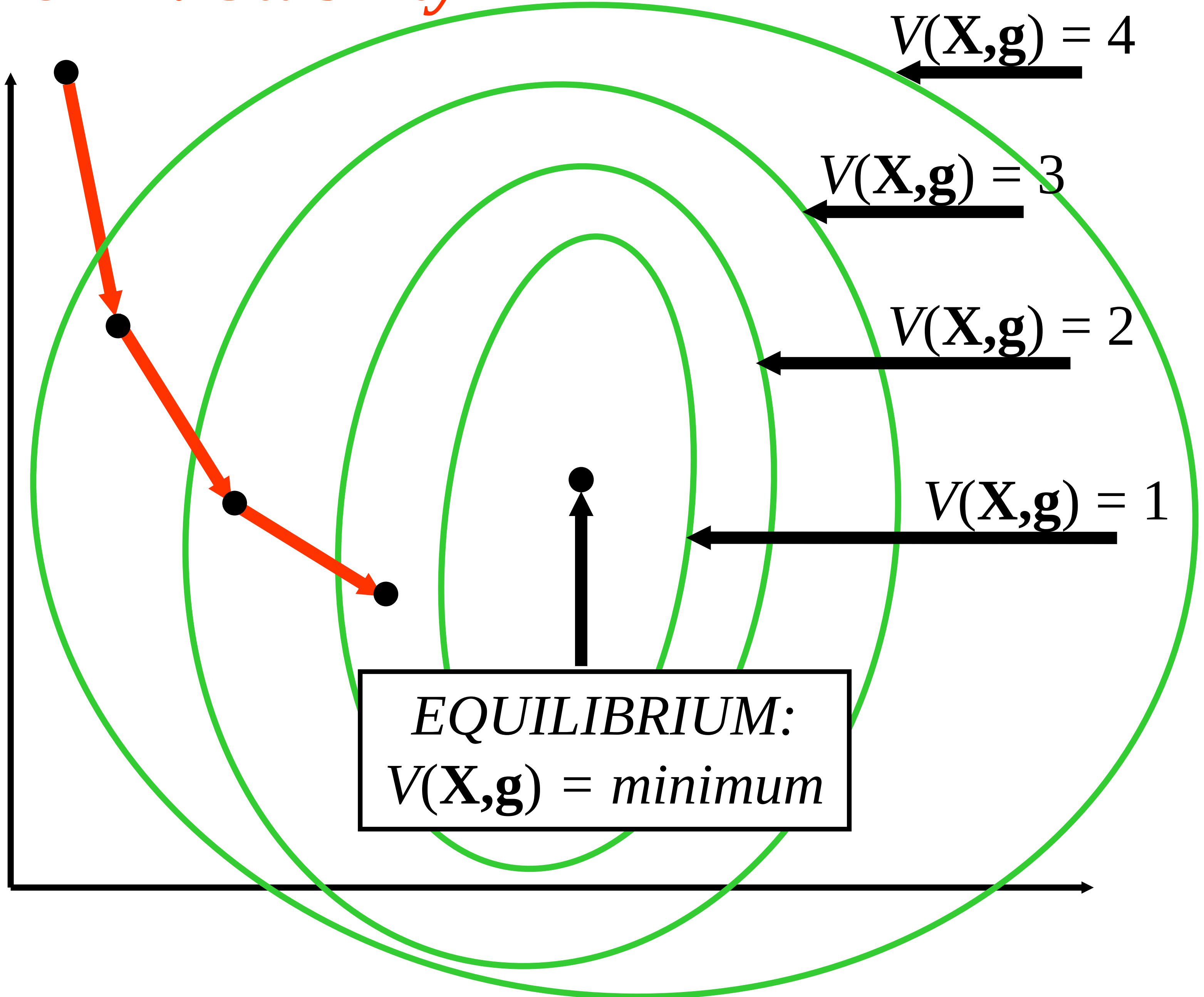

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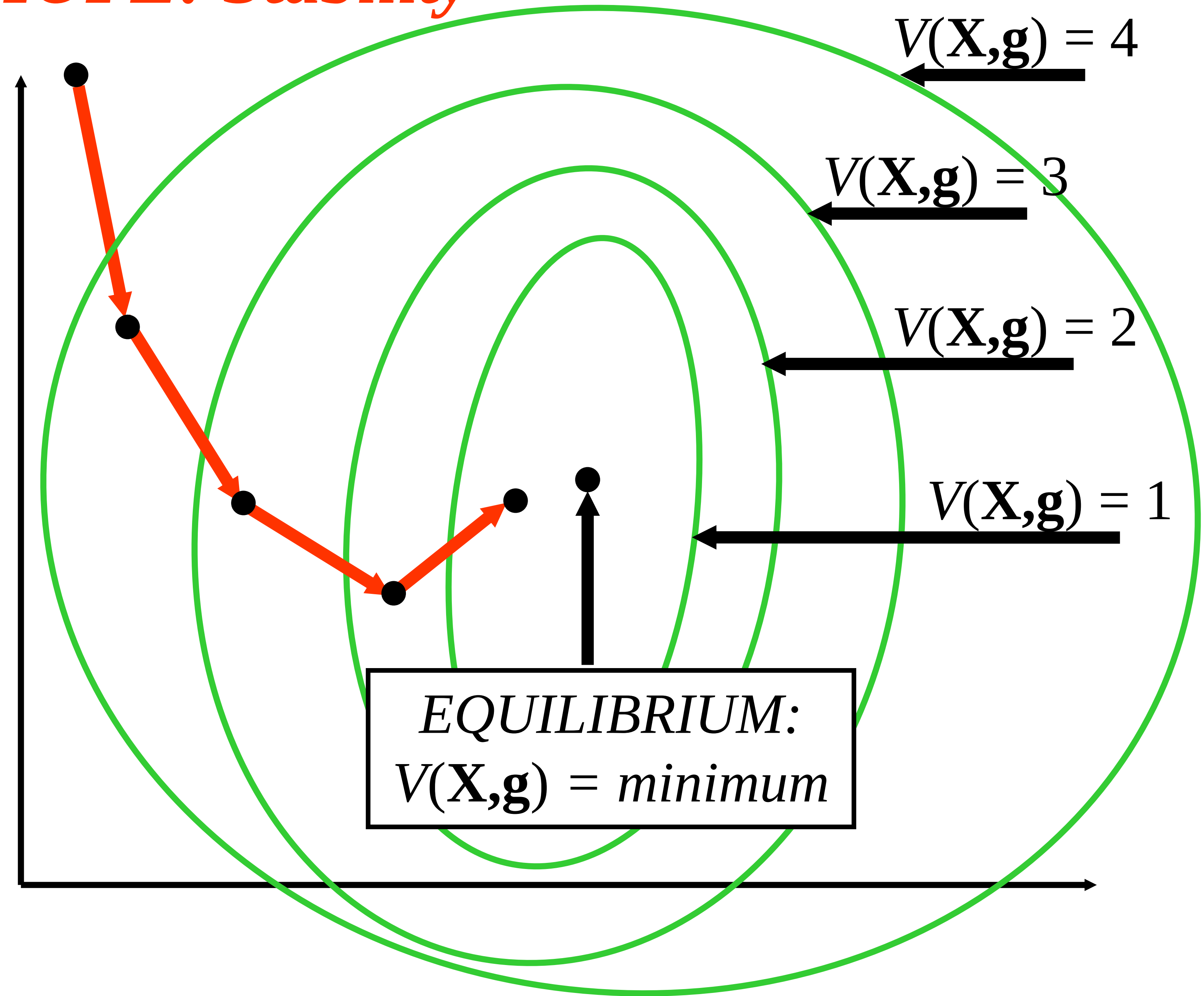
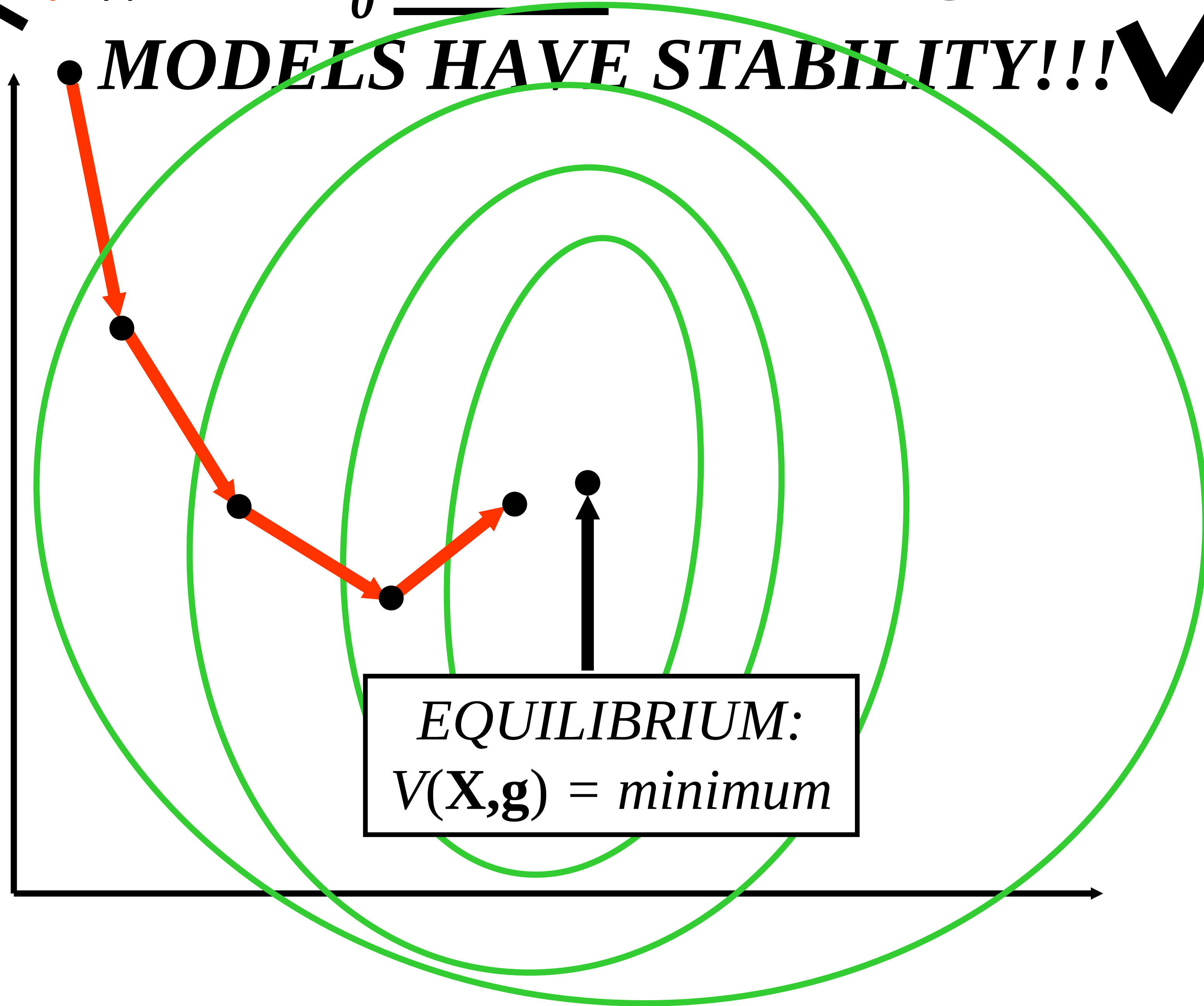


~~HOPE~~: WITH P_0 MANY DYNAMICAL MODELS HAVE STABILITY!!! ✓



Other policies?

STABLE WITH STANDARD POLICIES ???

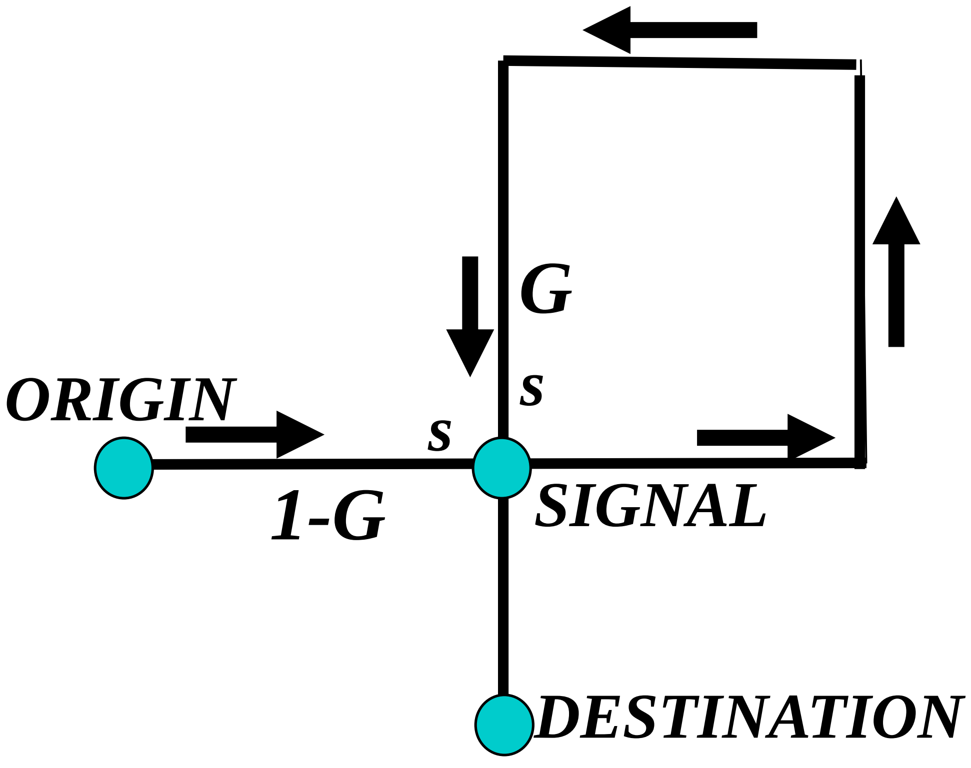
Other policies?

STABLE WITH STANDARD POLICIES ???

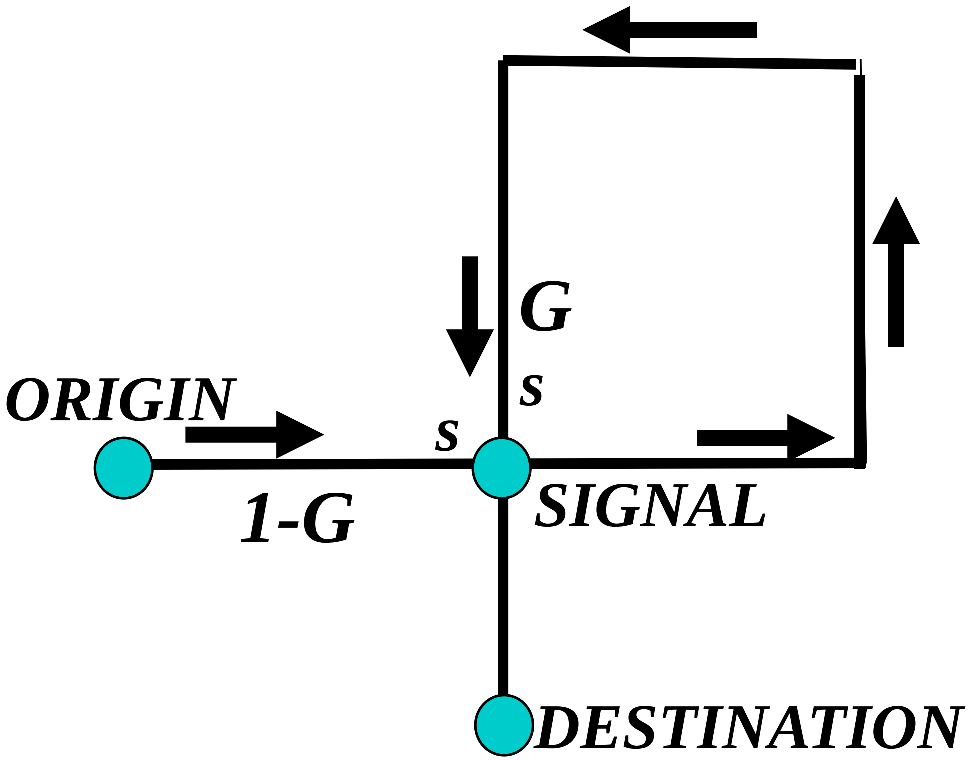
NO!

CONTROL WHICH MAXIMISES THROUGHPUT

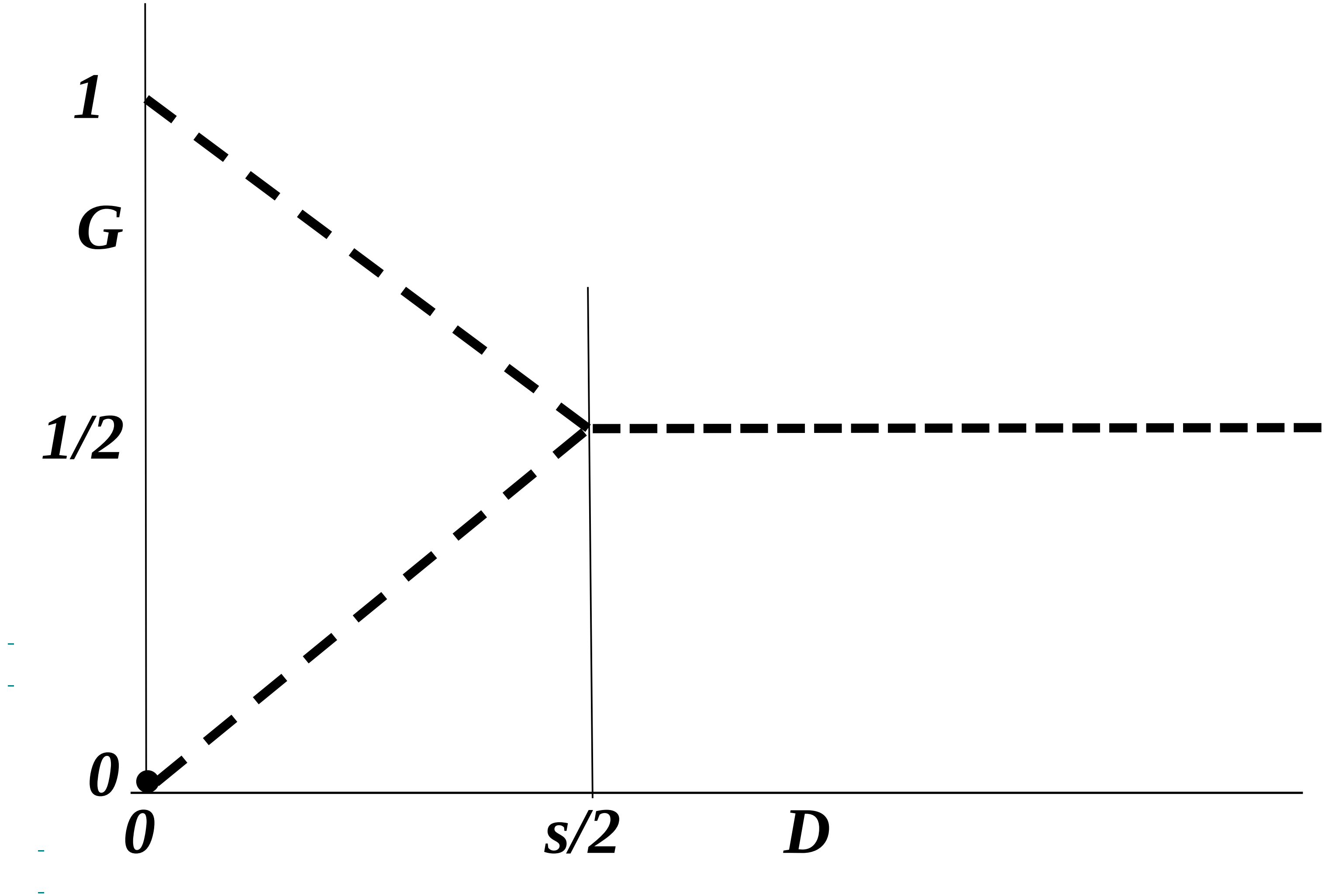
Even when demand exceeds capacity



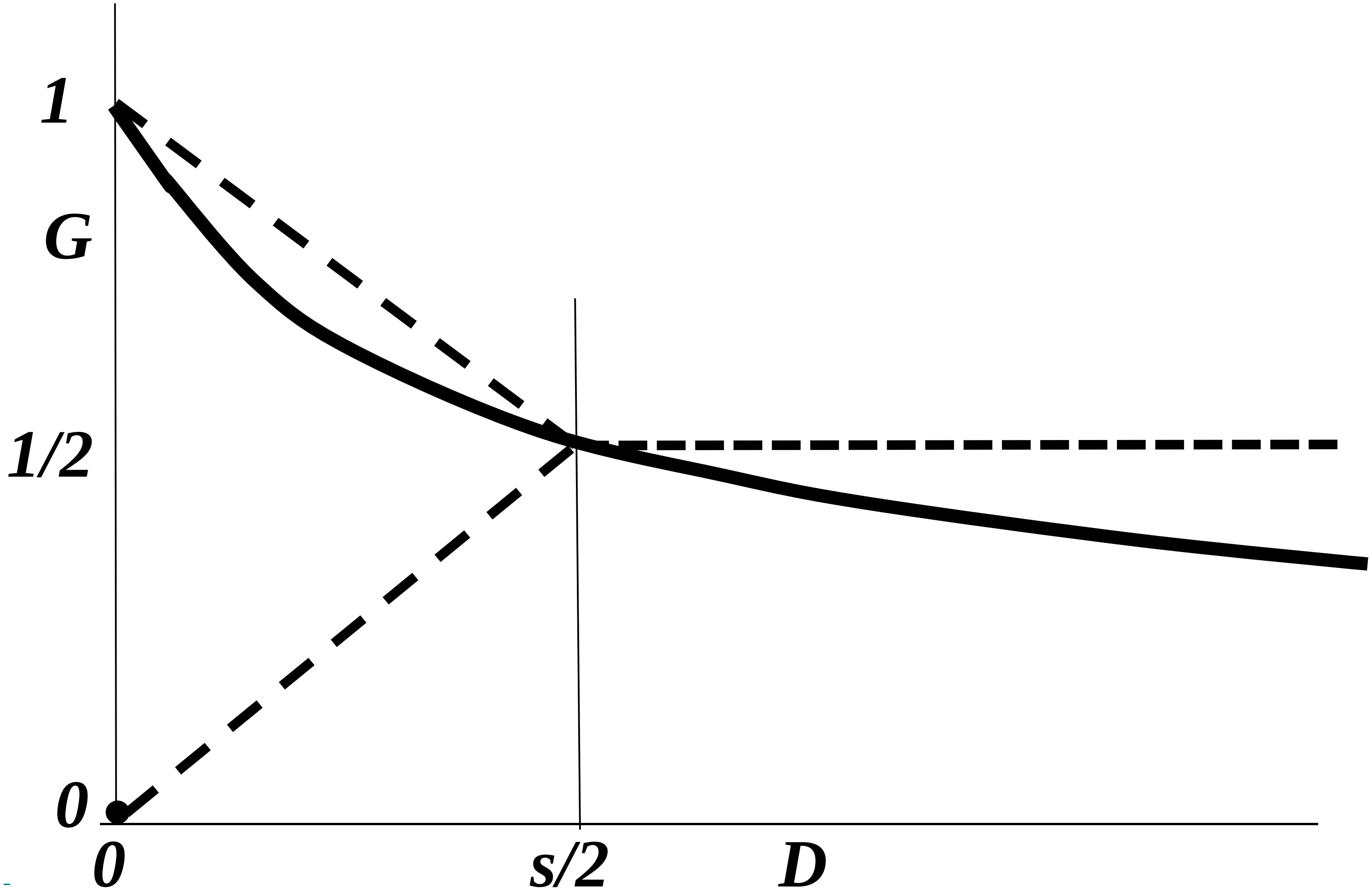
G
s
ORIGIN
s
1-G
SIGNAL
DESTINATION

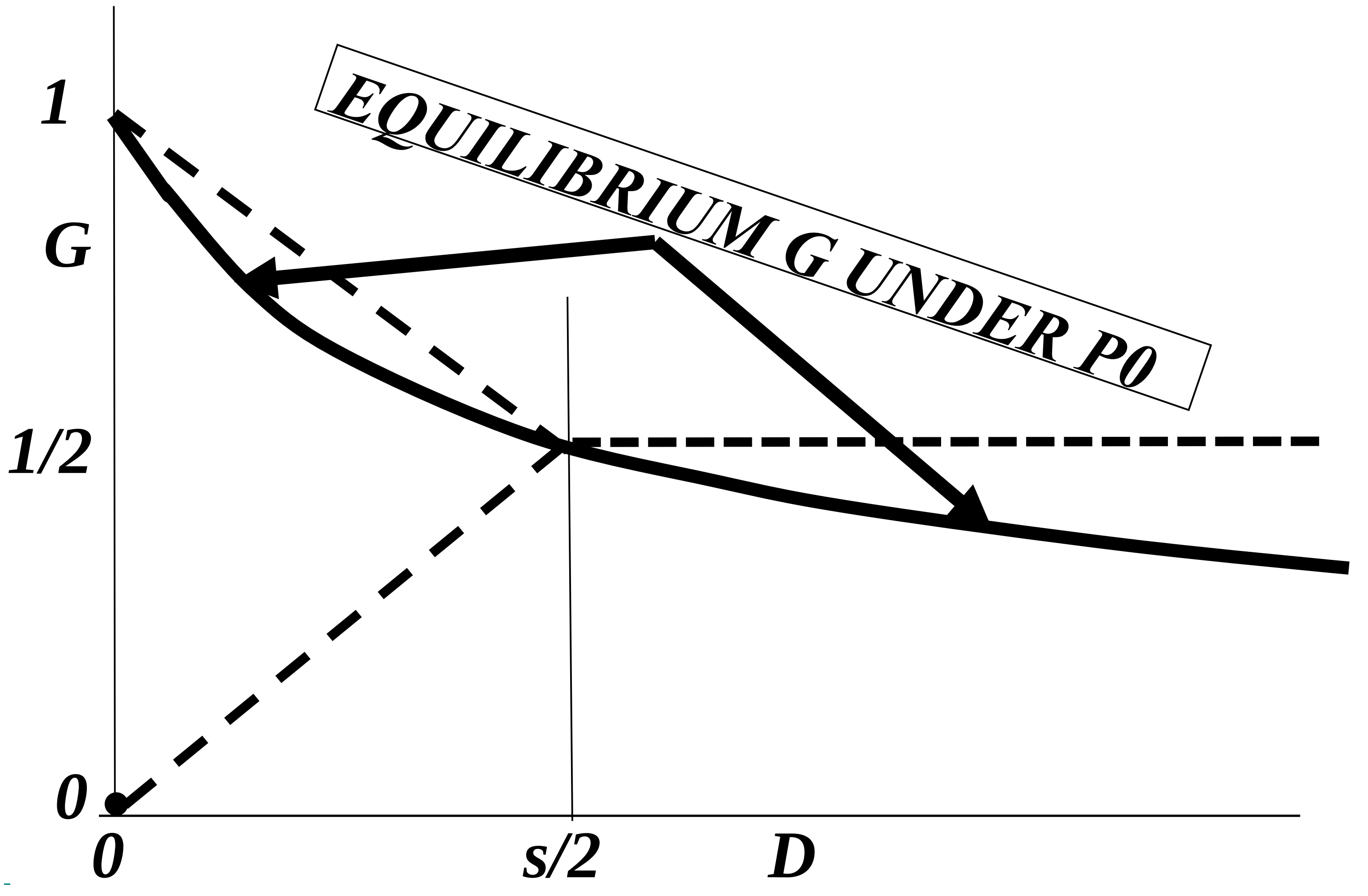


MAXIMUM FLOW = s/2

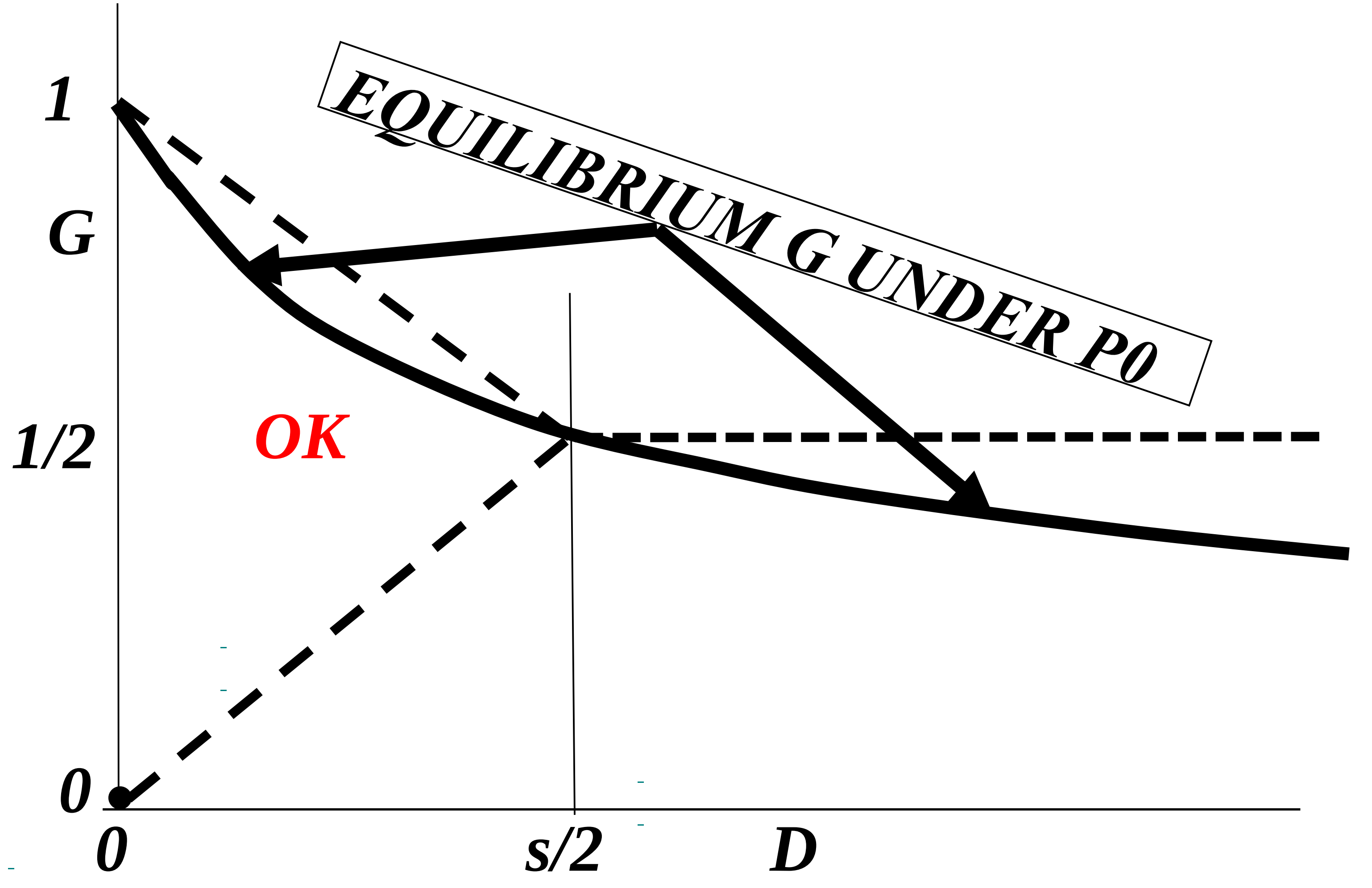


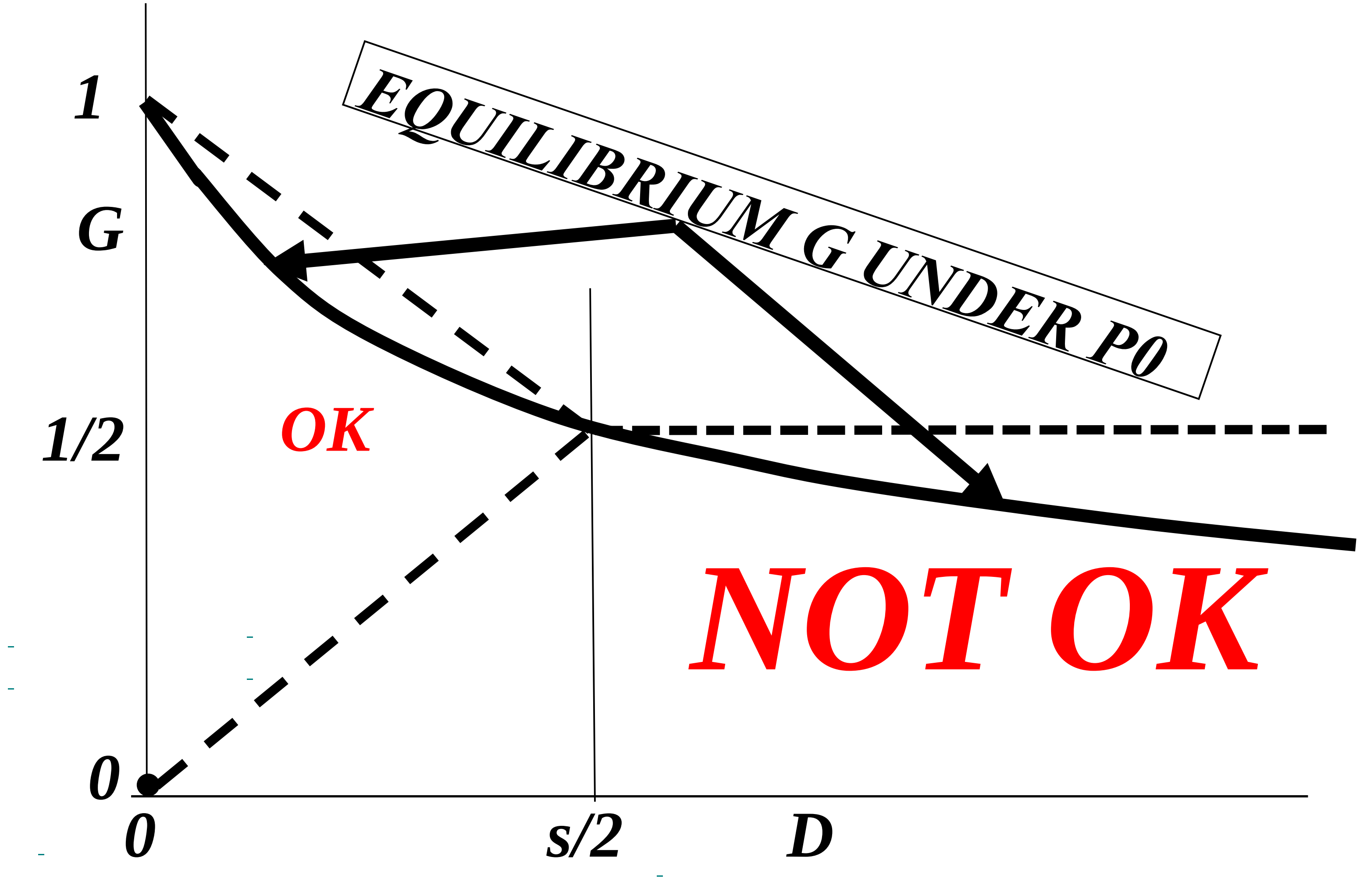
1
G
1/2
0
0
s/2
D

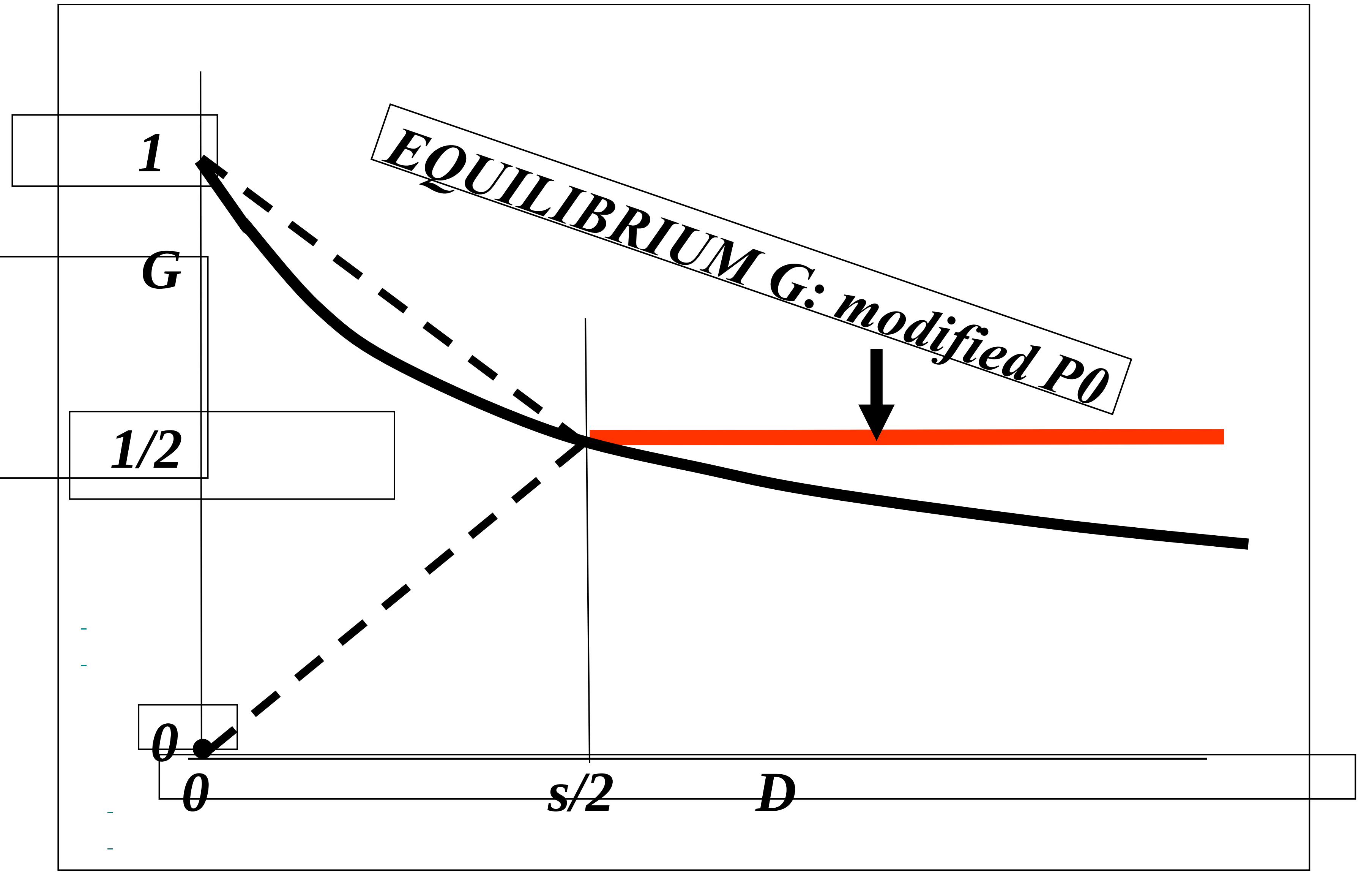

1
G
1/2
0
0
s/2
D



EQUILIBRIUM G UNDER P0
1
G
1/2
0
0
s/2
D


EQUILIBRIUM G UNDER P0
1
G
1/2
OK
0
0
s/2
D


EQUILIBRIUM G UNDER P0
1
G
1/2
OK
NOT OK
0
0
s/2
D


1
G
1/2
0
0
s/2
D
EQUILIBRIUM G: modified P0

SUMMARY

P0 modified maximises throughput of ONE network even when demand exceeds capacity

SUMMARY

P0 modified maximises throughput of ONE network even when demand exceeds capacity

Further work: Generalise!!!

QUESTIONS?

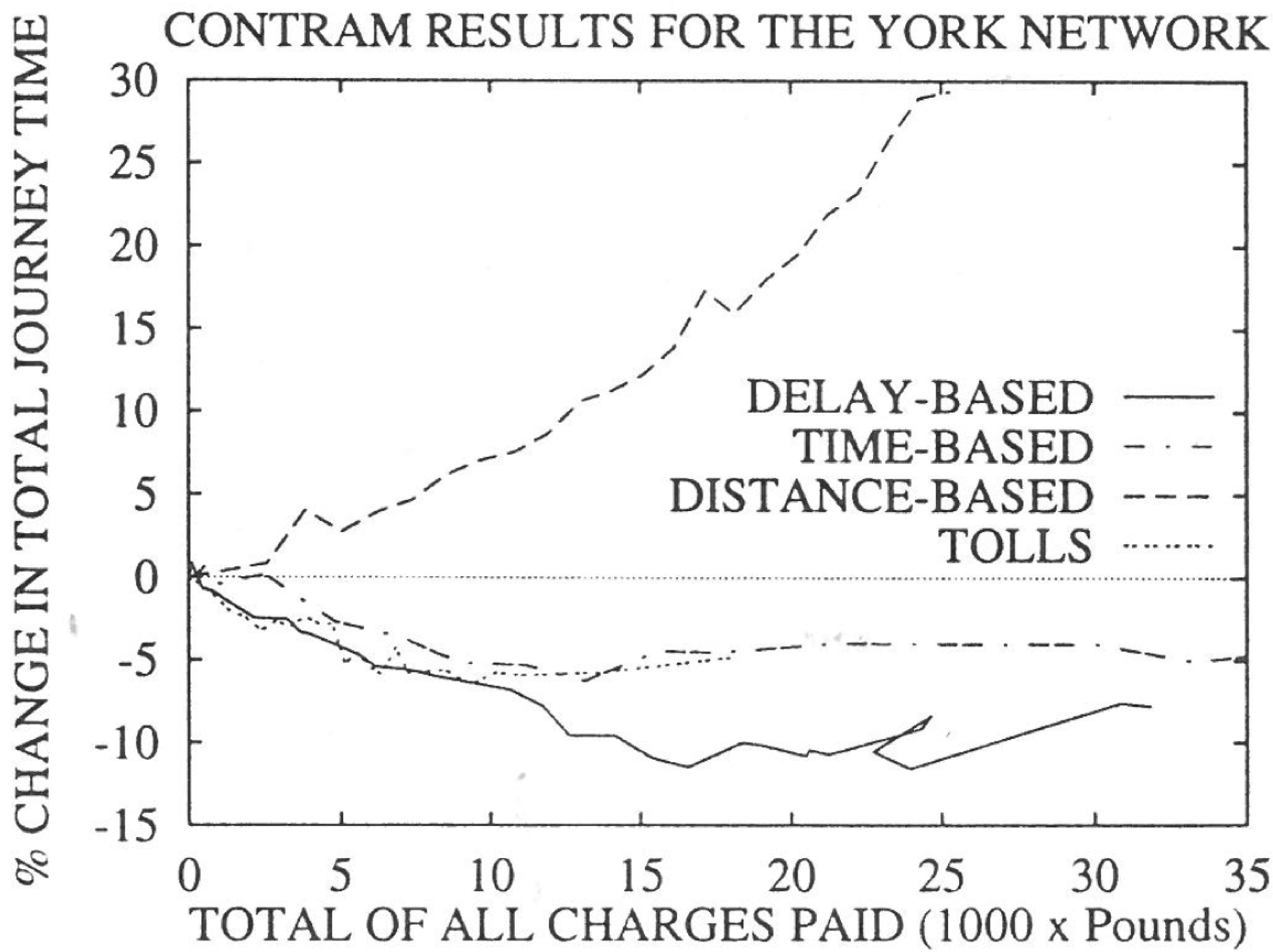
Other related work

Le, T., Kovacs, P., Walton, N., Vu, H. L., Andrew, L. H., Hoogendoorn, S. P. 2015. Decentralised Signal Control for Urban Road Networks. Transportation Research Part C, 58, 431-450. (Proportional Control Policy)

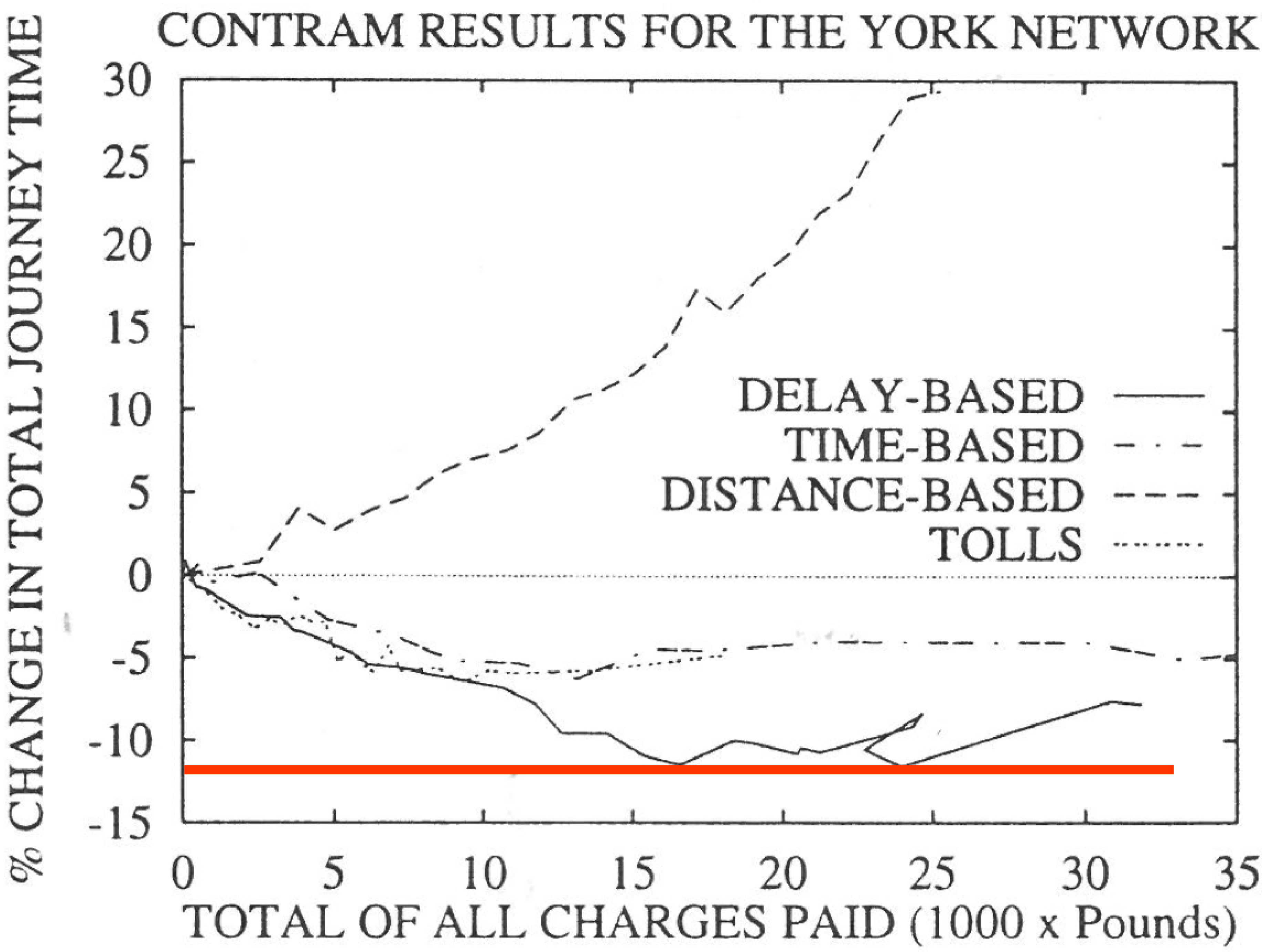
Peter Kovacs, Tung Le, Rudesindo Nunez-Queija, Hai L. Vu, Neil Walton, Proportional green time scheduling for traffic lights.

YORK RESULTS

These were obtained by Mustapha Ghali using a dynamic equilibrium program called CONTRAM (used to be supported by the Transport and Road Research Laboratory in the UK)



CONTRAM RESULTS FOR THE YORK NETWORK
% CHANGE IN TOTAL JOURNEY TIME
TOTAL OF ALL CHARGES PAID (1000 x Pounds)
DELAY-BASED
TIME-BASED
DISTANCE-BASED
TOLLS
30
25
20
15
10
5
0
-5
-10
-15
0
5
10
15
20
25
30
35



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TIME-BASED
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TOLLS
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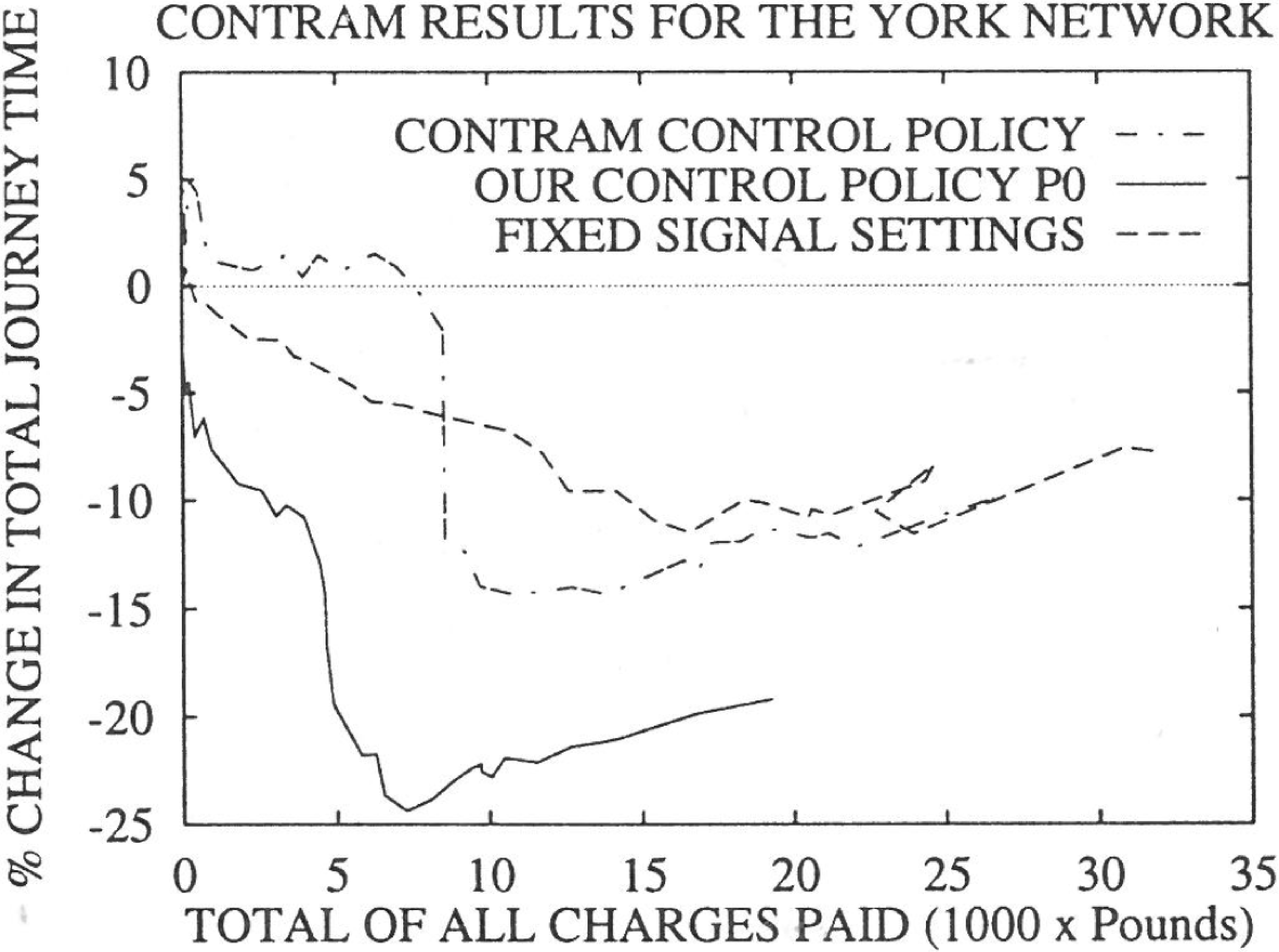
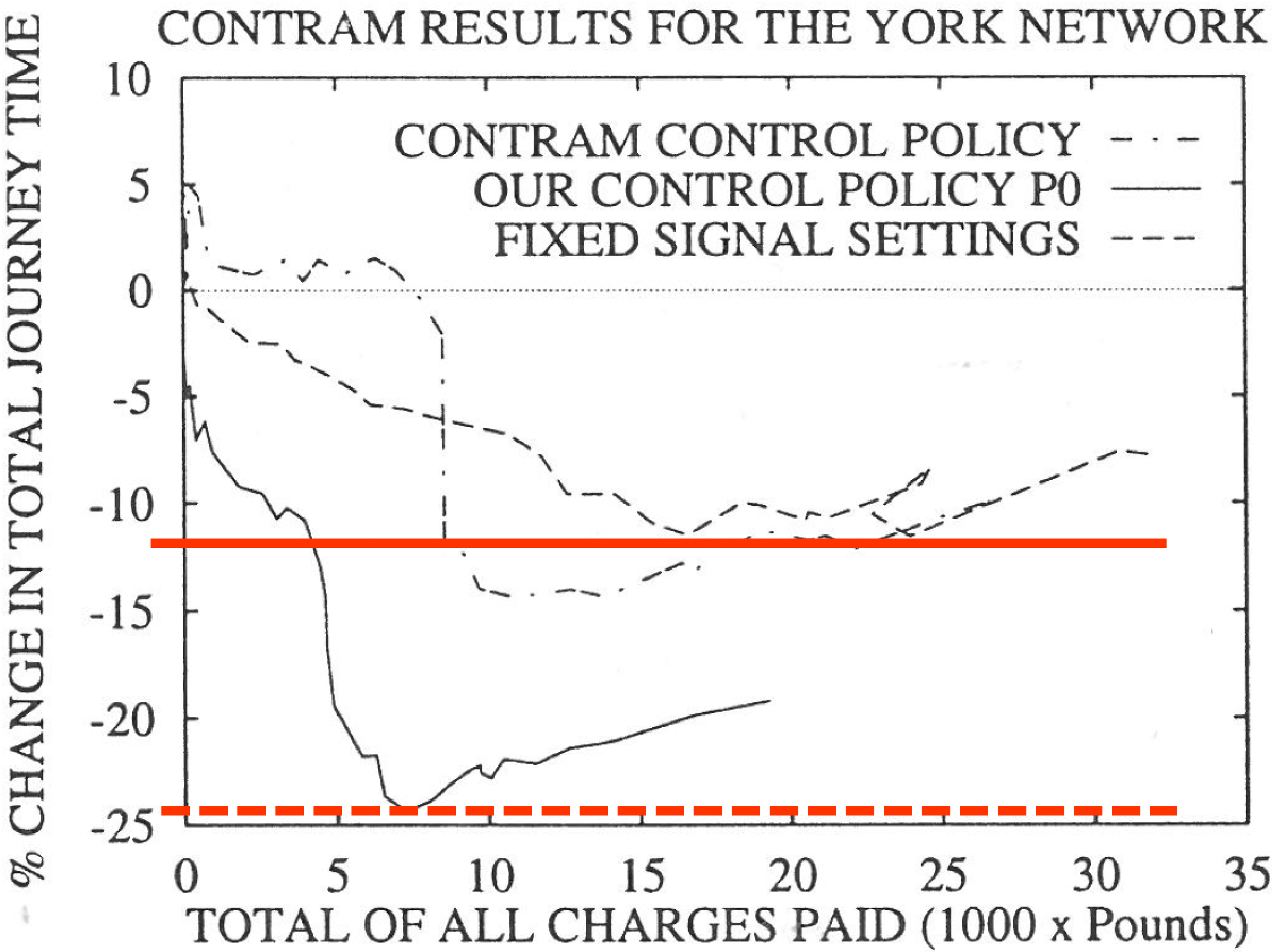
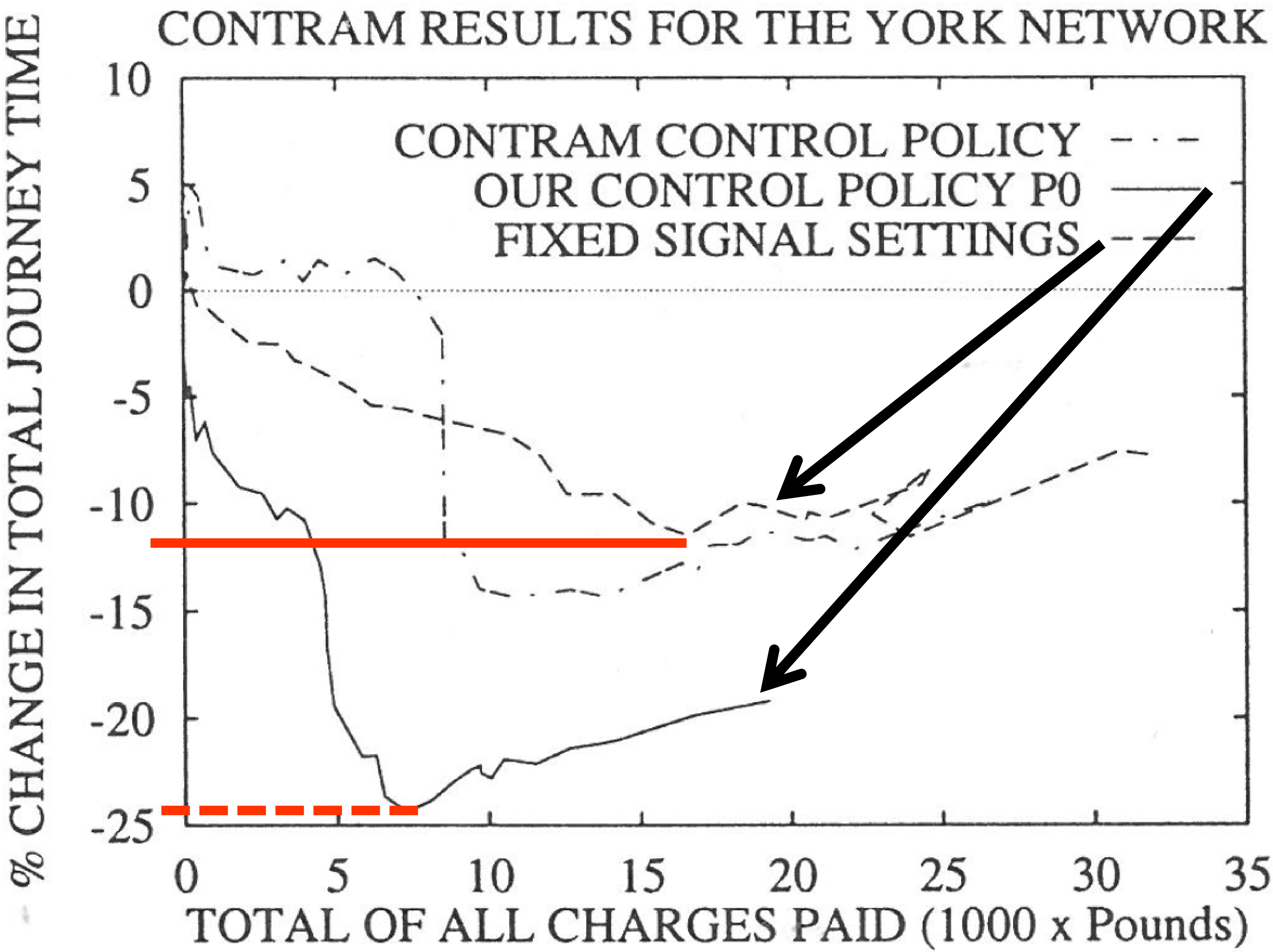
25
20
15
10
5
0
-5
-10
-15
0
5
10
15
20
25
30
35



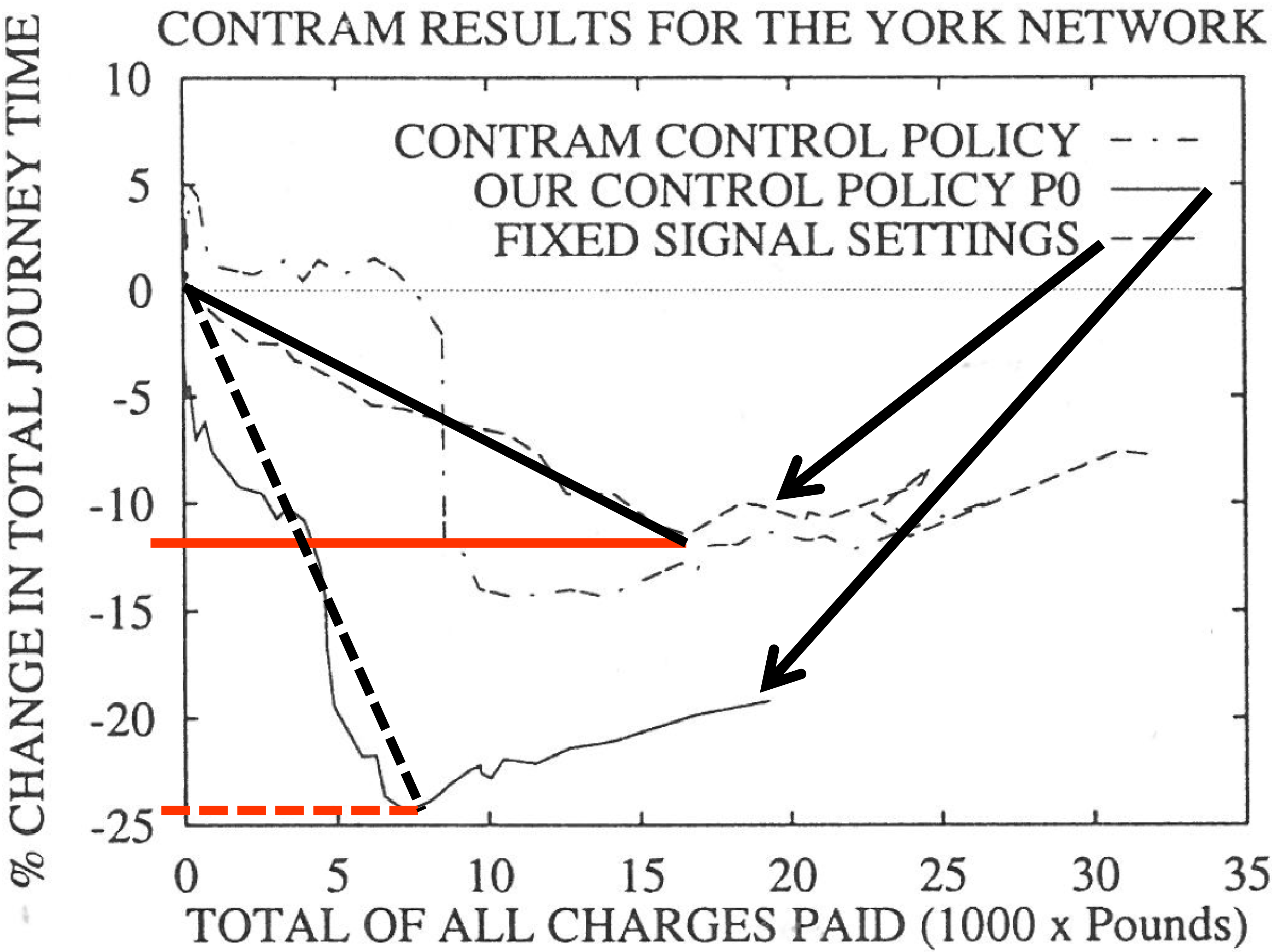
CONTRAM RESULTS FOR THE YORK NETWORK
CONTRAM CONTROL POLICY
OUR CONTROL POLICY P0
FIXED SIGNAL SETTINGS
% CHANGE IN TOTAL JOURNEY TIME
TOTAL OF ALL CHARGES PAID (1000 x Pounds)
10
5
0
-5
-10
-15
-20
-25
0
5
10
15
20
25
30
35



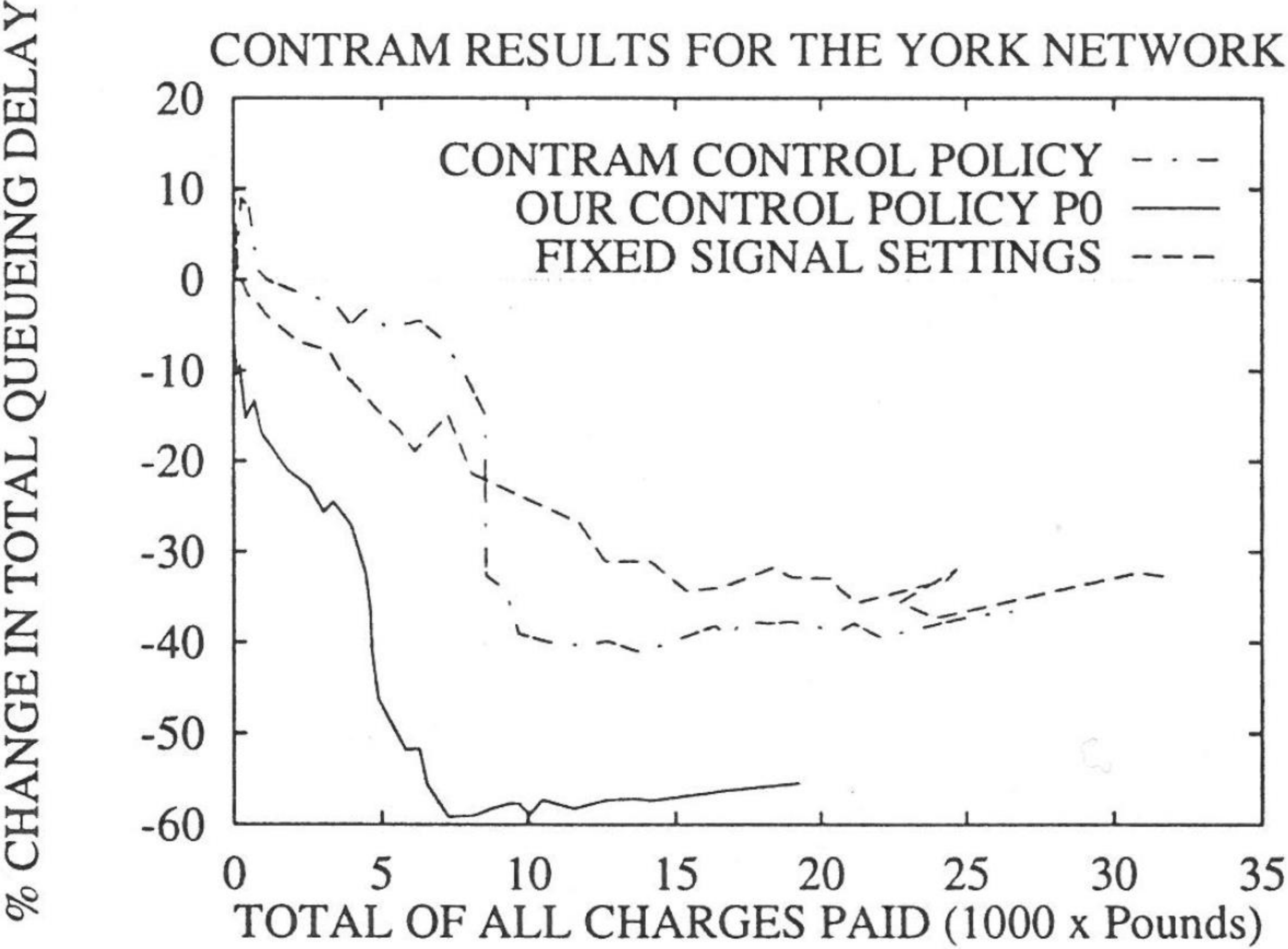
CONTRAM RESULTS FOR THE YORK NETWORK
CONTRAM CONTROL POLICY
OUR CONTROL POLICY P0
FIXED SIGNAL SETTINGS
% CHANGE IN TOTAL JOURNEY TIME
10
5
0
-5
-10
-15
-20
-25
0
5
10
15
20
25
30
35
TOTAL OF ALL CHARGES PAID (1000 x Pounds)

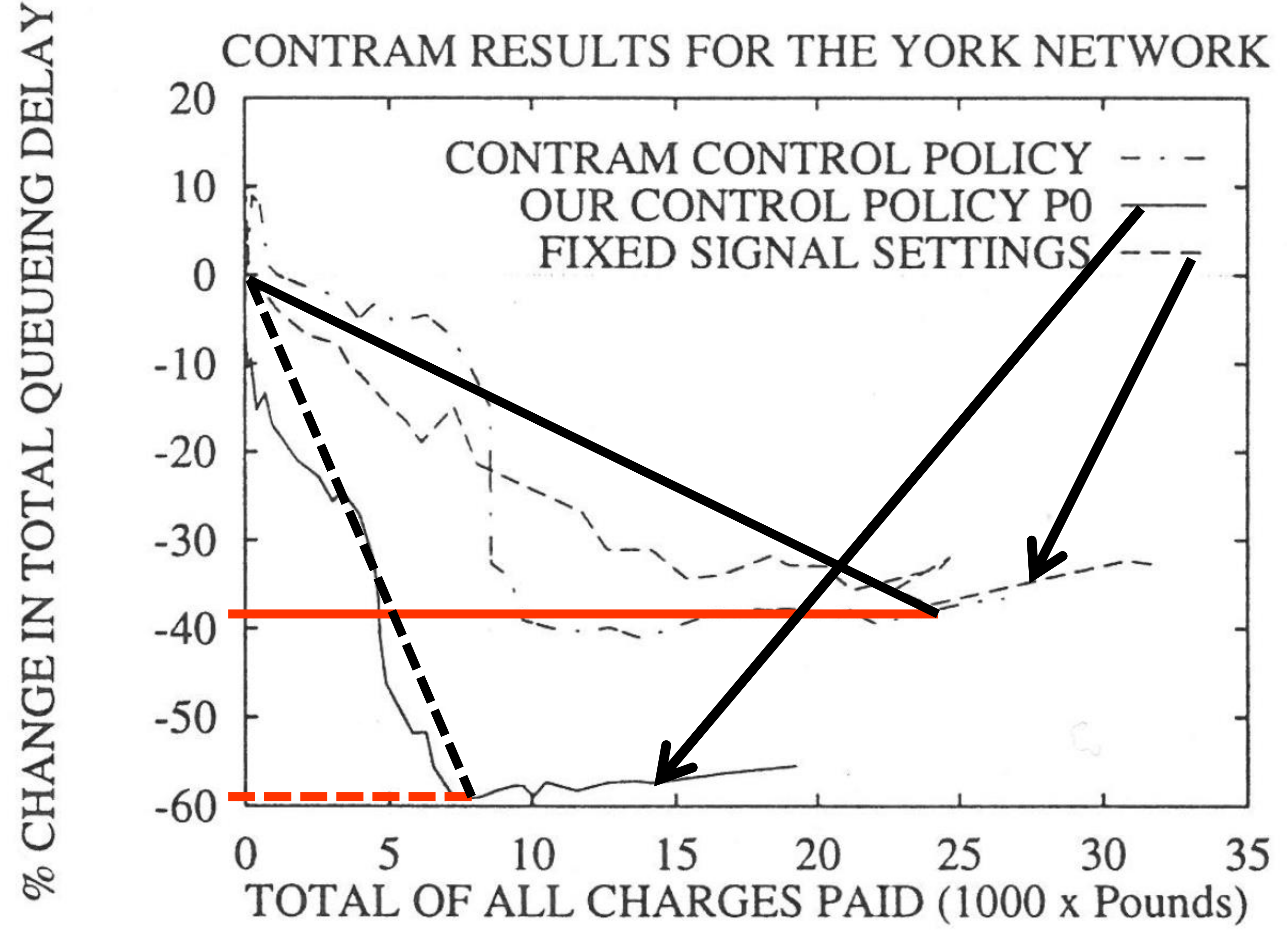


CONTRAM RESULTS FOR THE YORK NETWORK
% CHANGE IN TOTAL JOURNEY TIME
10
5
0
-5
-10
-15
-20
-25
0
5
10
15
20
25
30
35
TOTAL OF ALL CHARGES PAID (1000 x Pounds)
CONTRAM CONTROL POLICY
OUR CONTROL POLICY P0
FIXED SIGNAL SETTINGS



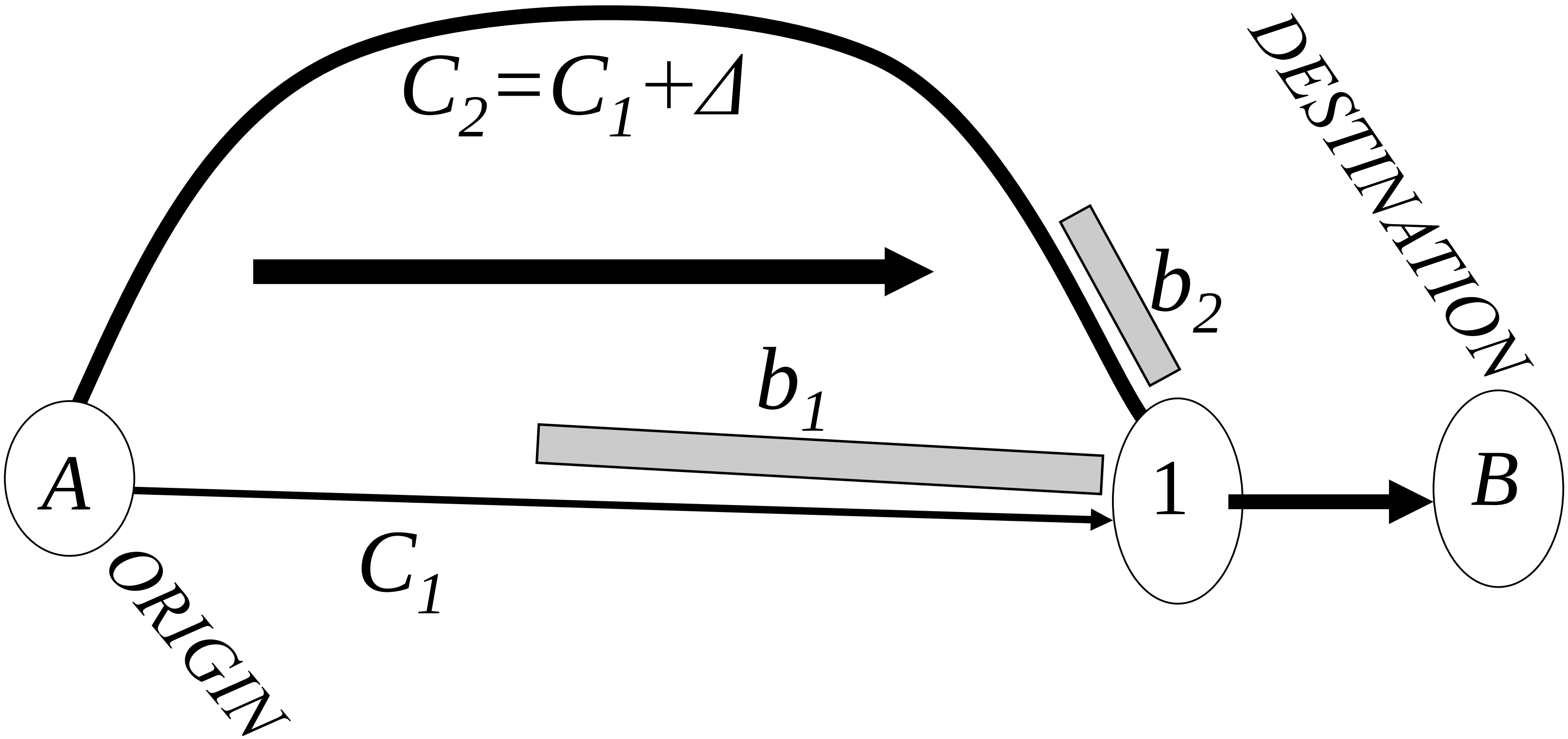
CONTRAM RESULTS FOR THE YORK NETWORK
% CHANGE IN TOTAL JOURNEY TIME
10
5
0
-5
-10
-15
-20
-25
CONTRAM CONTROL POLICY
OUR CONTROL POLICY P0
FIXED SIGNAL SETTINGS
0
5
10
15
20
25
30
35
TOTAL OF ALL CHARGES PAID (1000 x Pounds)


CONTRAM RESULTS FOR THE YORK NETWORK
% CHANGE IN TOTAL QUEUEING DELAY
CONTRAM CONTROL POLICY
OUR CONTROL POLICY P0
FIXED SIGNAL SETTINGS
20
10
0
-10
-20
-30
-40
-50
-60
0
5
10
15
20
25
30
35
TOTAL OF ALL CHARGES PAID (1000 x Pounds)


CONTRAM RESULTS FOR THE YORK NETWORK
CONTRAM CONTROL POLICY
OUR CONTROL POLICY P0
FIXED SIGNAL SETTINGS
% CHANGE IN TOTAL QUEUEING DELAY
20
10
0
-10
-20
-30
-40
-50
-60
0
5
10
15
20
25
30
35
TOTAL OF ALL CHARGES PAID (1000 x Pounds)

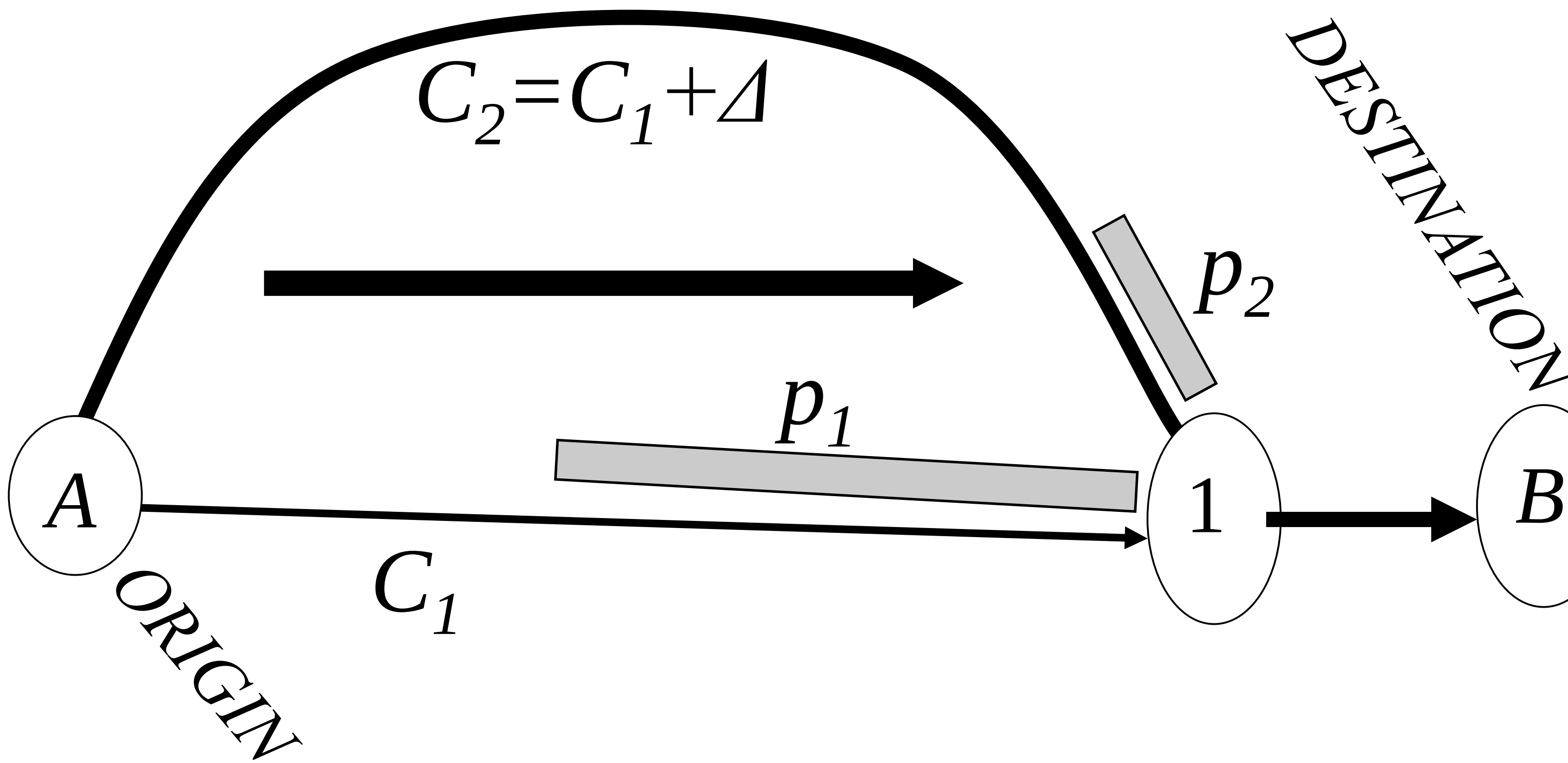
Questions?

$$P_0: s_1 b_1 = s_2 b_2$$



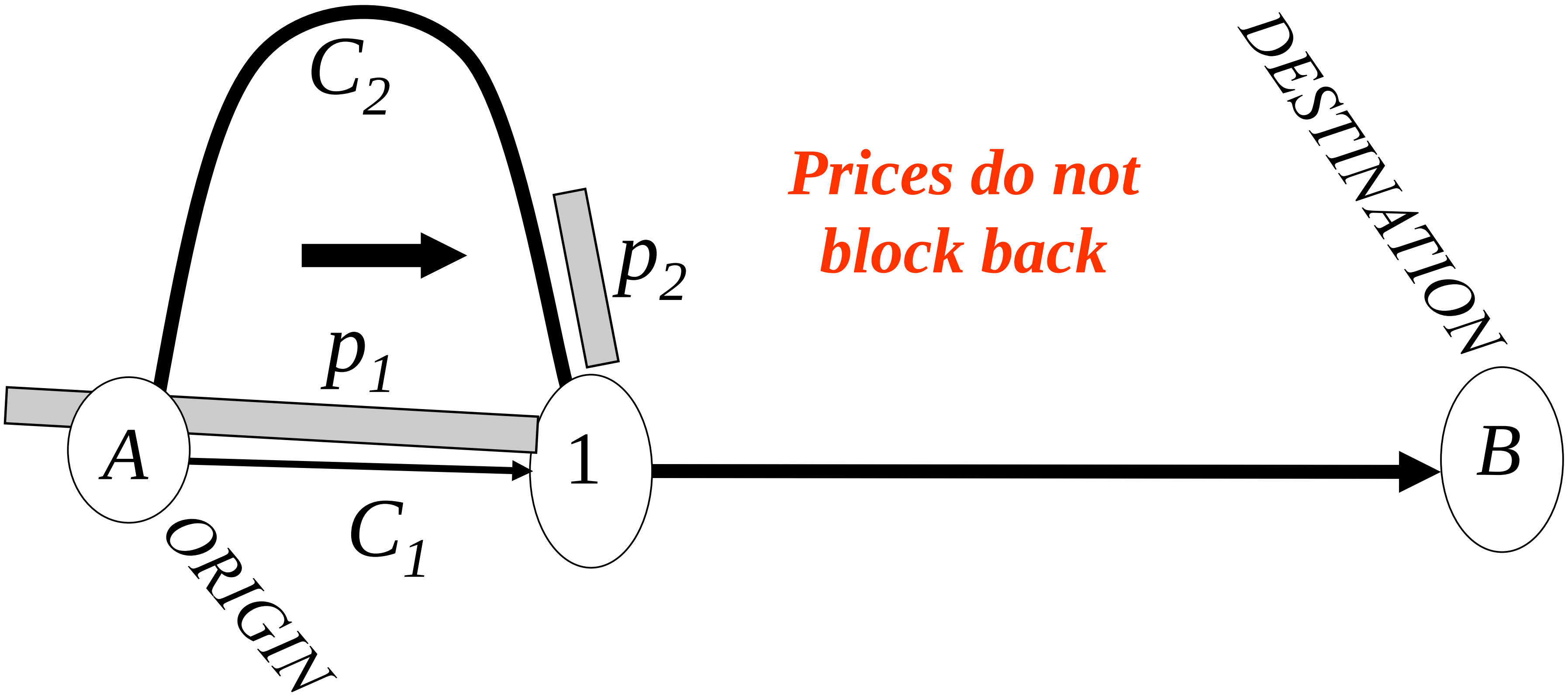
P_0: $s_1 b_1 = s_2 b_2$

P_0 with prices: $s_1 p_1 = s_2 p_2$



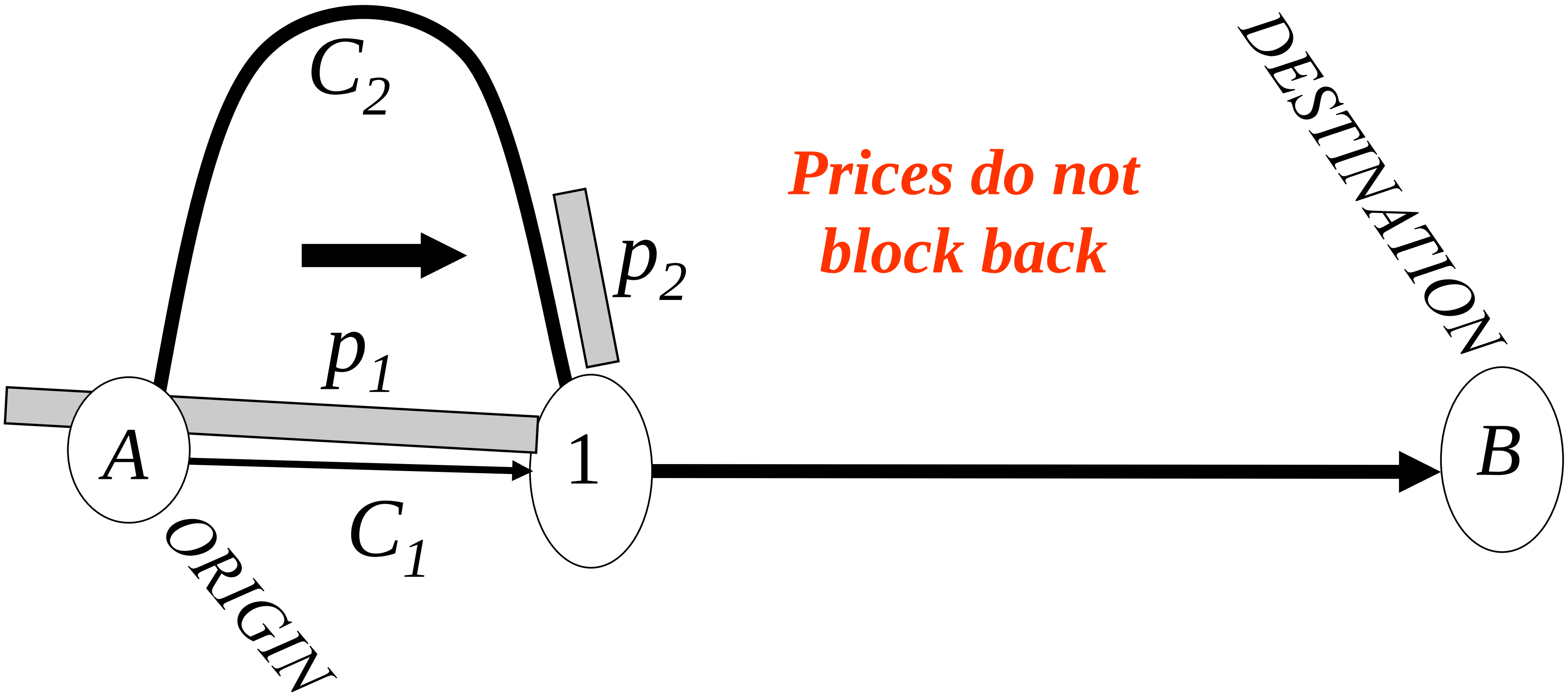
P_0: $s_1 b_1 = s_2 b_2$

P_0 with prices: $s_1 p_1 = s_2 p_2$



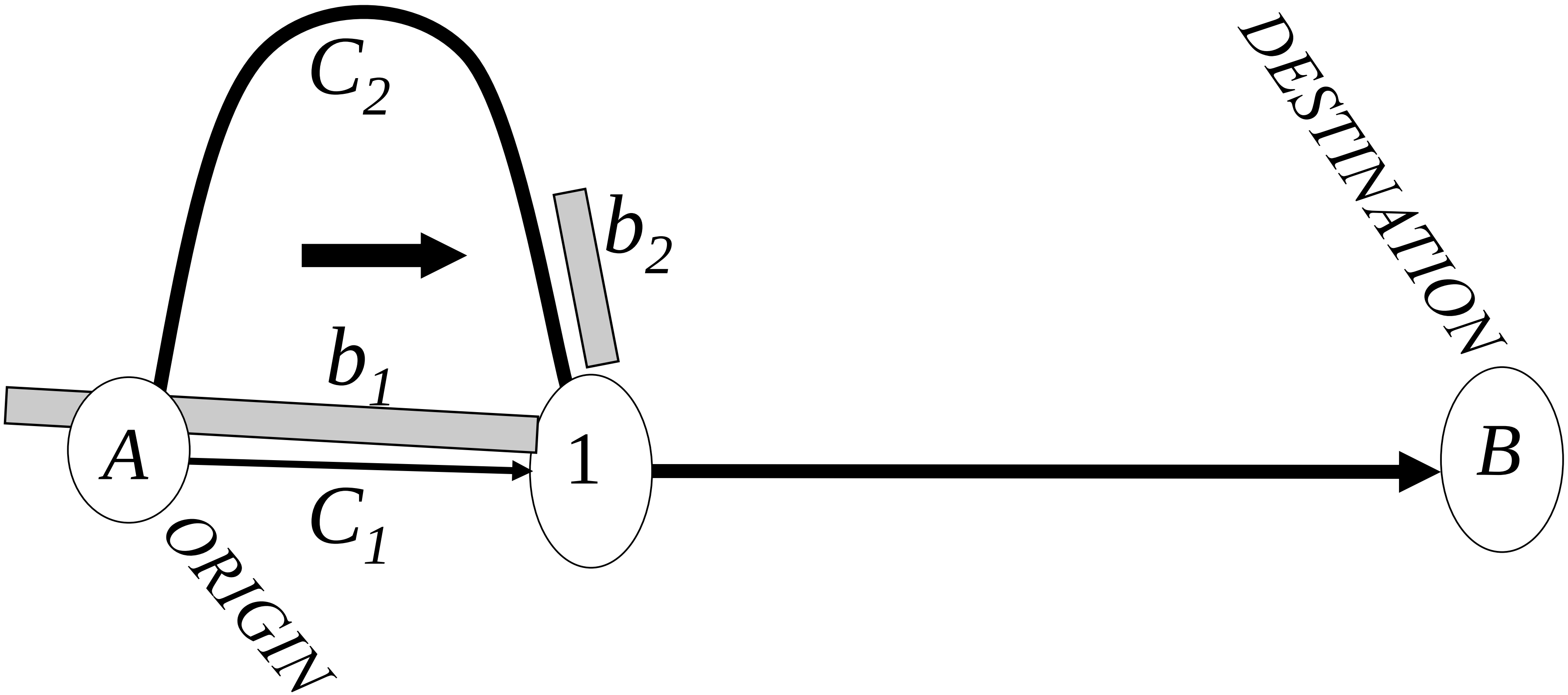
P_0: $s_1 b_1 = s_2 b_2$

P_0 with prices: $s_1 p_1 = s_2 p_2$ **FEASIBLE EQM**



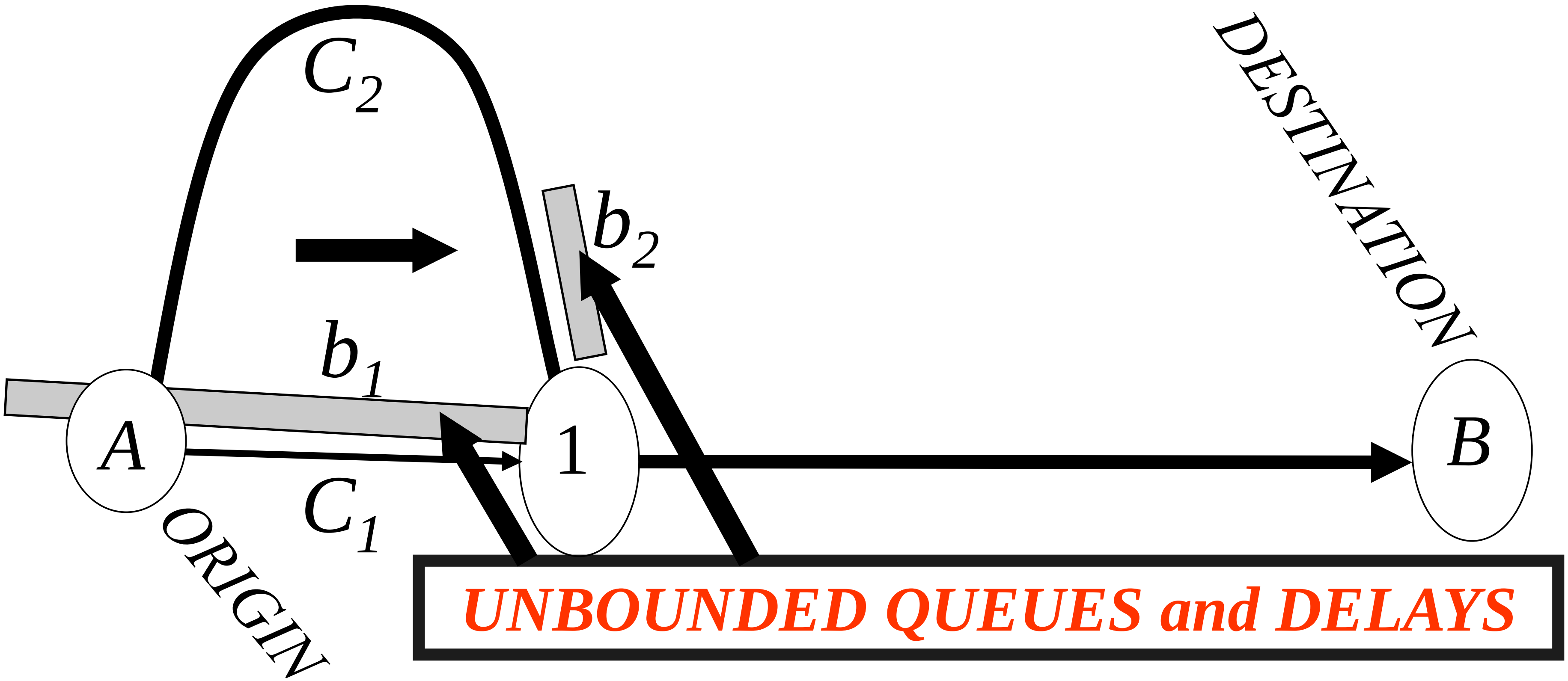
P_0: $s_1 b_1 = s_2 b_2$ **NO FEASIBLE EQM**

P_0 with prices: $s_1 p_1 = s_2 p_2$ **FEASIBLE EQM**



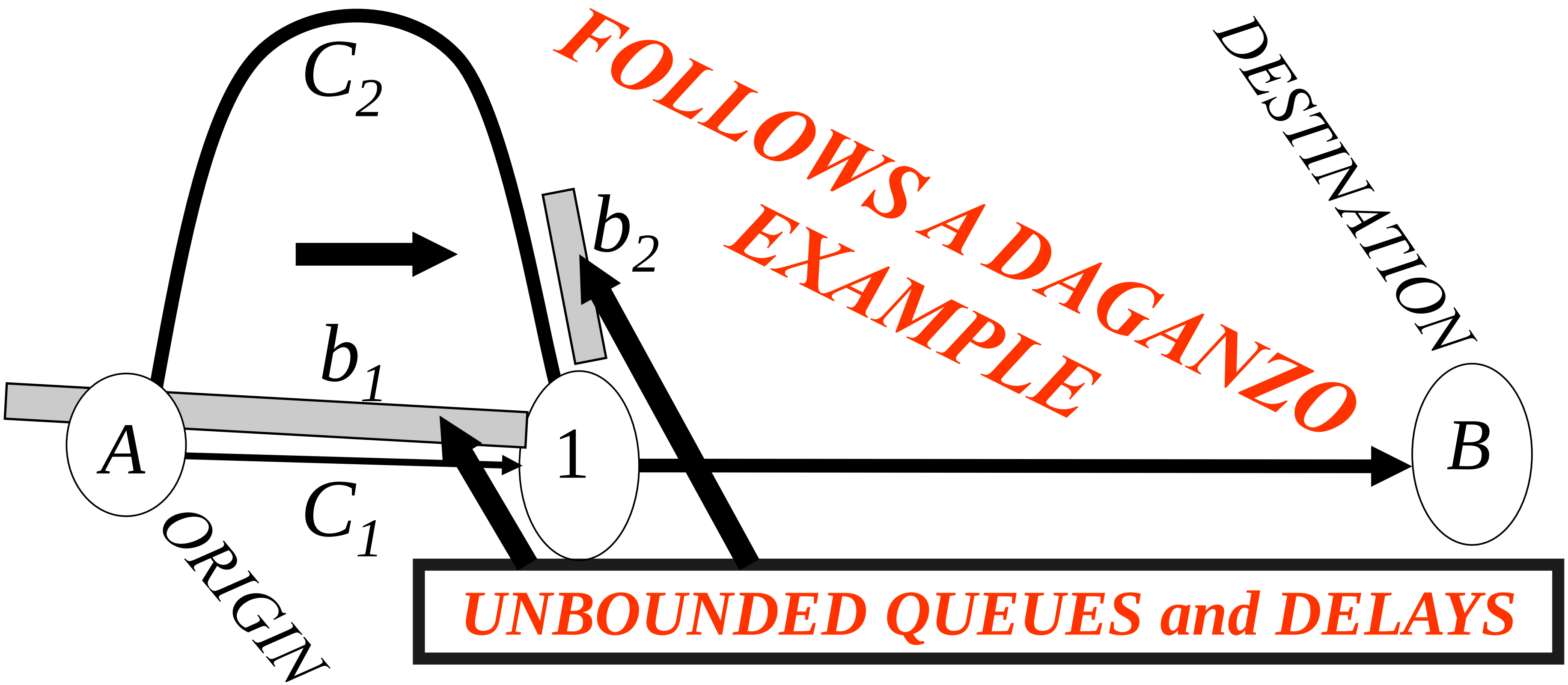
P_0: $s_1 b_1 = s_2 b_2$ **NO FEASIBLE EQM**

P_0 with prices: $s_1 p_1 = s_2 p_2$ **FEASIBLE EQM**



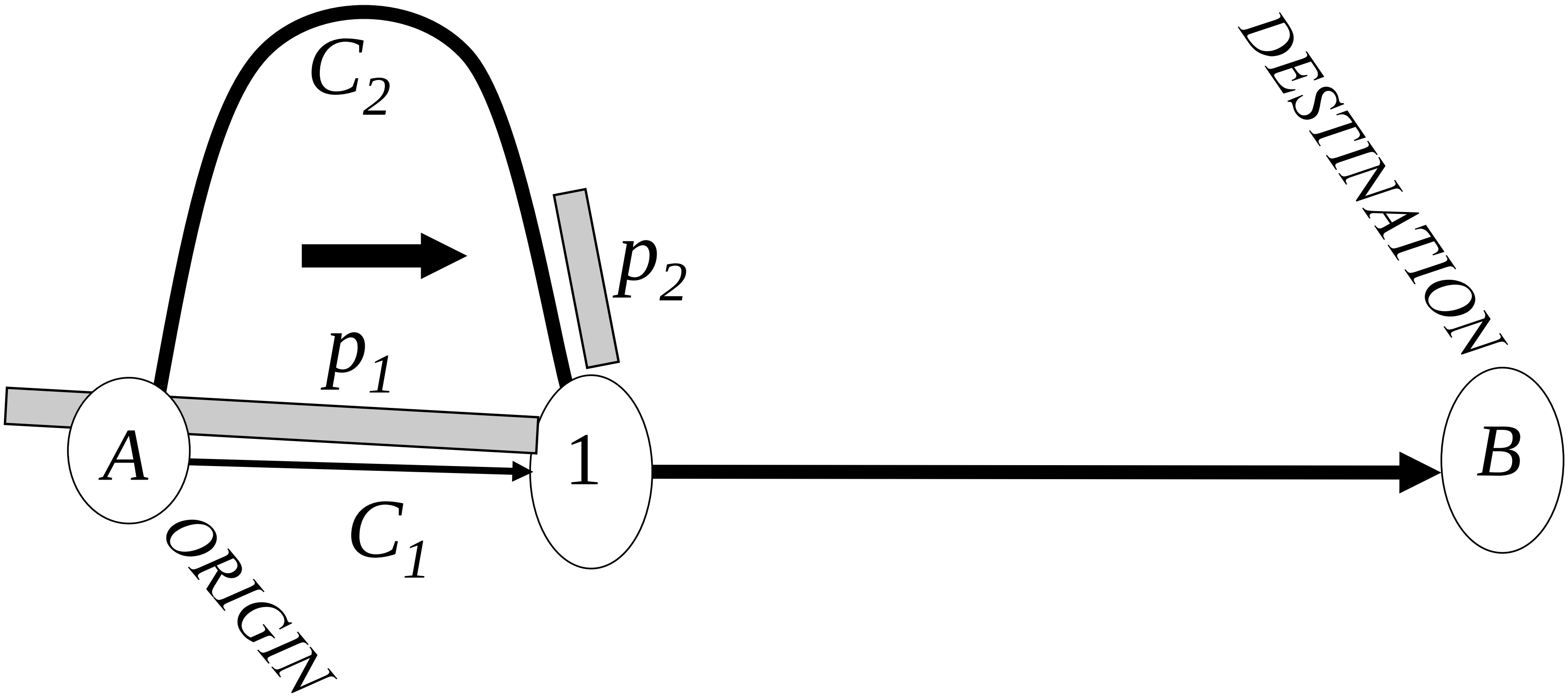
P_0: $s_1 b_1 = s_2 b_2$ **NO FEASIBLE EQM**

P_0 with prices: $s_1 p_1 = s_2 p_2$ **FEASIBLE EQM**



$$P_0: s_1 b_1 = s_2 b_2$$

$$P_0 \text{ with prices: } s_1 p_1 = s_2 p_2$$



Questions?