

# Asymmetric Interactions, and the Role of Incentives and Pricing: Implications for Network Modeling

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## Asymmetric (power) interactions

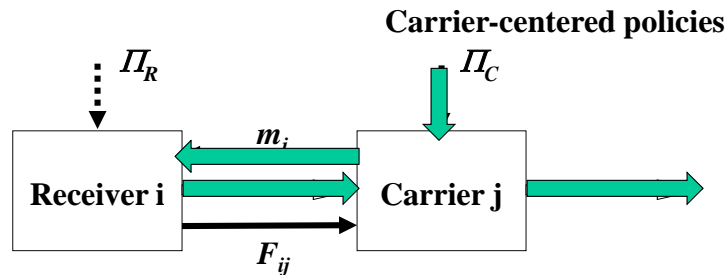
### ❖ Symmetric case:

- ❖ It does not matter which player is impacted with a cost/incentive because players transfer them

### ❖ Asymmetric case:

- ❖ One player has more power than the other
- ❖ Under some market conditions, dominated player cannot pass (some) costs to dominant player; dominant player could impose its will on the other
  - ❖ Pricing schemes that target the dominated player are doomed to fail
  - ❖ The key is to change the behavior of dominant agent

## Carrier centered policies, e.g. freight pricing <sup>3</sup>



### Legend:

- Decision about off-hour deliveries
- Price signals
- External stimuli

(This must happen for almost all receivers in the tour)



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## Examples <sup>4</sup>

- ❖ In urban freight transportation:
  - ❖ The interactions between receivers (dominant) and carriers (dominated) that determine delivery times
  - ❖ We'll discuss this in detail
- ❖ In passenger transportation:
  - ❖ The interactions between employer (dominant) and employees (dominated) that determine preferred arrival time, and time of arrival flexibility
  - ❖ We'll fly over work on in progress by Wilfredo Yushimito, Jeff Ban, and JHV



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## The urban freight demand case



## Part of a project that has been, at times...

- ❖ A science mystery
- ❖ A political thriller
- ❖ A melodrama
- ❖ A comedy
- ❖ A Greek tragedy
- ❖ A good drama with a happy ending...



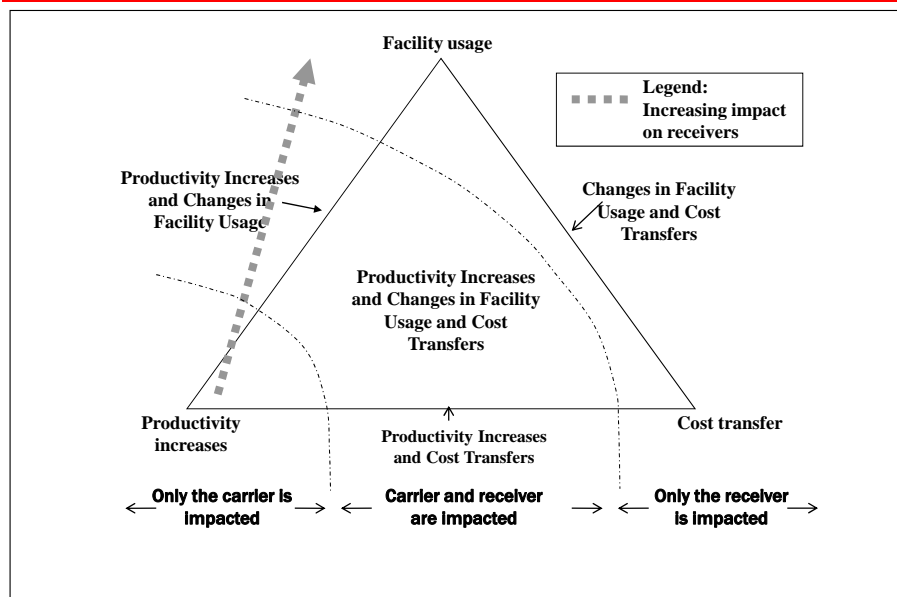
## We all know that...

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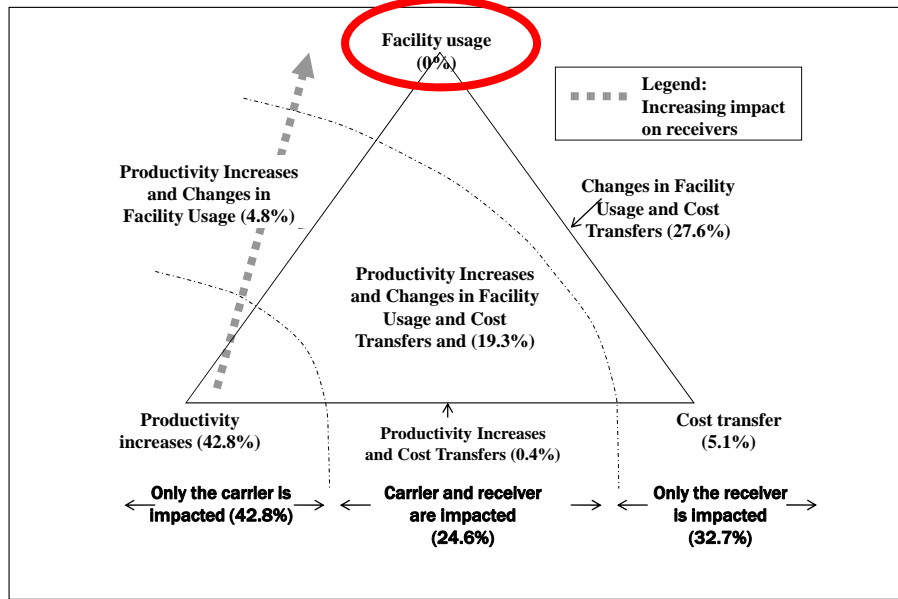
- ❖ If prices go up, transportation demand goes down
- ❖ In freight road pricing:
  - ❖ Tolls are imposed on truck traffic
  - ❖ Carriers pass the toll to the receivers / shippers
  - ❖ Receivers / shippers will react by moving their operations to the off peak hours
- ❖ Right?
- ❖ Not quite..... Reality is more complex than we think
- ❖ The experience of the Port Authority of New York and New Jersey's Time of Day Pricing Initiative (2001) provides great insight



## Observed Behavioral Changes (Holguin-Veras et al. 2006)<sup>8</sup>



## Observed Behavioral Changes *(Holguín-Veras et al. 2006)*



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The role of carrier-receiver interactions

## The decision about delivery time

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- ❖ Is made jointly between receivers and carriers
  - ❖ 40% by receivers, 38% between receivers and carriers and 22% by carriers
- ❖ Let's take a look at the payoff matrix
  - ❖ The first sign represents the impact on carrier and the second the impact on receiver **(This is the solution preferred by most receivers)**  
**(These are non-feasible solutions)**

		Receiver	
		Regular hours	Off-hours
Carrier	Regular hours	( -, + ) (I)	( -, - ) (II)
	Off-hours	( -, - ) (III)	( +, - ) (IV)

**The key is to provide incentives to receivers so that they prefer OHD!**

**(This is the solution preferred by most carriers)**

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The joint (carrier-receiver) behavioral response



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## Receiver behavior

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- ❖ Can be assumed to be a monotonic function of an external incentive

$$P(R_i \in \Omega_j^o / F) = P(F)$$

$$P(R_i \in \Omega_j^o / 0) = P(0) = p_0 \quad \text{Base case participation}$$

$$P(R_i \in \Omega_j^o / \infty) = P(\infty) = 1 \quad \text{All receivers participate if incentive is infinite}$$

- ❖ However, the random nature of the response gives rise to random configurations of service areas

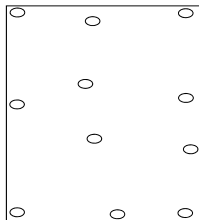


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## Typical random configurations

Base case operations:

$$A = A^{BC}$$



After receiving an incentive,  
the receivers will be split in  
two subsets:

- Regular hour receivers
- Off-hour receivers

Thus creating two delivery networks  
with two service areas

## Single tour carrier under Cordon TOD pricing 15

### ❖ Base case costs

$$C_j^{BC} = (C_{FC}^{BC} + C_{HB}^{BC}) + c_D^{BC} D^{BC} + c_T^{BC} T^{BC} + S^R$$

**The carrier has to be better off**

### ❖ Mixed case (with regular + off-hour deliveries)

$$C_j^M = [(C_{FC}^R + C_{HB}^R) + (C_{FC}^O + C_{HB}^O)] + [c_D^R D^R + c_D^O D^O] + [c_T^R T^R + c_T^O T^O] + S^R$$

### ❖ Necessary condition for carrier to move

$$G_j^M - C_j^M \geq G_j^{BC} - C_j^{BC}$$

$$[(C_{FC}^R + C_{HB}^R) + (C_{FC}^O + C_{HB}^O) - (C_{FC}^{BC} + C_{HB}^{BC})] + [c_D^R D^R + c_D^O D^O - c_D^{BC} D^{BC}] + [c_T^R T^R + c_T^O T^O - c_T^{BC} T^{BC}] \leq \Delta G_j, \text{ iff } N^O < N^{BC}$$

### ❖ Key finding: The toll surcharge plays no role! (in the mixed case the carrier also pays the surcharge)



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## The paradox of Cordon TOD 16

### ❖ The results show that in a mixed operation, the toll surcharge plays no role:

$$[(C_{FC}^R + C_{HB}^R) + (C_{FC}^O + C_{HB}^O) - (C_{FC}^{BC} + C_{HB}^{BC})] + [c_D^R D^R + c_D^O D^O - c_D^{BC} D^{BC}] + [c_T^R T^R + c_T^O T^O - c_T^{BC} T^{BC}] \leq \Delta G_j, \text{ iff } N^O < N^{BC}$$

### ❖ If all receivers switch to the off-hours, the surcharge plays a role!:

$$c_T^O T^O - c_T^{BC} T^{BC} \leq \Delta G_j, \text{ iff } N^O = N^{BC}$$

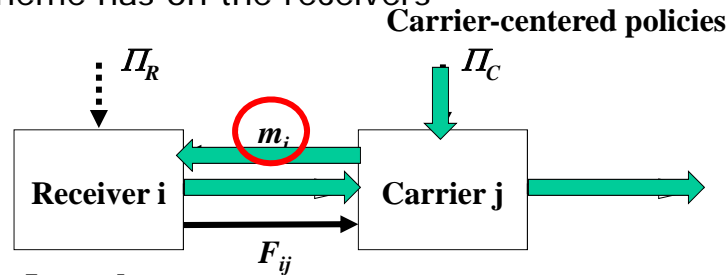
### ❖ However, the surcharge is not needed after all!

### ❖ Why?! Because in the off-hours the time related cost savings are so large that they provide the incentive needed for the carrier to switch

## Impacts on receivers

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- ❖ So far the discussion has centered on the impacts that the pricing scheme has on the carrier
- ❖ Let's focus now on the impacts that the pricing scheme has on the receivers



**Legend:**

- Decision about off-hour deliveries
- Price signals
- ⋯ External stimuli



## Delivery rates

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- ❖ In a competitive market, prices equal marginal cost
- ❖ Computing the marginal cost, one could obtain:

- ❖ Cordon time of day pricing

$$m_j^{R,S}(N^R) = c_D \frac{\partial D^R}{\partial N^R} + c_T^R \frac{\partial T^R}{\partial N^R}$$

**Monetized extra time and distance to deliver**

- ❖ Time-distance pricing

$$m_j^{R,TDP}(N^R) = (c_D + \alpha_D^R) \frac{\partial D^R}{\partial N^R} + (c_T^R + \alpha_T^R) \frac{\partial T^R}{\partial N^R} = \left( c_D \frac{\partial D^R}{\partial N^R} + c_T^R \frac{\partial T^R}{\partial N^R} \right) + \left( \alpha_D^R \frac{\partial D^R}{\partial N^R} + \alpha_T^R \frac{\partial T^R}{\partial N^R} \right)$$

**Toll costs**

- ❖ Key finding:

With TDP carriers will be able to transfer costs (explaining ATA's and other groups' positions)



## Would TDP induce the receivers to switch? 19

❖ For this to happen, the toll signal reaching the

receivers:  $m_j^{R,TDP}(N^R) = \phi \sqrt{L_{ox} L_{oy}} \left[ \left( c_D + \frac{c_T^R}{u^R} \right) + \left( \alpha_D^R + \frac{\alpha_T^R}{u^R} \right) \right] \frac{\partial D(N^R)}{\partial N^R}$

❖ Must be larger than the receivers' cost to switch:

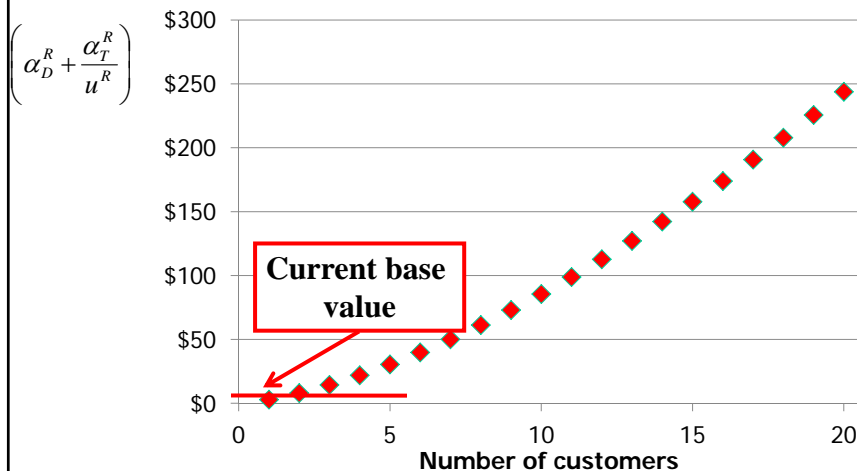
$$\Delta C_{i=N^R} = \bar{m}^o \left[ \frac{\phi}{u^R} \left( \frac{N^R - 1}{N^R + 1} \right) \sqrt{A_o} + \bar{\tau}^o N^R \right]$$

❖ This implies:  $\phi \sqrt{A_o} \left( \alpha_D^R + \frac{\alpha_T^R}{u^R} \right) \frac{\partial D(N^R)}{\partial N^R} \geq \bar{m}^o \left[ \frac{\phi}{u^R} \left( \frac{N^R - 1}{N^R + 1} \right) \sqrt{A_o} + \bar{\tau}^o N^R \right]$

$$\left( \alpha_D^R + \frac{\alpha_T^R}{u^R} \right) \geq \frac{\bar{m}^o \left[ \frac{\phi}{u^R} \left( \frac{N^R - 1}{N^R + 1} \right) \sqrt{A_o} + \bar{\tau}^o N^R \right]}{\phi \sqrt{A_o} \frac{\partial D(N^R)}{\partial N^R}}$$

**Tolls must be larger than the ratio of the expected incremental cost of switching to the expected marginal distance traveled**

## Minimum time-distance unit tolls 20



**These are humongous tolls! (The current value is about \$6/mile)**  
**Implication: TDP could induce a change in very short tours**

## "Integrative Freight Demand Management in the New York City Metropolitan Area"



## Interlocking components

- ❖ Behavioral/economic components
  - ❖ Analyses of most promising industry segments
  - ❖ Incentives to receivers of cargo willing to do OHD
- ❖ Technology component
  - ❖ GPS to assess performance (cell phones, own systems)
- ❖ Network modeling component
  - ❖ Mesoscale traffic model to assess local impacts
  - ❖ Regional model to assess networkwide impacts
- ❖ Industry/Agency outreach component
  - ❖ To get feedback from all involved
- ❖ Small scale pilot test component
  - ❖ To assess real life impacts...

JHV aged  
twenty years

## Regular vs. Off-Hour Deliveries (1 of 2)

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## Regular vs. Off-Hour Deliveries (2 of 2)

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## Typical results from satisfaction surveys

- ❖ Scale: 1 = Very favorable, 5 = Very unfavorable
- ❖ Whole Food Vendors: 1.55
- ❖ Participating drivers:
  - ❖ Travel speeds = 1.33
  - ❖ Congestion = 1.11
  - ❖ Parking = 1.11
  - ❖ Stress levels = 1.11
  - ❖ Time to deliver goods = 1.38
  - ❖ Time to complete the route = 1.44
  - ❖ Driver's feeling of safety = 1.86

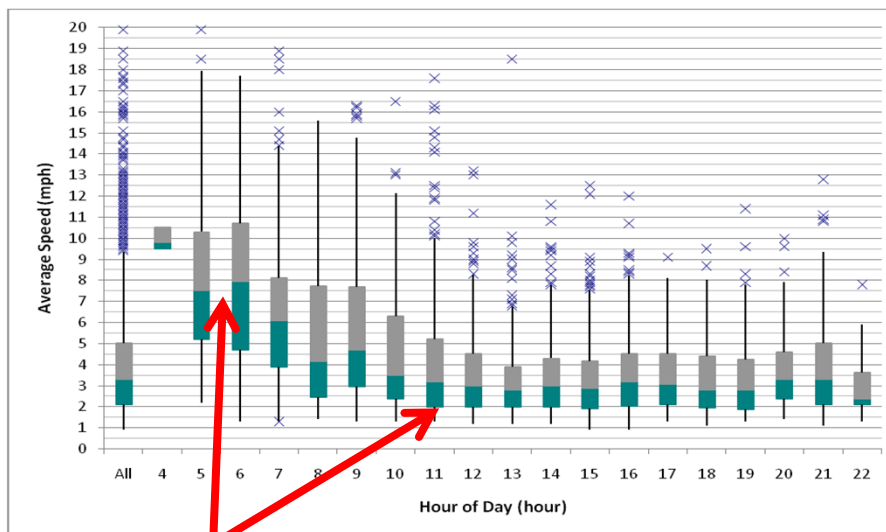
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## Average space travel speeds

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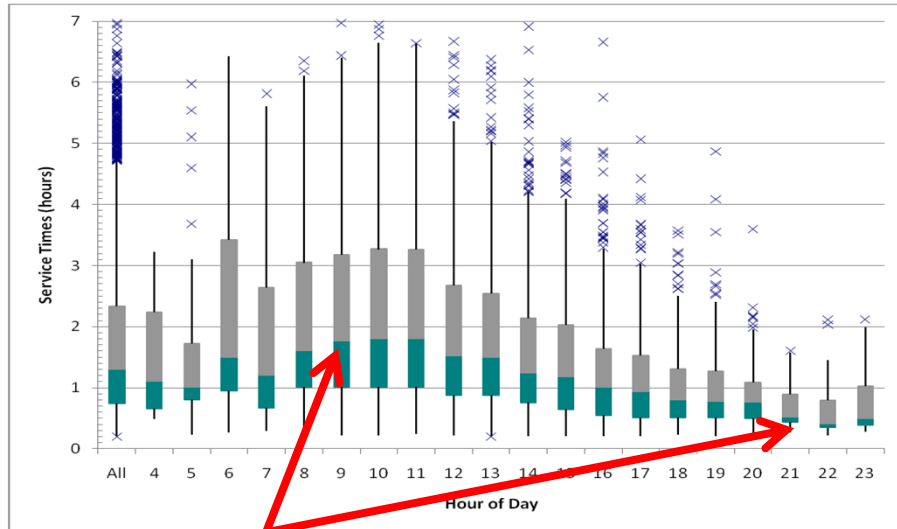
More than twice as fast



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## Average service times

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More than three times as fast

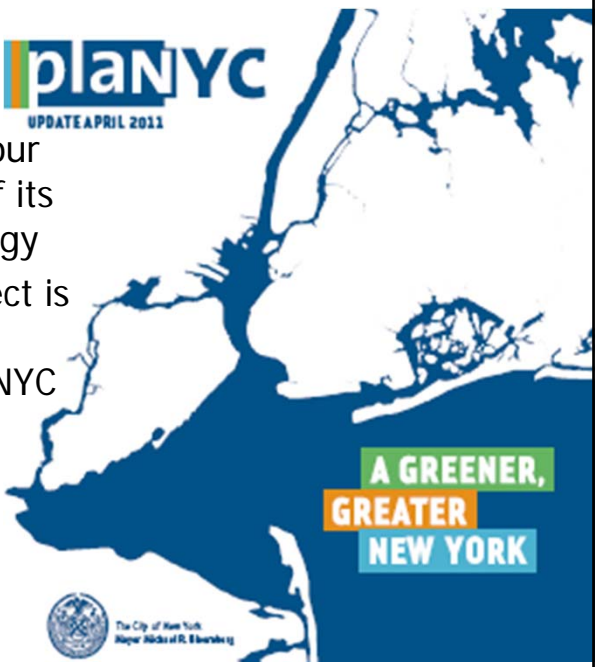


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## At the end of the financial incentive...

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- ❖ Receivers doing staffed OHD:
  - ❖ Reverted back to the regular hours
- ❖ Receivers doing unassisted OHD:
  - ❖ Stayed in the off-hours !
  - ❖ Why?
    - ❖ Reliability
    - ❖ The financial incentive provided allowed to explore OHD (if something went wrong, the incentive would have paid for the costs)
- ❖ This shows the potential of unassisted OHD
  - ❖ Much lower costs than staffed OHD
  - ❖ Same benefits



❖ NYC adopted off-hour deliveries as part of its sustainability strategy

❖ A 2nd USDOT project is going to do a full implementation in NYC

A GREENER,  
GREATER  
NEW YORK

The City of New York  
Mayor Michael R. Bloomberg

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## The Staggered Work Hour Problem

## Facts about Commuting: Work/School Trips

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- ❖ Compulsory trips more often during peak hours:
  - ❖ NY/NJ: 87.94% in the AM and 61.83% in PM were To/From Work or other compulsory trips (Holguín-Veras et al., 2005)
- ❖ Flexibility (Emmerink and van Beek, 1997)
  - ❖ 67% of respondent do not have flexibility at all (work)
- ❖ Work arrival flexibility (Holguín-Veras et al., 2005):
  - ❖ 67.4% of users who travelled for work determined their time of travel on the basis of their work schedules
  - ❖ Cars / Transit :
    - ❖ Flexibility on earlier arrival (20.4 / 18.3 minutes)
    - ❖ Flexibility on later arrival (12.3 / 9.1 minutes)



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## Work Trips: Characteristics

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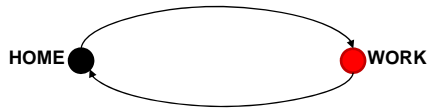
- ❖ Work Constraints:
  - ❖ "Employers are likely to have more discretion than workers in scheduling work hours...Most employees face a Hobson's choice" (Jones ,1977)
- ❖ Flexibility:
  - ❖ Departure time decision influenced by work schedule flexibility (Abkowitz, 1981)
  - ❖ Flexibility on arrivals or suitable transit choices are a necessary condition for implementing congestion pricing (Emmerink and van Beek, 1997, Holguín-Veras et al., 2005)



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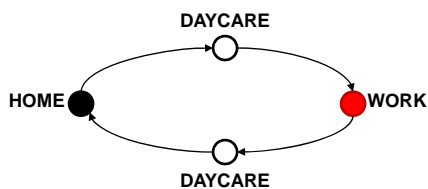
## Parallel with Off-Hour Deliveries

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		FIRM	
		STD	SWH
WORKER	STD	(- , +)	Infeas.
	SWH	Infeas.	(+ , -)

Firm requires Incentive



		FIRM	
		STD	SWH
WORKER	STD	(+ , +)	Infeas.
	SWH	Infeas.	(- , -)

Both require Incentive



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## Overview of Models

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- ❖ Compute optimal incentive level:
  - ❖ Computing economic welfare
  - ❖ Modeling Dynamic User Equilibrium
- ❖ Computing traffic response for a given incentive
  - ❖ For a given incentive, what's the impact on traffic?



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# Mathematical Formulation: MPEC w/DUE

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$$\begin{aligned}
 & \text{Min } \sum_k \left[ (\beta_0 + \beta_1 k + \beta_2 k^2) \sum_i v_{is}^k \right] - \theta \sum_i \sum_{k < \bar{k}} v_{is}^k - \theta \sum_i \sum_{k > \bar{k}} v_{is}^k \\
 & \text{subject to } \begin{array}{l} \text{Additional cost of the firm due to SWH} \\ \text{Incentive for employees who arrive early} \\ \text{Incentive for employees who arrive late} \end{array} \quad \left. \begin{array}{l} \text{Additional Costs imposed by SWH are compensated by incentive} \\ \text{Route Choice} \\ \text{Departure Time Choice} \\ \text{Flow Conserv.} \end{array} \right\}
 \end{aligned}$$

$$\begin{aligned}
 & 0 \leq u_{as}^{km} \perp \Phi_u(u, \pi, d) = \left\{ \tau_a^k(u) + \sum_{l-1 \leq e_a^{k,l}(u) / \Delta < i} \lambda_a^{3,k,l}(u) \pi_{h_a^s}^{l-1} + [1 - \lambda_a^{3,k,l}(u)] \pi_{h_a^s}^l - \pi_{i_a^s}^k \right\} \geq 0, \forall a, s, k' \\
 & 0 \leq d_{is}^{km} \perp \left( (\pi_{is}^{km} + \phi - \xi(\bar{k}_m - k_0)^2) \right) - \mu_{is}^m \geq 0, \quad \forall k, m, i, s \\
 & 0 \leq \eta - \alpha_1(\bar{k}_m - \sigma - \Pi) \perp \eta - \alpha_2(\Pi - \bar{k}_m - \sigma) \geq 0 \\
 & 0 \leq \phi \perp \phi - \eta \geq 0 \\
 & 0 \leq \mu_{is}^m \perp \sum_k d_{is}^{km} - dd_{is}^m \geq 0 \\
 & 0 \leq \pi_{is}^{km} \perp \Phi_\pi(u, \pi, d) = \left( \sum_{a \in A(i)} u_{as}^{km} - d_{is}^{km} - \sum_{a \in B(i)} v_{as}^{km} \right) \geq 0, \forall i, s, i \neq s, k' \\
 & \sum_i \sum_m dd_{is}^m - Q_{is} = 0
 \end{aligned}$$



## Conclusions

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## Chief conclusion

- ❖ A comprehensive consideration of the interactions between the agents that determine time of travel is extremely important because:
  - ❖ It allows to identify the incentive/pricing structures needed to enact change
  - ❖ It avoids penalizing the dominated agent in the (false) hope that it could change the behavior of dominant player
  - ❖ It leads to business friendly policies

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## Addressing the issues, removes the opposition<sup>38</sup>

- ❖ Sample publications praising the OHD project:
- ❖ Secretary of Transportation:  
<http://fastlane.dot.gov/2010/07/guest-blogger-rita-administrator-peter-appel-nyc-project-uses-offhour-deliveries-to-fight-gridlock.html>
- ❖ Wall Street Journal:  
<http://online.wsj.com/article/SB10001424052748704334604575339292960610492.html>
- ❖ New York City Department of Transportation:  
[http://www.nyc.gov/html/dot/html/pr2010/pr10\\_028.shtml](http://www.nyc.gov/html/dot/html/pr2010/pr10_028.shtml)
- ❖ Journal of Commerce: <http://www.joc.com/trucking/new-york-expand-peak-truck-program>
- ❖ BLOG Coverage
  - ❖ <http://www.crainsnewyork.com/article/20100701/FREE/100709981#>
  - ❖ <http://www.theepochtimes.com/n2/content/view/38422/>
  - ❖ <http://transportationnation.org/2010/07/02/pilot-study-off-hours-deliveries-save-time/>
  - ❖ <http://momandpopnyc.blogspot.com/2010/07/real-gem-from-nycs-sadik.html>

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8 - September 20, 2010 TRANSPORT TOPICS

## Off-Hours Pilot Targets NYC Congestion

(Continued from p. 1)

Off-hours deliveries also produced a "sharp reduction" in parking tickets and fines, which for the eight carriers in the pilot program can exceed \$1,000 a month per truck, according to the analysis.

The off-hours experiment was created by researchers at Rensselaer Polytechnic Institute in Troy, N.Y., which worked with the Office of Freight Mobility.

What we found through the pilot is that the receivers really hold the key to making the whole thing understand why cities such as Chicago and San Francisco are considering complicated congestion pricing plans instead.

The critical element in the New York City pilot was the freight receivers, said John Karnas, a project manager in the Office of Freight Mobility.

Other programs aimed at relieving metropolitan congestion have not lowered traffic counts much, Karnas said. Truck drivers, for example, may like such incentives as lower tolls for off-peak travel, but receivers, not truckers, determine delivery patterns, Karnas said.

In the New York pilot project, participating truckers and receivers got cash incentives ranging from



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COVER 1 (1 of 68) 100%

## Fleets Say They Discovered Time, Cost Bonanza Through New York's Night-Delivery Experiment

By Michele Fuetsch  
Staff Reporter

When Joe Killeen heard that New York City needed participants for its trial off-hours delivery program, he did more than volunteer his Kearny, N.J., trucking firm, New Deal Logistics. Killeen persuaded eight Foot Locker stores he supplies in Manhattan to volunteer, which meant the retail outlets agreed to substitute night deliveries for the daytime shoe shuttles New Deal normally runs under the Hudson River.

"Instead of leaving here at 7 o'clock in the morning and spending an hour and a half trying to get through the Holland Tunnel, [trucks were] on the other side . . . in 25 minutes," Killeen said of the night trips.

For carriers in the pilot program, which lasted from October 2009 through January 2010, the results were dramatic.

Off-hour deliveries improved average travel speeds by as much as 75%, according to the analysis submitted to one of the program's funders, the Research and Innovative Technology Administration, or RITA, of the U.S. Department of Transportation.

Adding to the off-hours benefit, data generated by Global Positioning System devices on the trucks showed that trucks delivering between 7 p.m. and 6 a.m. averaged 30 minutes at a receiver's site, compared with an average of 100 minutes during the day on streets clogged with traffic and lacking space to park.



More than 100,000 truck deliveries, like this one above, are made in New York City every day. A pilot program tested night deliveries.

800 million a year in savings.

Among the important findings in the pilot, said Holguin-Veras, was that carriers running day routes into cities absorb staggering costs for such issues as traffic delays, tolls and parking violations.

Killeen said New Deal Logistics pays \$3,500 to \$4,000 a month in parking fines in New York — after persuading courts to "whittle" down some of those fines.

Another New Jersey trucking firm, New England Motor Freight, paid \$380,000 in fines

helped shape the experiment.

In the end, however, NEMP did not participate. The carrier's biggest New York City receivers, Starbucks Corp., Walgreens and Borders Group Inc., do not take night deliveries, Conery said.

"I'd change my whole operation to a night operation if that was available to me," said Conery, taking off the potential savings in labor, idling and traffic delays, "but the fact is, until the companies buy into it, it doesn't matter what the carriers want to do."

gram began, Killeen said. Abercrombie & Fitch asked him to begin cargo runs five nights a week to resupply its Manhattan stores.

Now that New York's pilot program has ended, the research team focuses on how to create permanent off-hours delivery systems, Holguin-Veras said.

Carriers, receivers or potential funding sources for the program may contact the New York City Office of Freight Mobility at 212-539-6670 or visit the website at [www.nyc.gov/trucks](http://www.nyc.gov/trucks).

10:59 x 11.58 x

we have used CAT Scale and they have done a great job for our company and for our drivers. We need somebody we can trust and that is CAT Scale. Thou have your bark

Thanks

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