

**Economy of scale and the role of
publicly available congestion
information for local delivery industry:
Agent-based simulation approach**

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Outline

- 1. Background and motivation**
- 2. Overview of study framework**
- 3. Simulation approach**
- 4. Findings**
- 5. Challenges**

Real-time/advanced travel information system

In the U.S.

- Travel time information collected from: detectors, cameras, satellite imaging, cell phones, GPS, etc.
- Distributed via publicly accessible means (radio/TV, Internet, etc.) – direct provision by the government or outsourcing (e.g. Tele Atlas)
- Growth of customized travel information sent via text messages and e-mails (e.g. NAVTEQ-Traffic.com), Westwood One – SmartTraveler, etc.)
“predictive traffic trends, vehicle speeds, congestion levels, travel times, and delay times delivered via Web, wireless device, radio, television, and in-vehicle navigation systems.”

Motivation

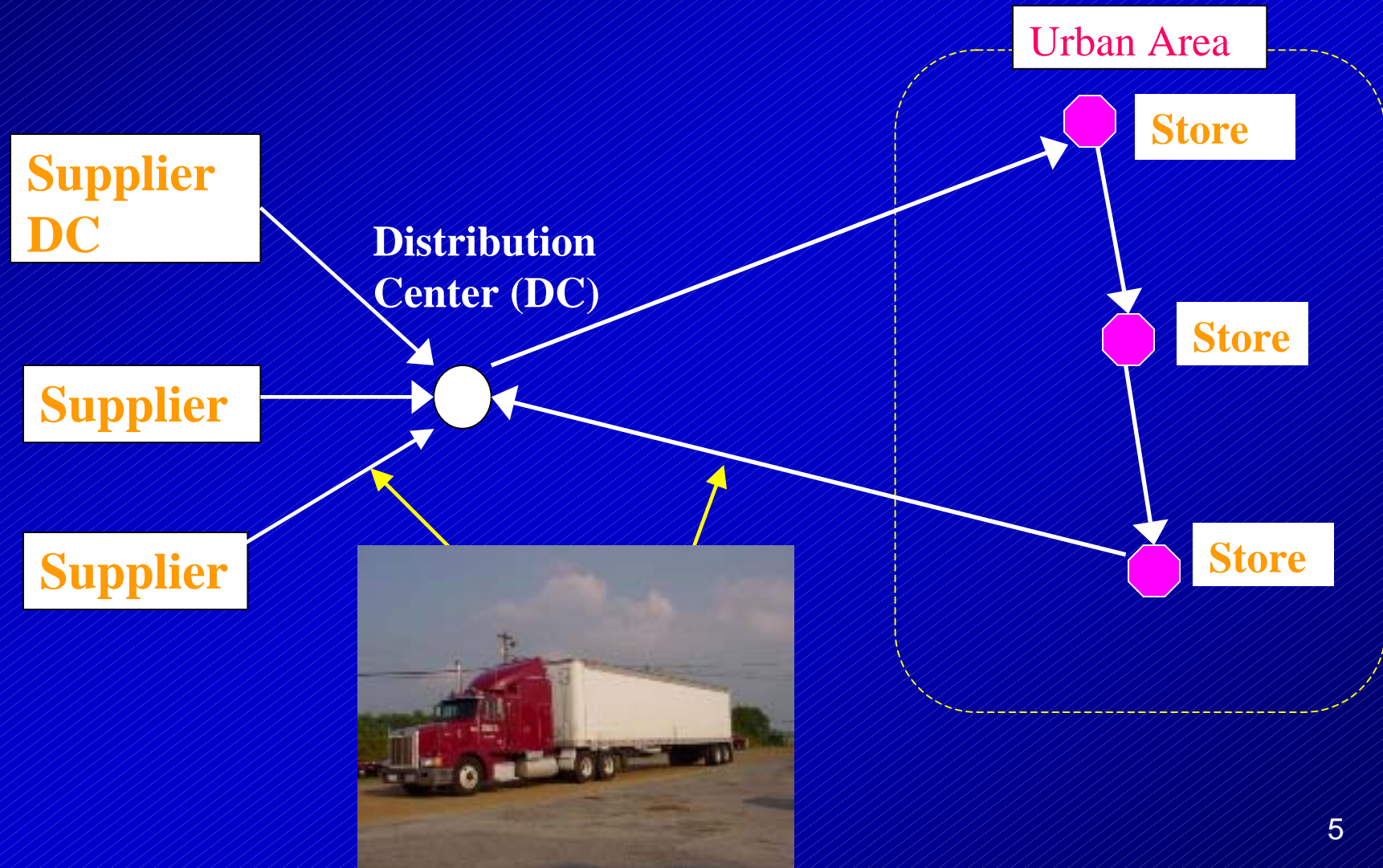
Broad questions:

- Where is the travel information business heading?
- Is there a justification for non-exclusive (“public”) provision of travel information?
- Are there positive externalities that are overlooked?

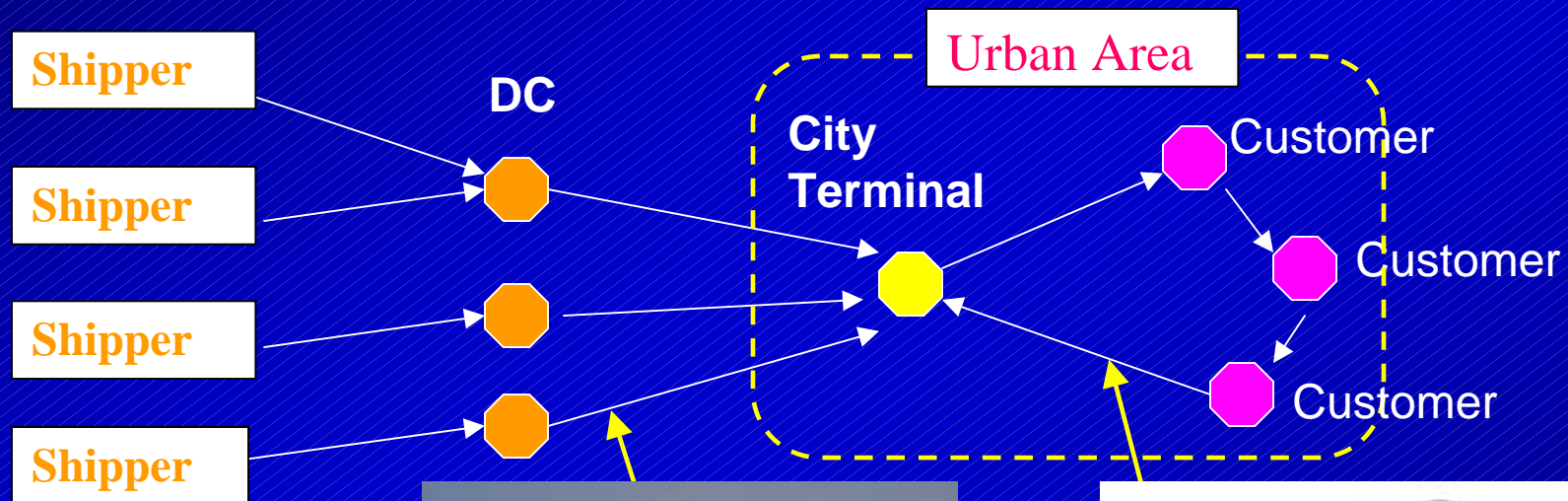
Hypothesis:

Publicly available travel information (or affordable equivalent in the private sector) benefits smaller goods delivery firms by lowering the market entry barrier

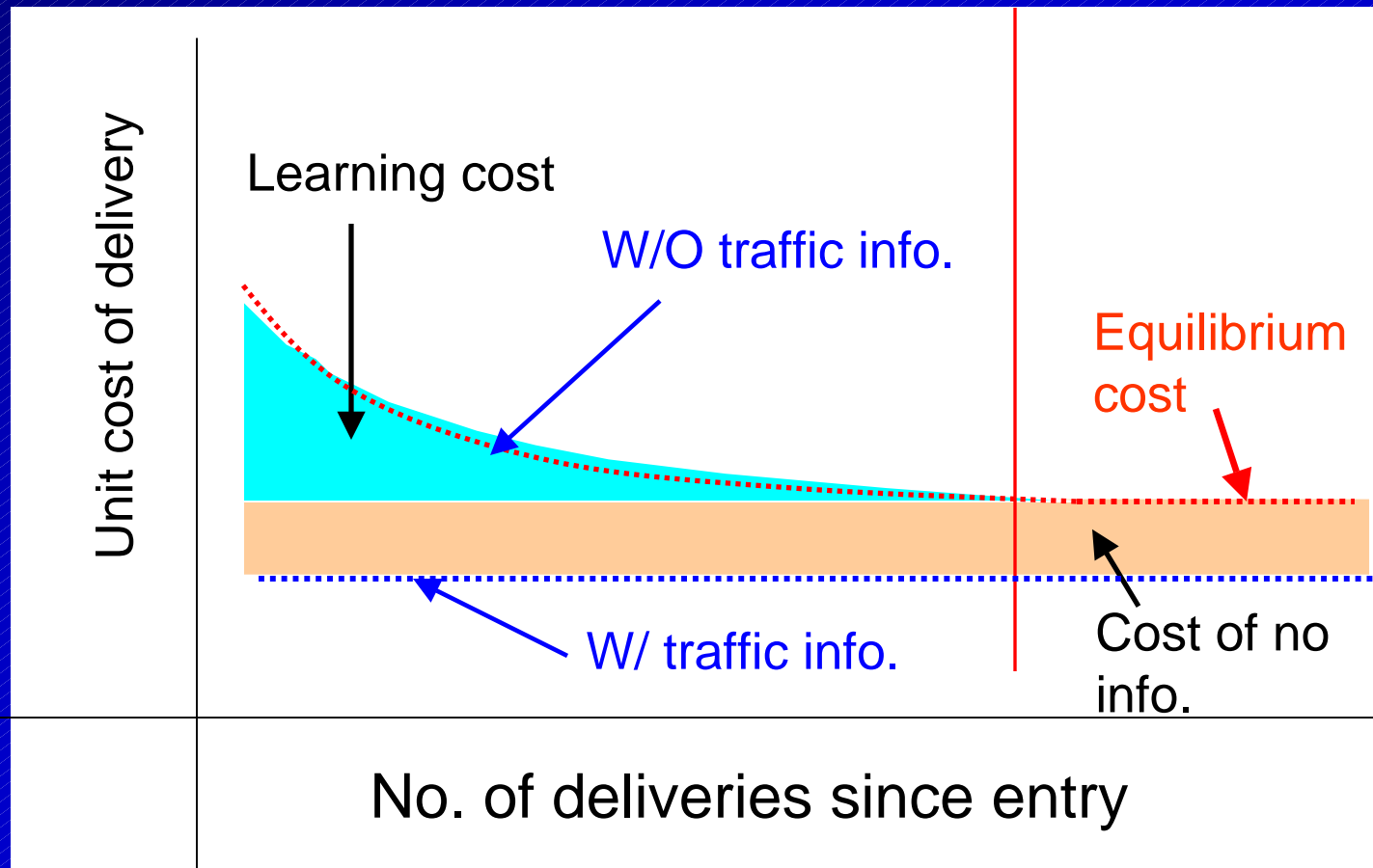
“Peddle run” system commonly used in the U.S. by retail chains



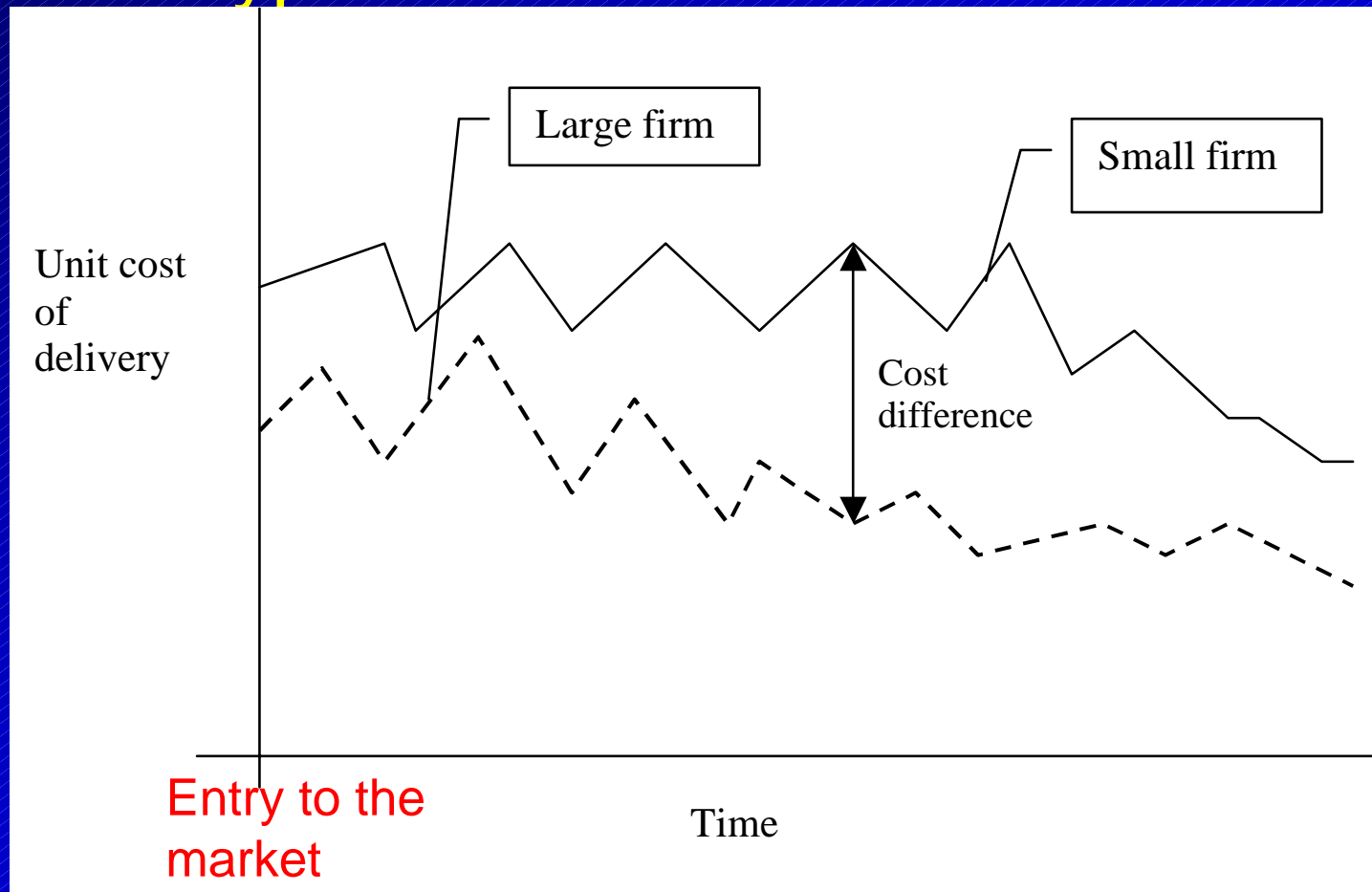
“Single-stage” system commonly used by parcel delivery/pick-up services



For each firm ...



Economy of scale at work - Hypothesis w/o traffic info -



Exploratory examination of an entry into a hypothetical urban area by delivery service firms of different sizes

⇒ Compare efficiency for “with” vs. “without” information cases 8

Overview of Research

Expected outcomes:

Large firms have shorter learning period (lower entry cost) \Rightarrow smaller benefit from travel time information \Rightarrow publicly available traffic information lower entry barrier for smaller firms

However, magnitude of benefit may depend on various factors:

- Sizes of competing firms
- Environment (network configuration, congestion level, link travel time variation)



Build an exploratory simulation model of goods delivery to examine the hypothesis under different environment

Agent-based simulation

Agent-based model (ABM)

- Derived from complex systems perspective (i.e. emergence of pattern from behaviors and interactions of numerous intelligent agents)
- Behaviors are controlled by a set of rules defined for each agent.
- Generally, agents do not act according to global rules.
- Not necessarily suited for forecasting
- Flexible platform to simulate wide-ranging (especially emergent) phenomena
- Key components of simulation: agent, environment

Taxonomy of ABM

AGENT

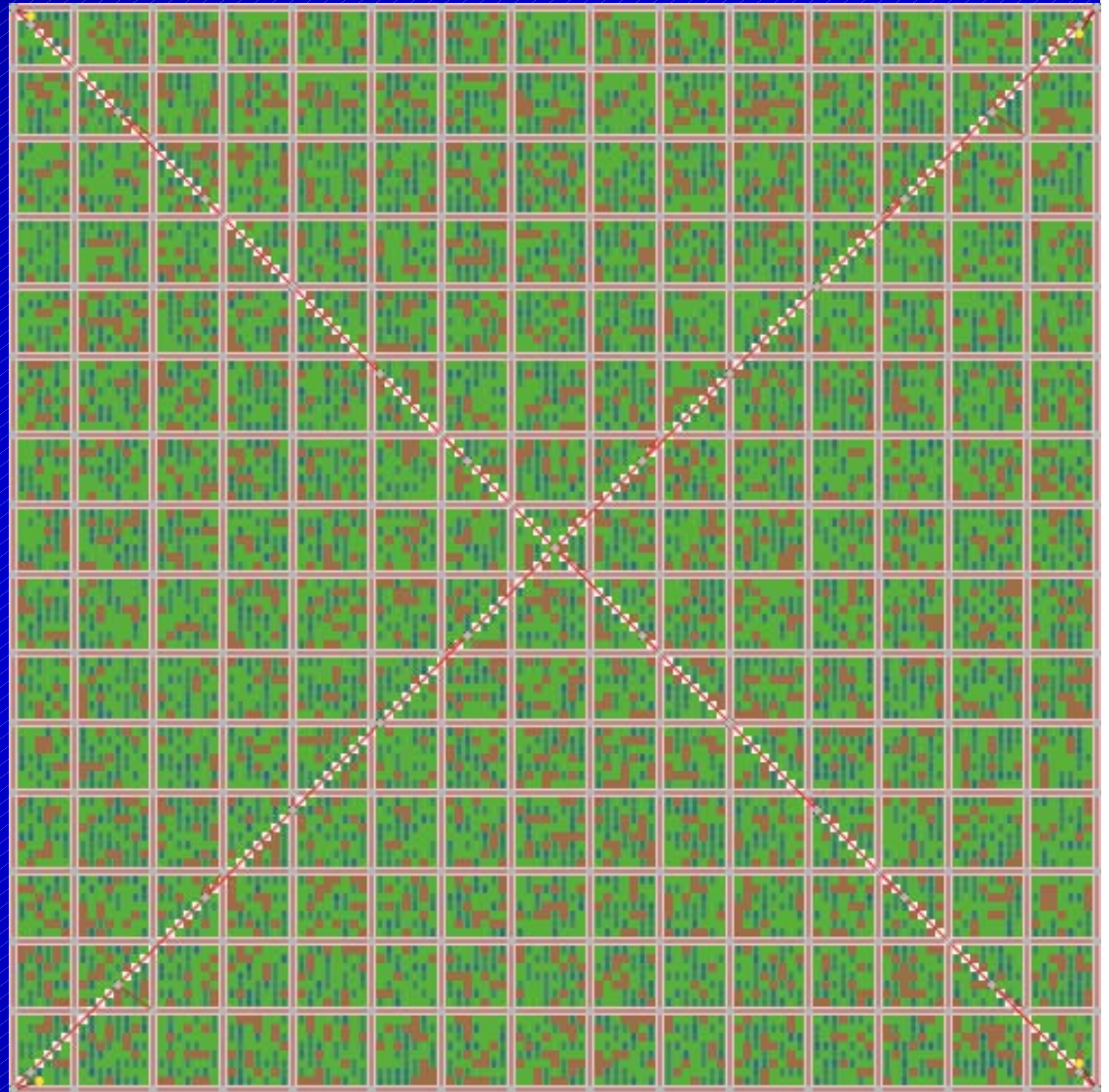
		Designed	Analyzed
ENVIRONMENT	Designed	<ul style="list-style-type: none"> - Model description Abstract - Purpose Discovery of relationship - Verification Theoretical comparison 	<ul style="list-style-type: none"> - Model description Experimental - Purpose Laboratory experiment - Verification Repetition
	Analyzed	<ul style="list-style-type: none"> - Model description Historical - Purpose Explanation - Verification Qualitative: goodness of fit 	<ul style="list-style-type: none"> - Model description Empirical - Purpose Prediction - Verification Quantitative: goodness of fit

Considerations:

- Data availability
- Resource limitations
- Level of complexity
- System required

Simulation Environment

- City: 18 mile x 18 mile
- Land use: Road, commercial, residential located in 100mx100m Patches
- Land use: Houses & jobs randomly allocated
- Congestion from background traffic



Delivery tour simulation

- Customers are generated randomly across the city
- There is a product differentiation between small, medium, and large firms (i.e. no competition for customers)
- Each tour covers 4 customers
- Firms dispatch trucks from the terminal
 - Large: 6 tours/cycle*
 - Medium: 4 tours/cycle*
 - Small: 2 tours/cycle*
- At the end of a cycle, firms update their knowledge of travel time for each link based on the mean of the sample (from the past deliveries)

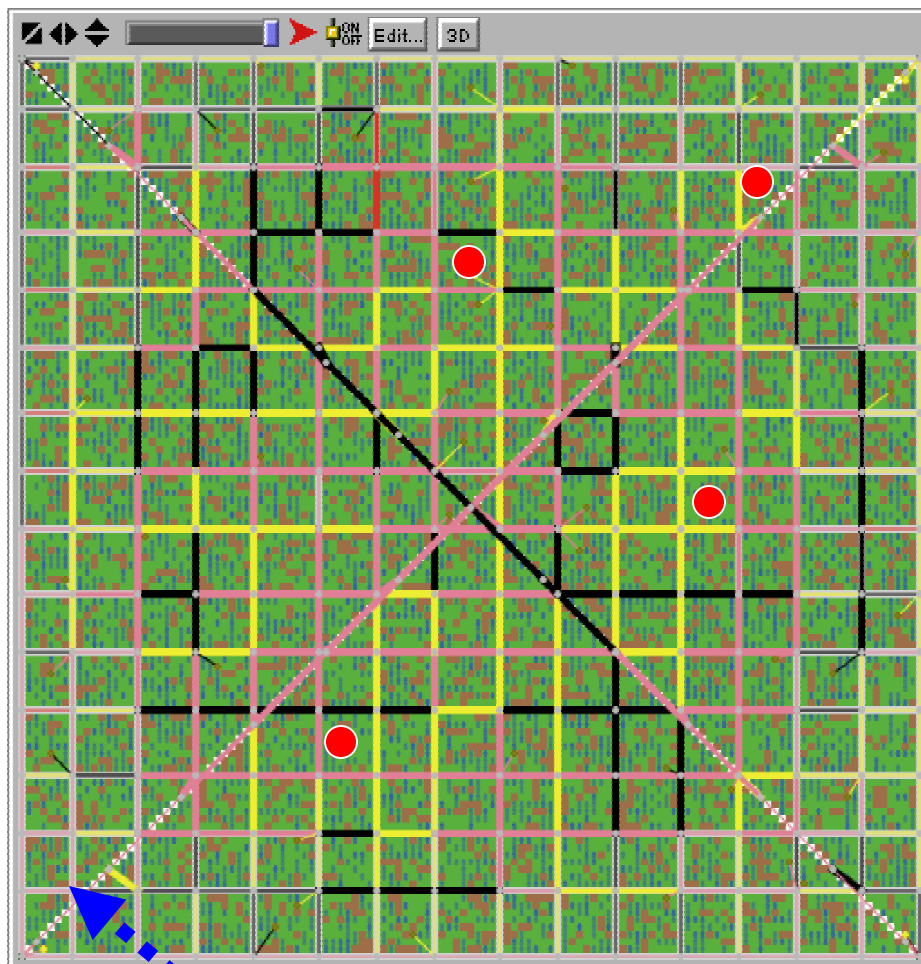
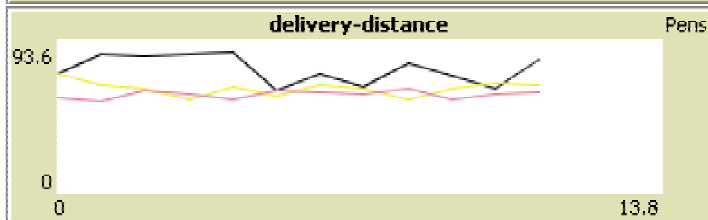
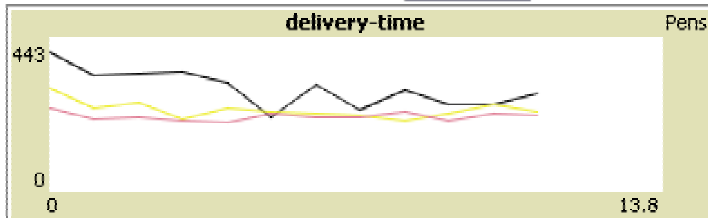
Click setup and then go buttons to setup the

On Off circle?

The number of stores one tour covers. Same for companies with different sizes

Size of small company
 Size of medium company
 Size of big

Click tour to simulate the learning process. Click export-plots to save the simulation results. Identify the file dir and name. File extension is defaulted



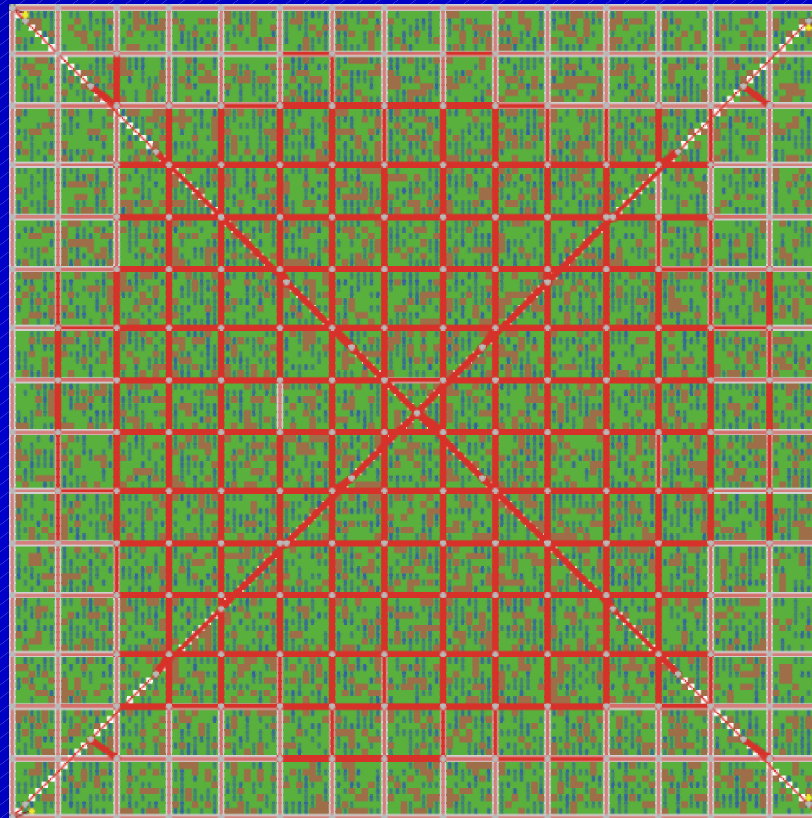
Use these slides to return the initial

Dispatch

NetLogo programming environment (Wilenski, 1999)

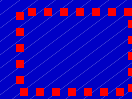
Background traffic

- Congestion generated by (shortest-path) home-to-work trips made by the population
- Degree of congestion = $f(\text{population, network size, link capacity})$



Environment

Parameter	Values tested
Network size	8x8, 15x15, 20x20
Population	6000, 7000, 8000, 9000, 10000
Freeway orientation	Diagonal, parallel
Spacing between ramps	10, 16, 20
Freeway link capacity	400, 500, 600, 700, 800
Street link capacity	75, 100, 125, 150
Stops per delivery tour	3, 4



Values eventually used in scenario simulations

Selection criteria:

- Link V/C ratio must be realistic
- Effect on simulation outcome
- Computation time

Simulation scenarios

Variables: Congestion level, travel time variation, real-time traffic information

Scenario	Population	Expwy capacity	Local capacity	Travel time variation factor	w/ traffic info?
1	7000	500	100	0.5	Y
2	7000	500	100	0.5	N
3	7000	500	100	0.3	Y
4	7000	500	100	0.3	N
5	8000	500	100	0.3	Y
6	8000	500	100	0.3	N
7	6000	500	100	0.3	Y
8	6000	500	100	0.3	N

Adding random delay to link travel time

- For a link i ,

$TT_i = \max(\text{Variable congested time}, \text{Free-flow time})$

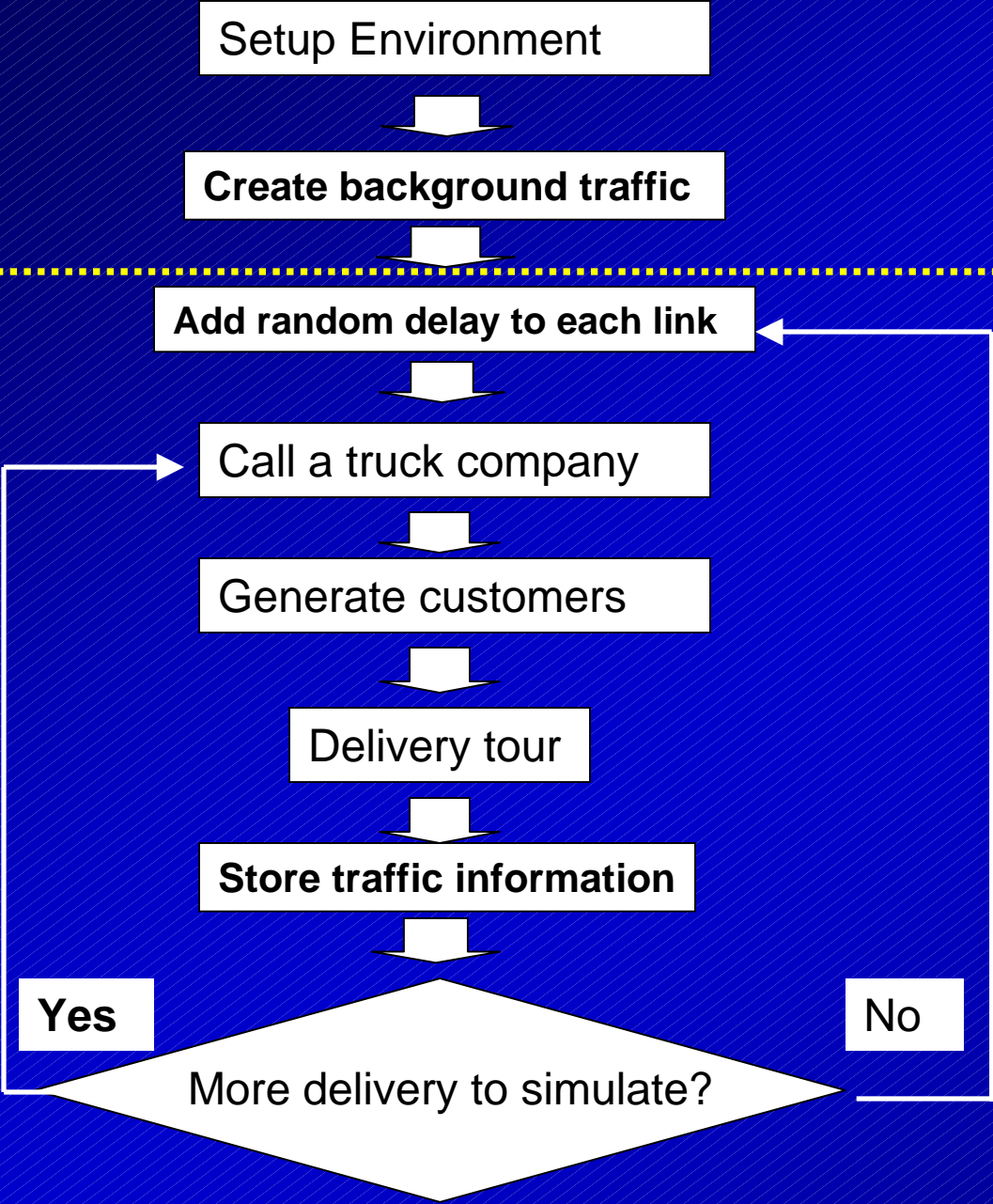
Variable congested time = $\sim N(\mu = \text{Loaded travel time}, \sigma = \text{variability factor} \times \text{loaded travel time})$

Variability factors of 0.3 and 0.5 were used

e.g. For a link with loaded travel time = 5 min

Variable congested time = $\sim N(5, 0.3 \times 5)$

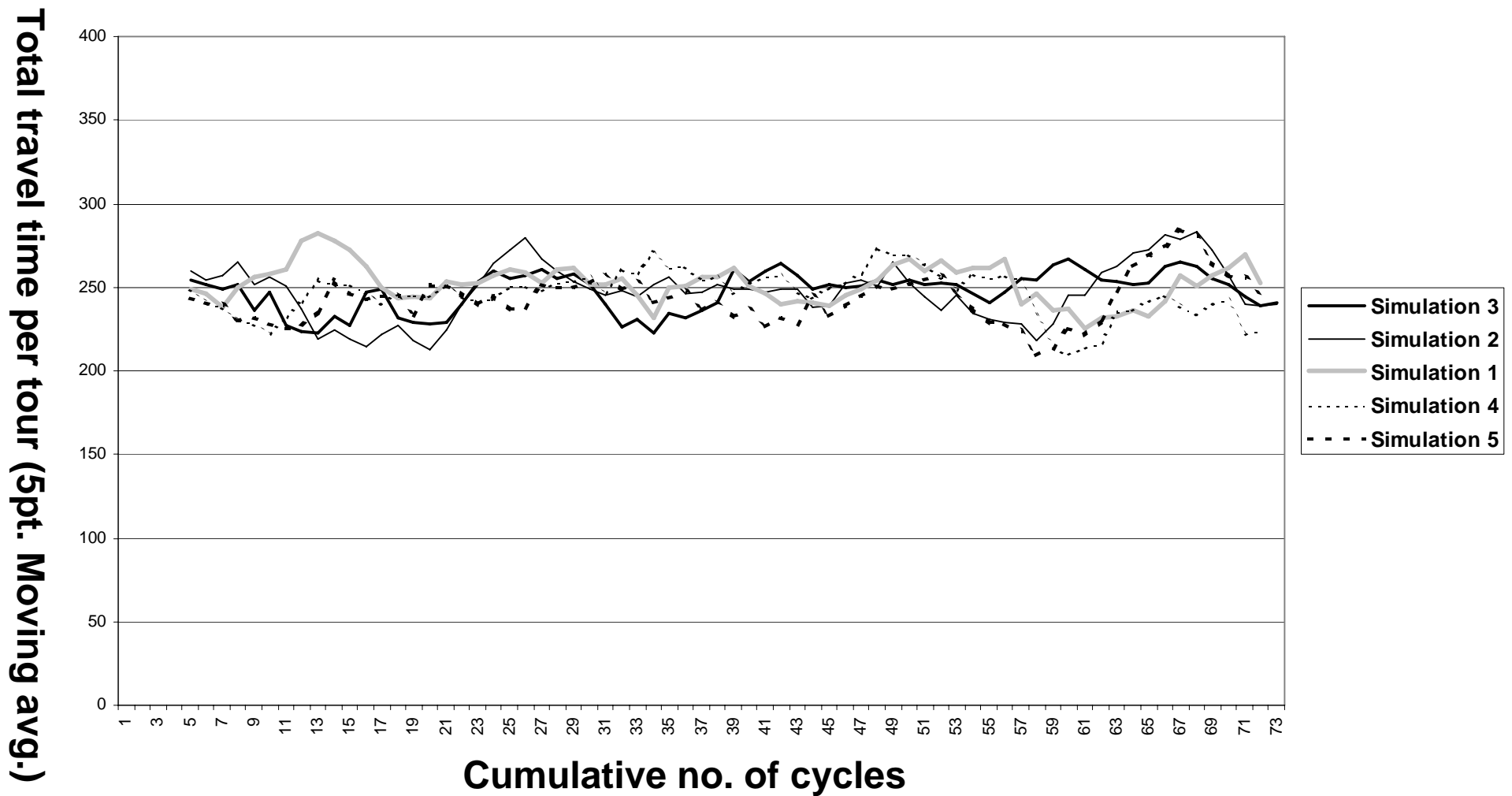
Simulation flow chart



70 cycles

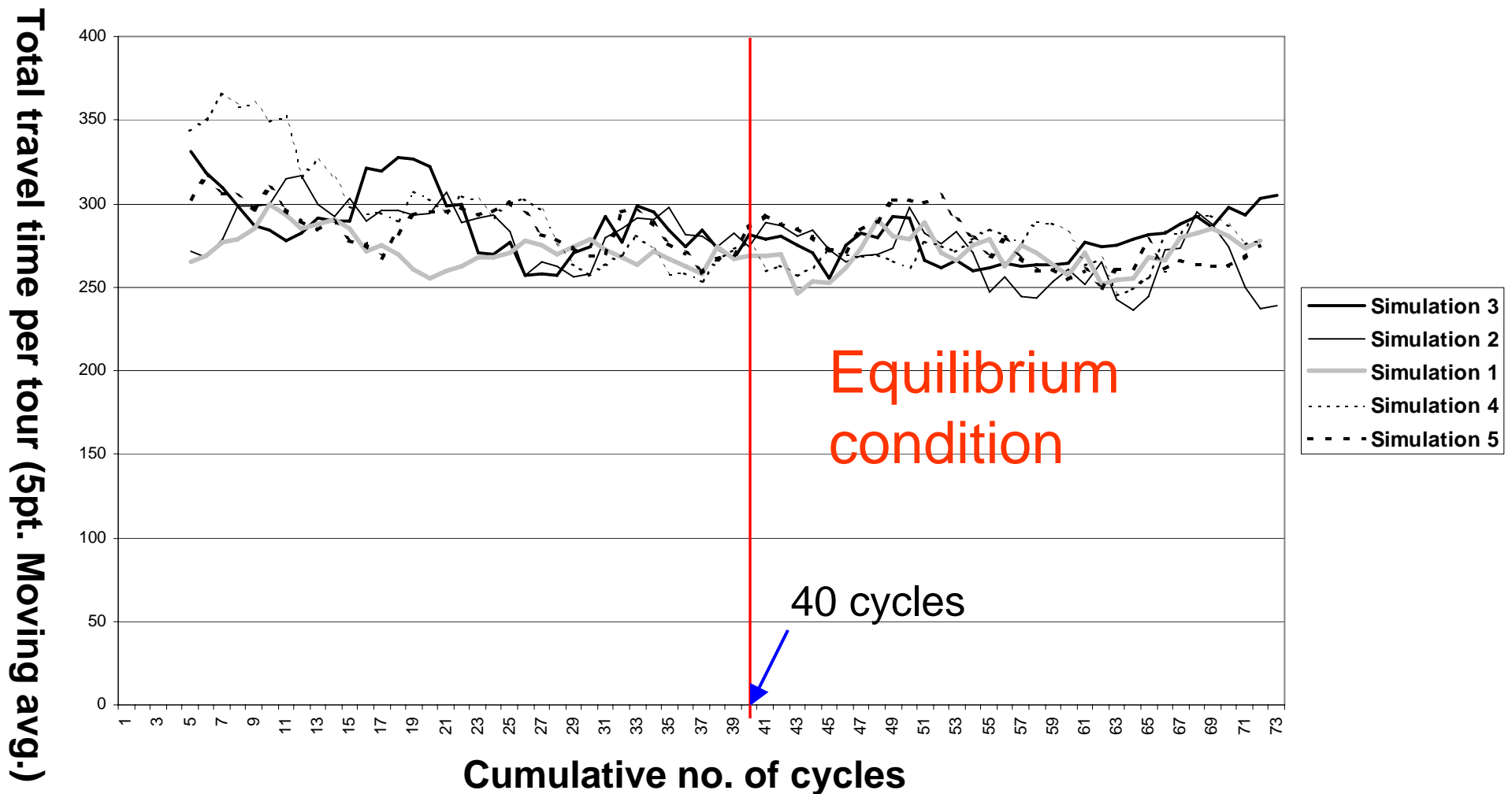
5 runs each for 8 scenarios

Scenario 1 (Moderate congestion, 0.5 variability factor, with info.)



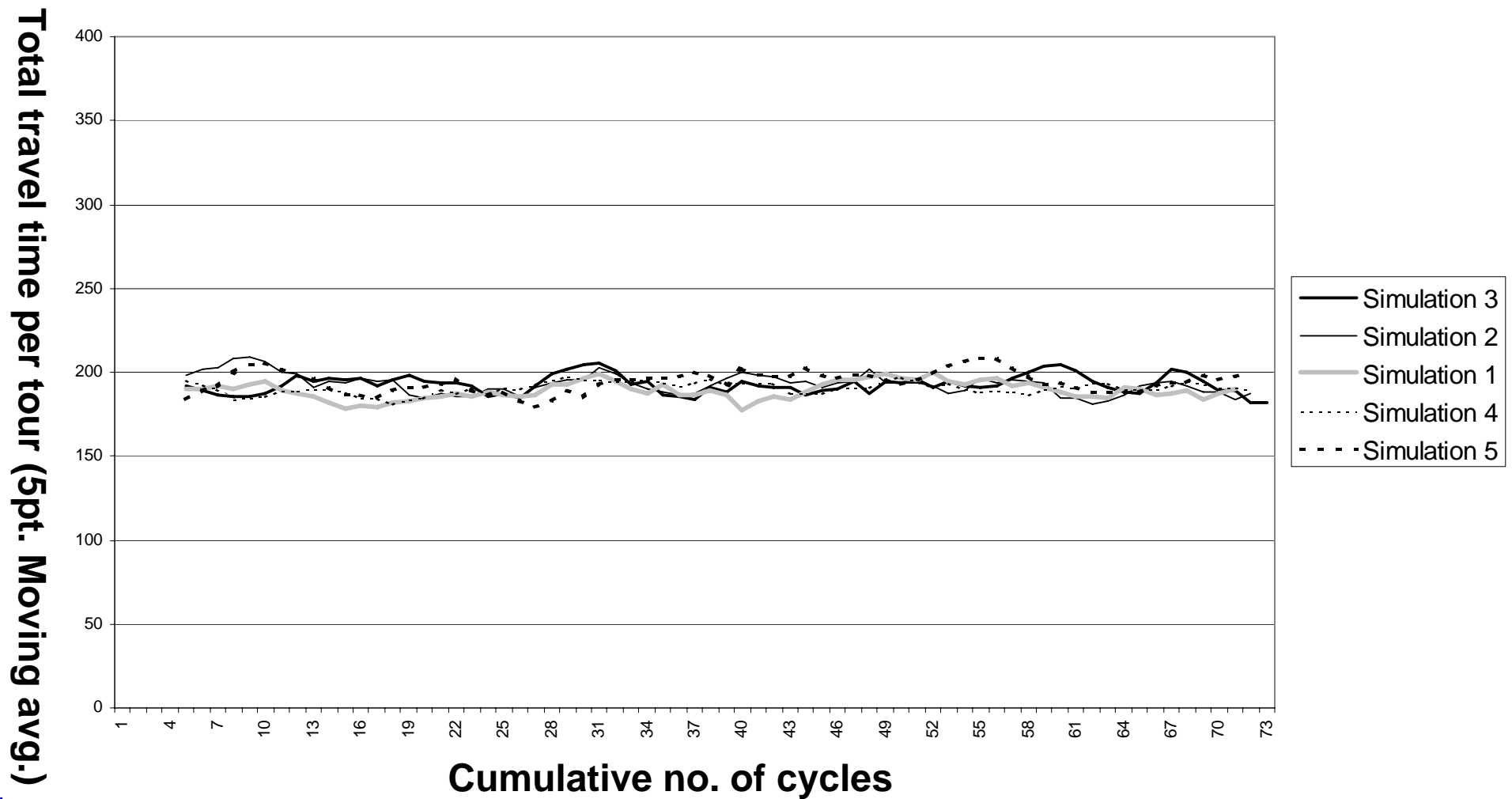
Small firm

Scenario 2 (Moderate congestion, 0.5 variability factor, without info.)



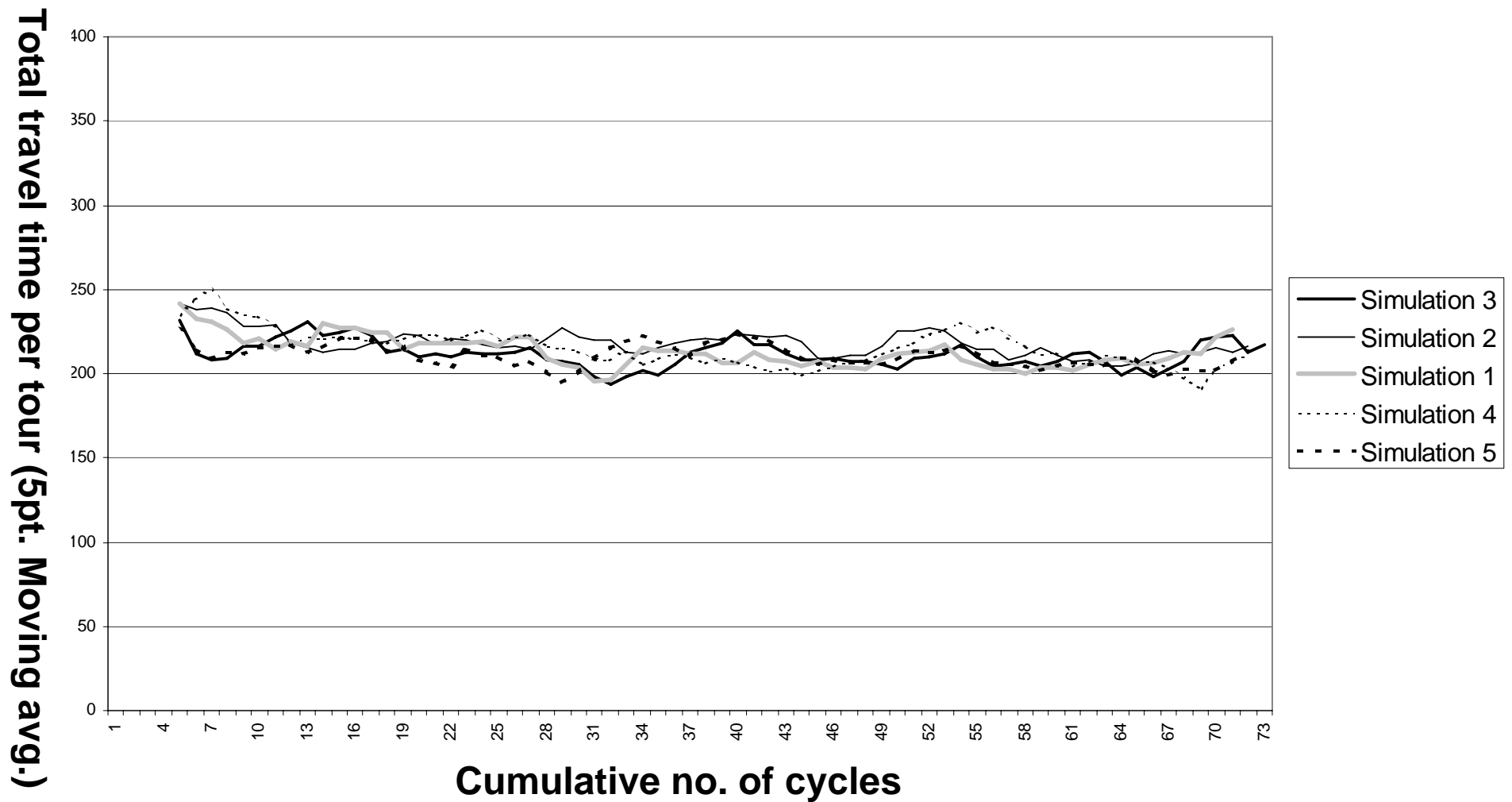
Small firm

Scenario 1 (Moderate congestion, 0.5 variability factor, with info.)



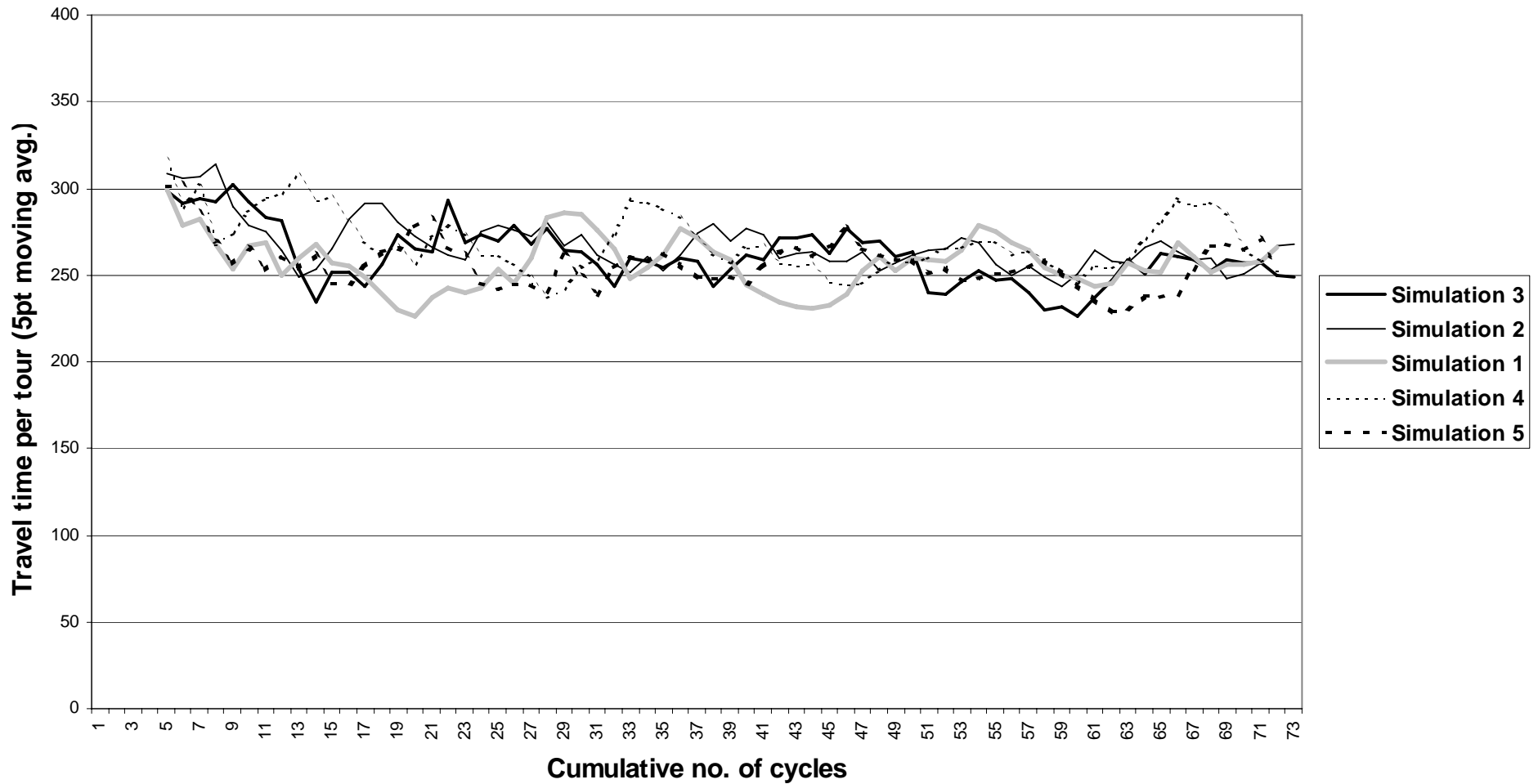
Large firm

Scenario 2 (Moderate congestion, 0.5 variability factor, without info)



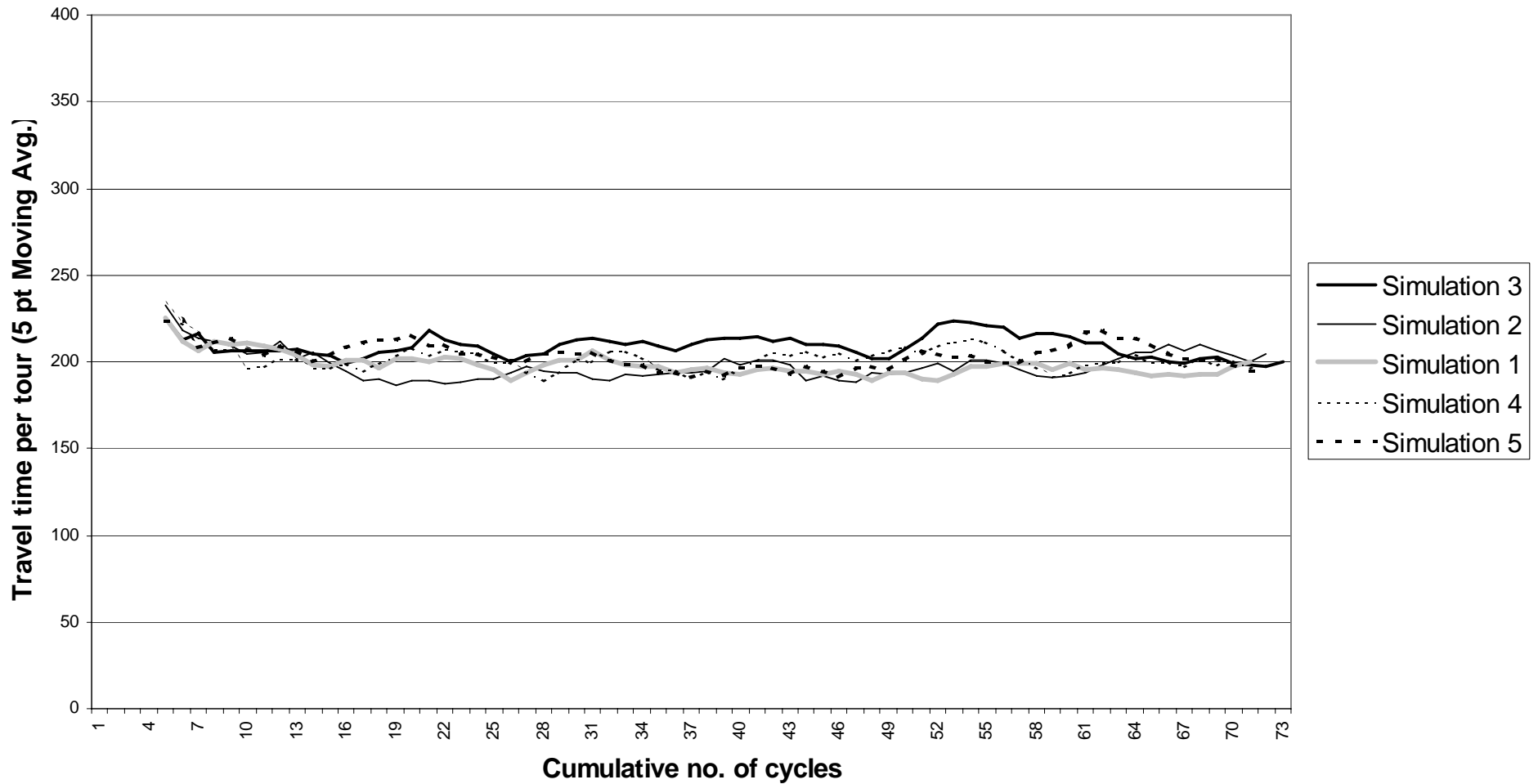
Large firm

Scenario 4 (Moderate congestion, 0.3 variability factor, without info)



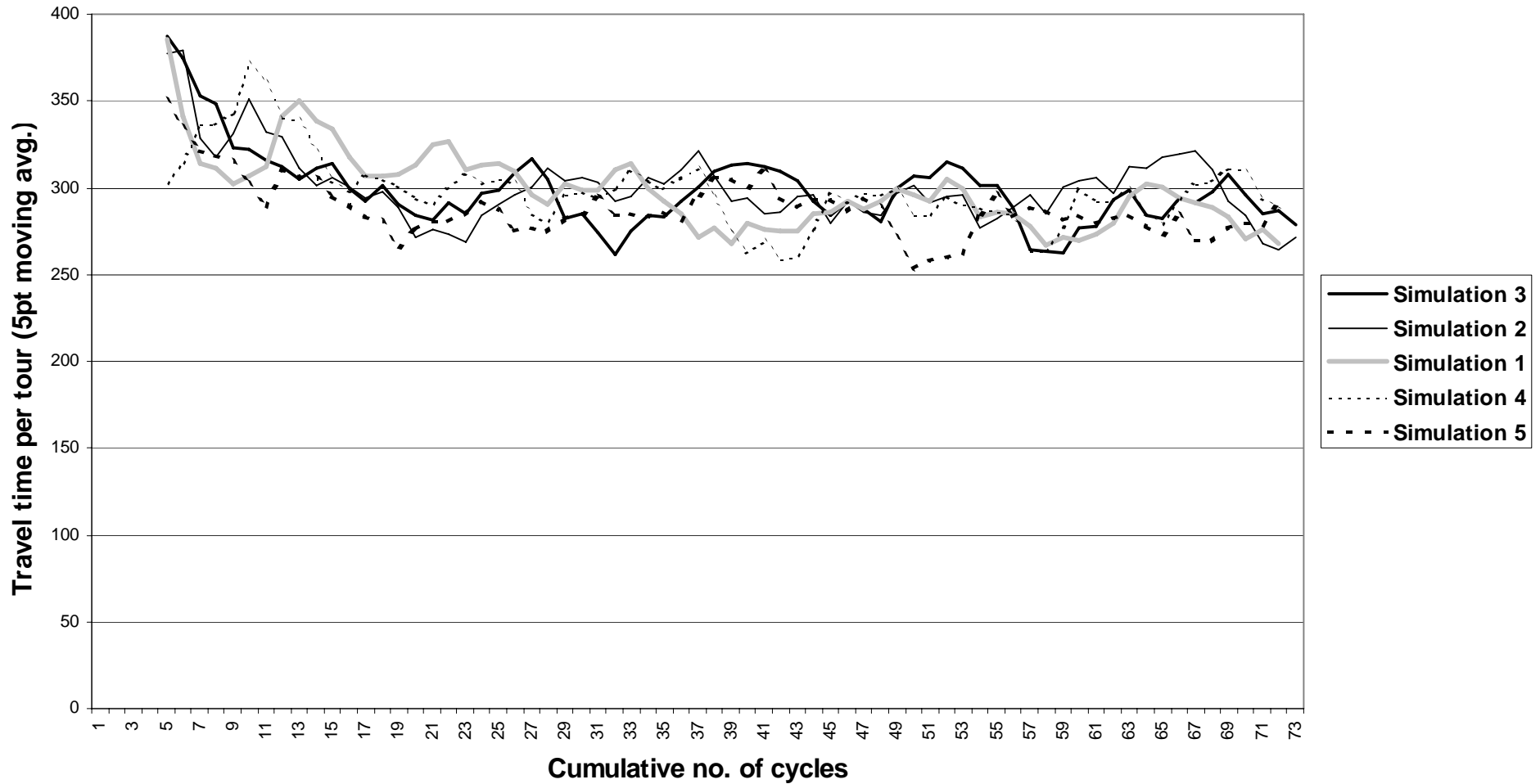
Small firm

Scenario 4 (Moderate congestion, 0.3 variability factor, without info)



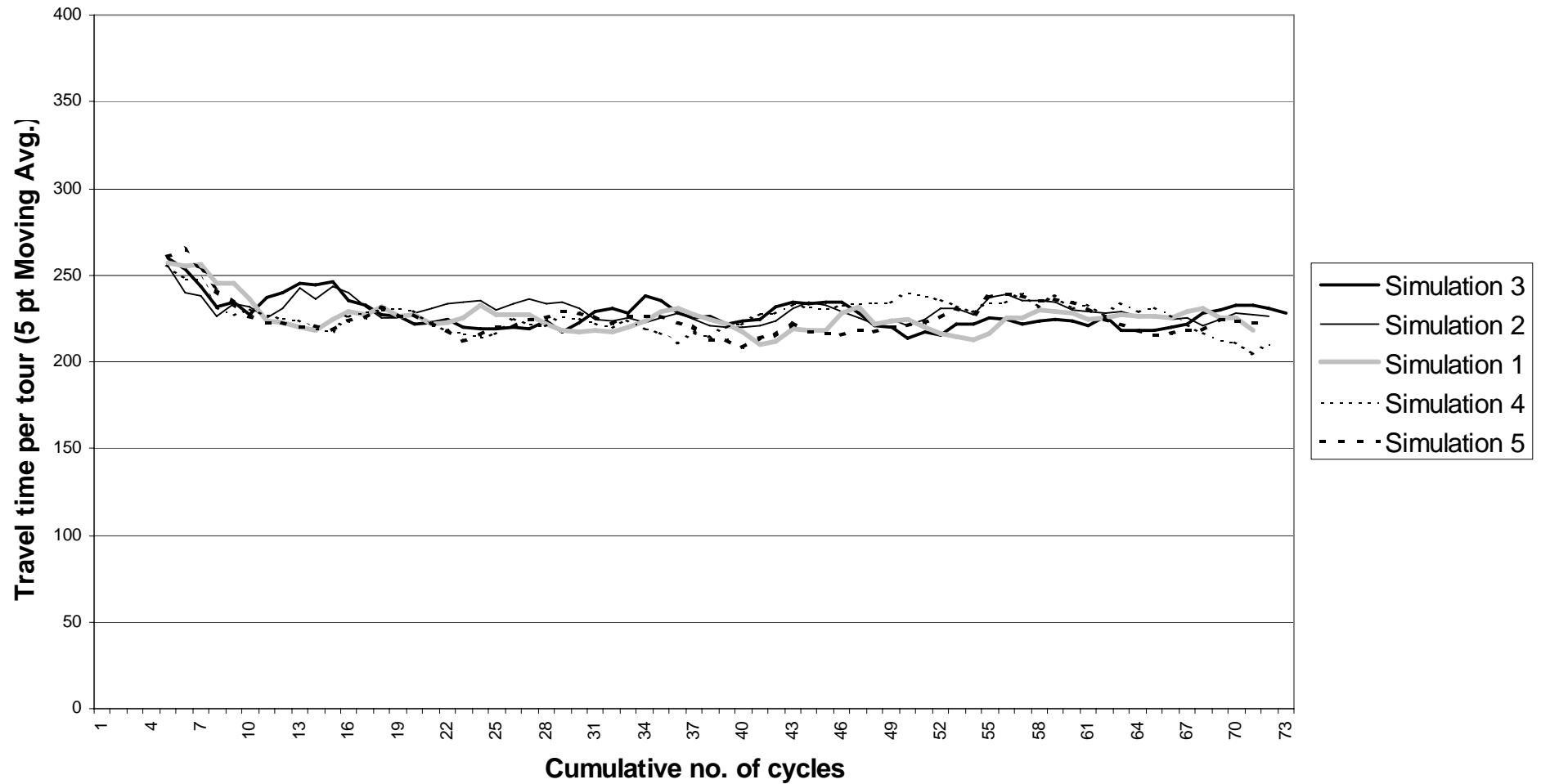
Large firm

Scenario 6 (Severe congestion, 0.3 variability factor, without info)



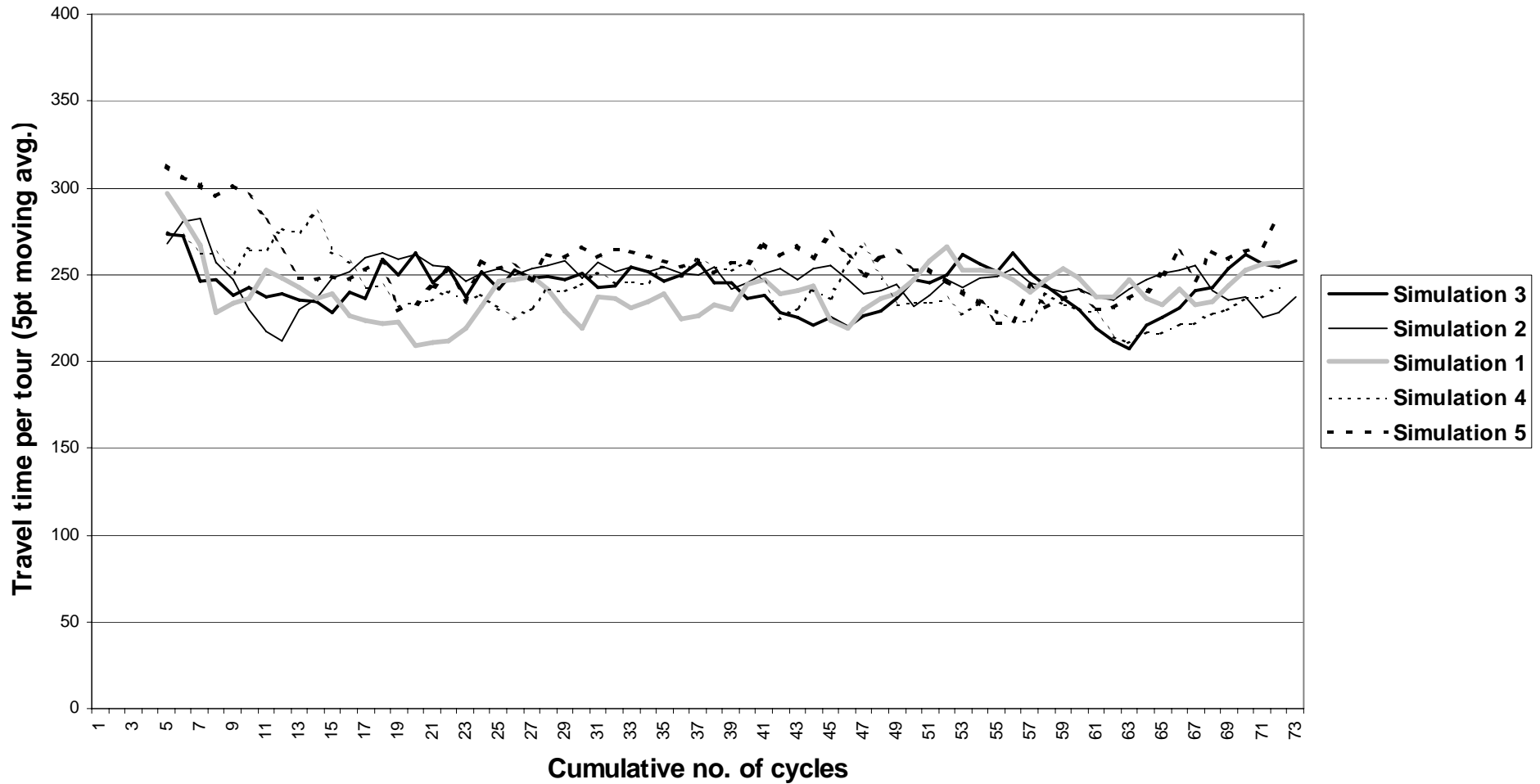
Small firm

Scenario 6 (Severe congestion, 0.3 variability factor, without info)



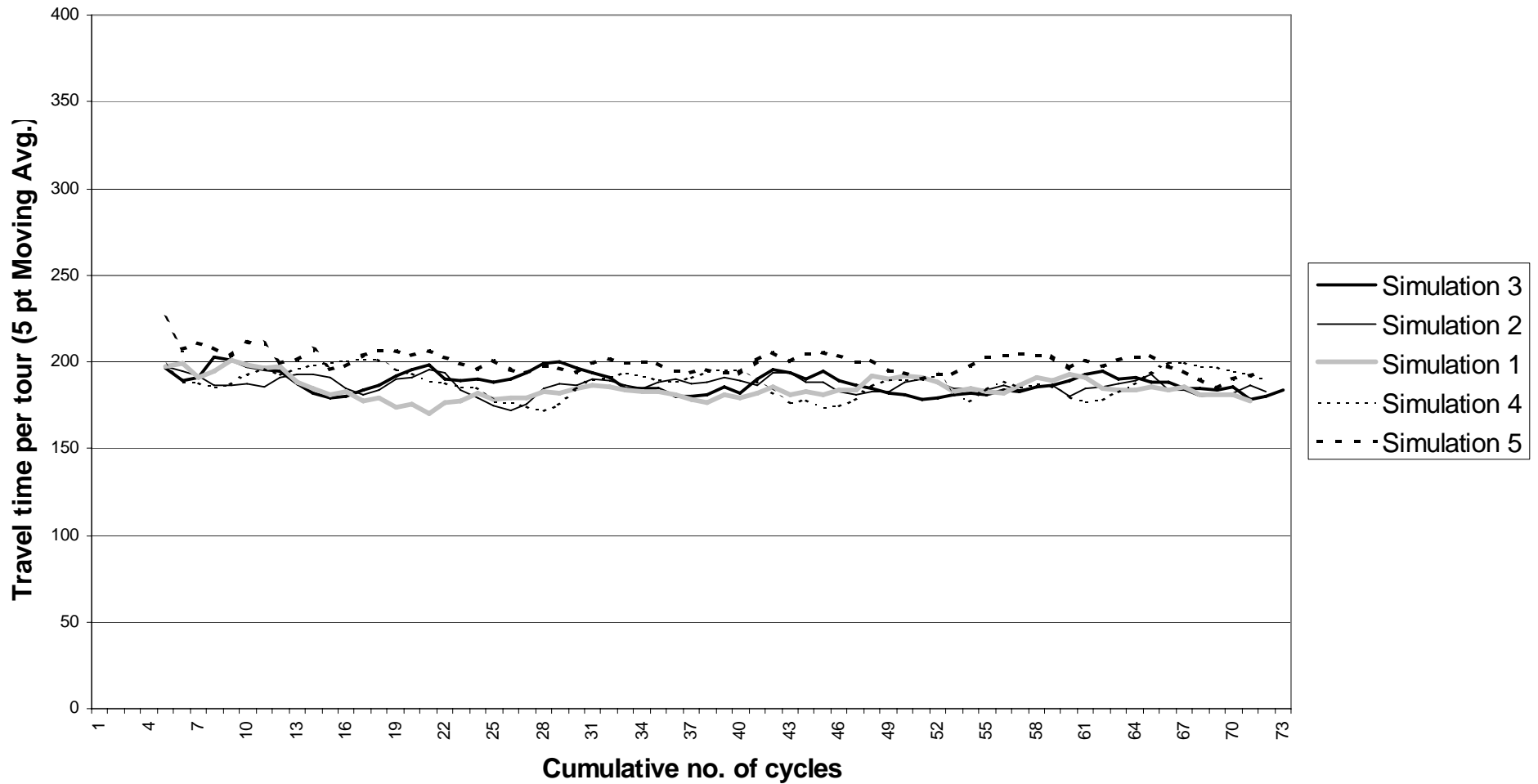
Large firm

Scenario 8 (Light congestion, 0.3 variability factor, without info)



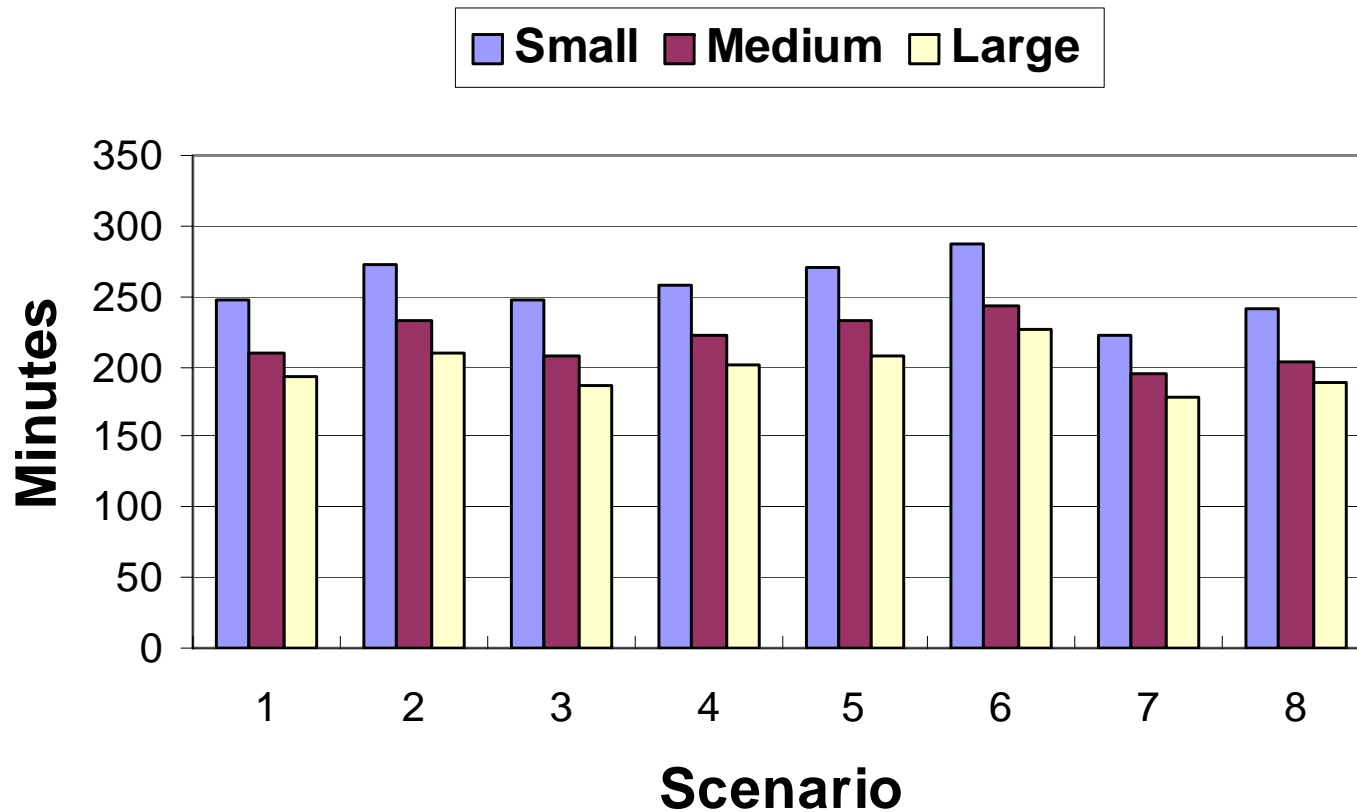
Small firm

Scenario 8 (Light congestion, 0.3 variability factor, without info)



Large firm

Equilibrium time/tour



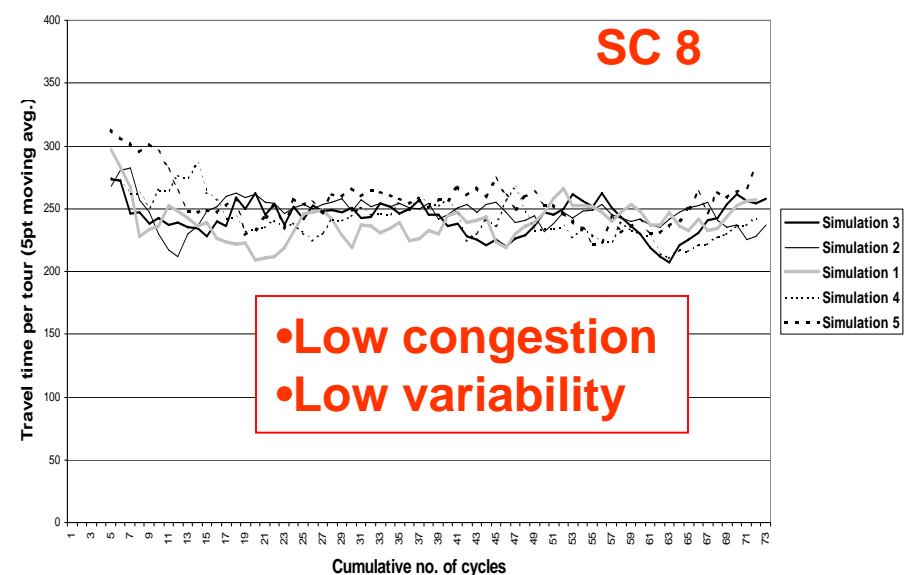
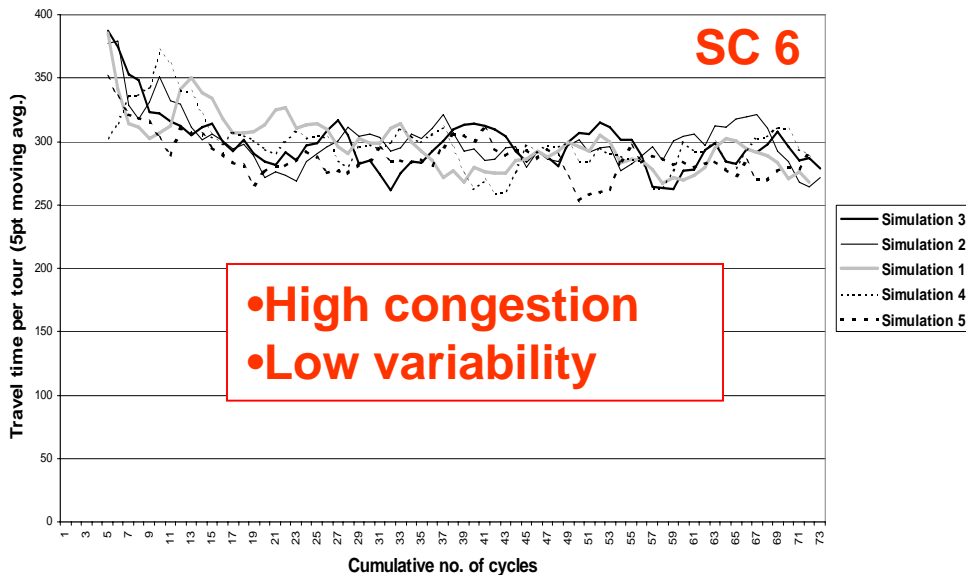
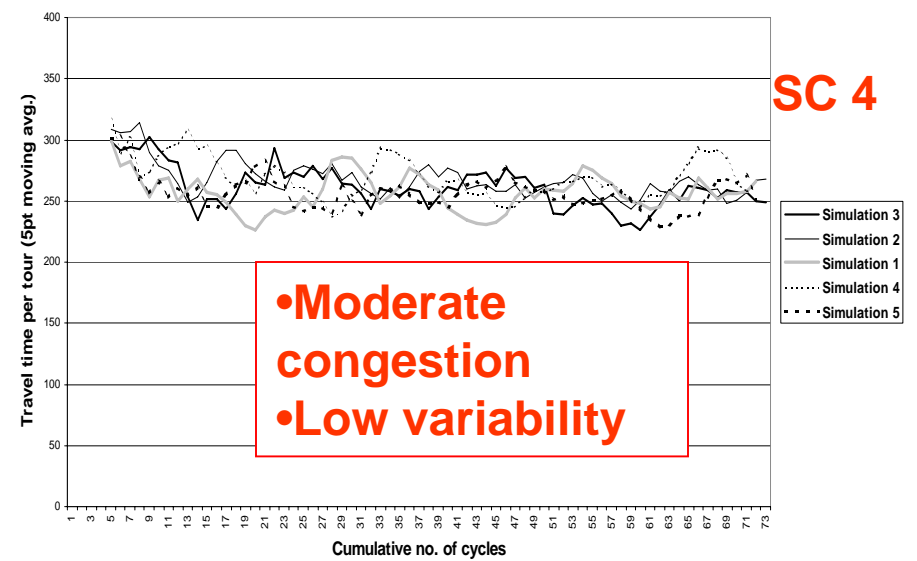
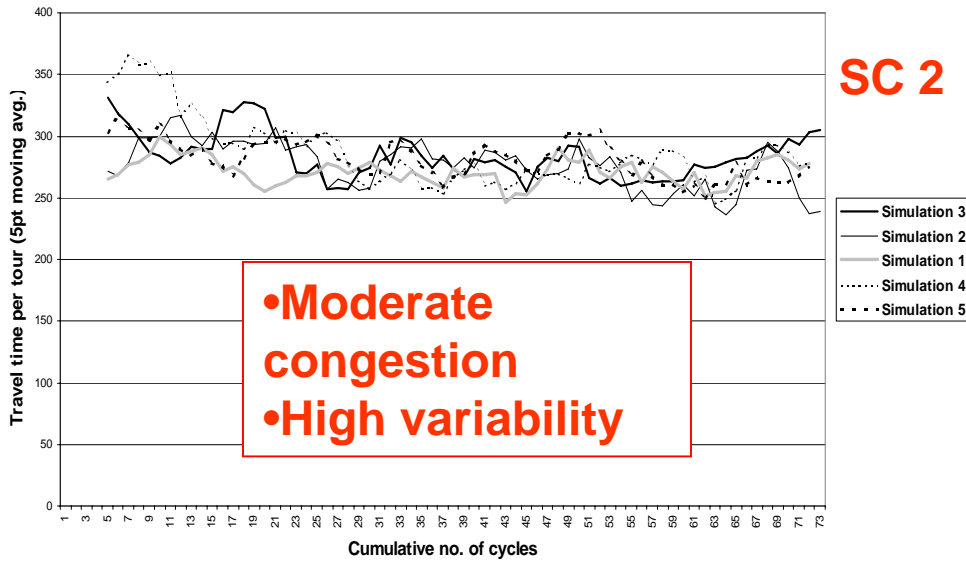
Scenario 1&2 (Moderate congestion, 0.5 variability factor)

Scenario 3&4 (Moderate congestion, 0.3 variability factor)

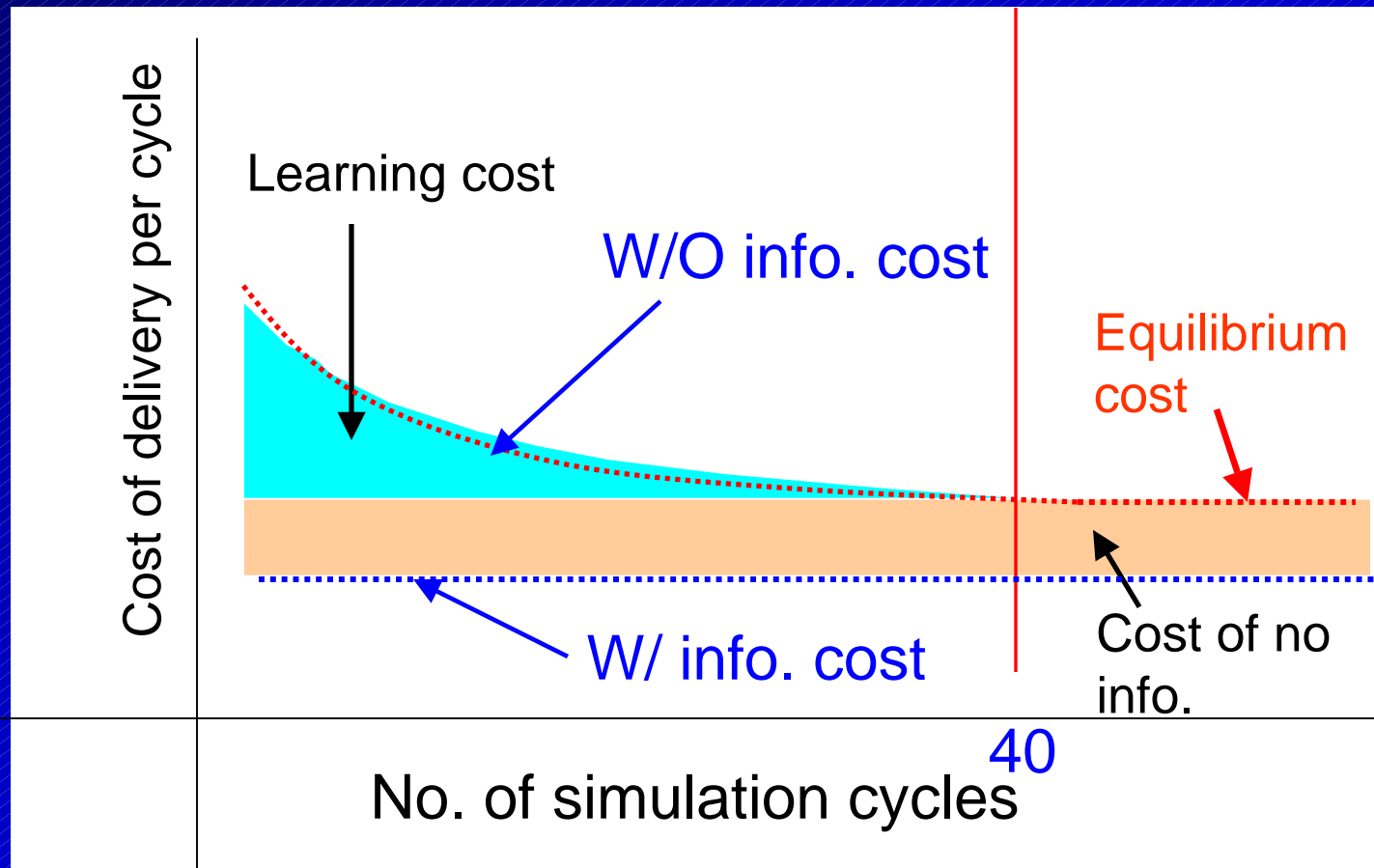
Scenario 5&6 (Severe congestion, 0.3 variability factor)

Scenario 7&8 (Light congestion, 0.3 variability factor)

Comparison of “without info” scenarios - Small firm -



Calculation of costs



\$ per mile data from Transport Canada, fuel prices, fuel economy for 2-axle, single unit van

Benefit of Travel Time Information (per tour)

(Avg. of 5 simulation runs)

Scenario	Median V/C	Var. Factor	Small		Medium		Large	
			Learning cost	Permanent	Learning cost	Permanent	Learning cost	Permanent
1 & 2	0.97	0.5	5.7	13.4	1.7	14.1	2.3	10.0
3 & 4	0.97	0.3	4.0	5.9	1.3	8.3	1.2	7.9
5 & 6	1.21	0.3	7.0	9.8	3.4	6.4	1.1	10.5
7 & 8	0.76	0.3	3.8	11.1	1.6	4.9	1.8	5.8

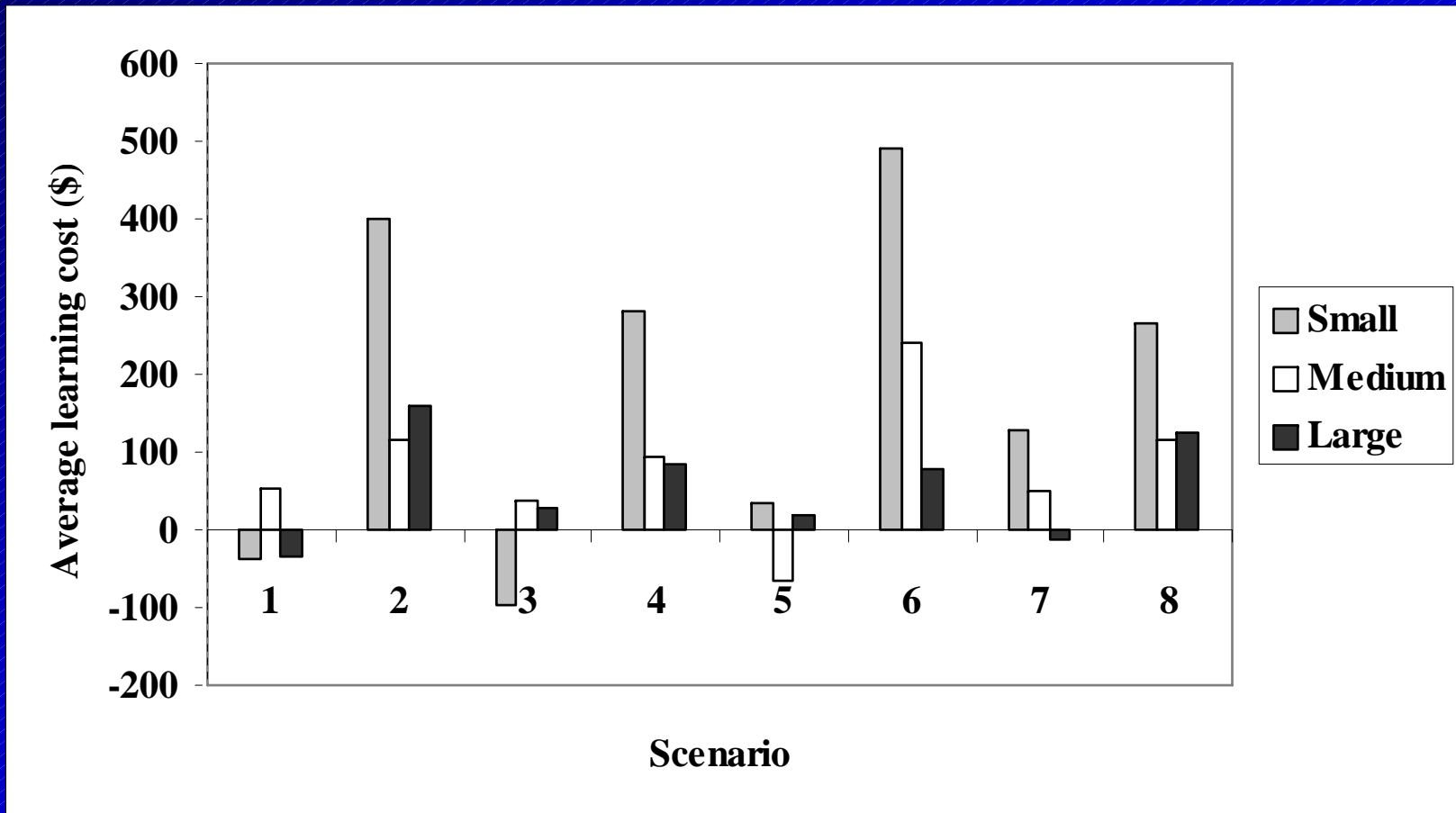
Scenario 1&2 (Moderate congestion, 0.5 variability factor)

Scenario 3&4 (Moderate congestion, 0.3 variability factor)

Scenario 5&6 (Severe congestion, 0.3 variability factor)

Scenario 7&8 (Light congestion, 0.3 variability factor)

Learning Costs Comparisons



Scenario 1&2 (Moderate congestion, 0.5 variability factor)

Scenario 3&4 (Moderate congestion, 0.3 variability factor)

Scenario 5&6 (Severe congestion, 0.3 variability factor)

Scenario 7&8 (Light congestion, 0.3 variability factor)

Conclusions

- Simulation of “learning” traffic conditions was conducted
- Benefit of traffic information increases with the level of congestion & variability
- Savings from knowing real link travel time (as opposed to estimating) is often greater than the saving in learning cost
- Without publicly available traffic information...
 - For medium or large firms, learning cost is negligible
 - For small firm, learning cost can be an issue (up to 4.5% of total cost)
- Simulation-to-simulation variability in the benefit is large in some cases

Future work

- Stochastic decision by the trucks
- More simulation runs
- Variations in terminal locations
- Better optimization algorithm
- Simulation of congestion caused by incident
- Larger network
- Real-time (during the tour) updating of traffic data