

Assessment of tradeoffs among urban delivery vehicles

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Objectives of this research

- ❖ Assess the overall economic performance of different vehicle types used for urban deliveries
 - ❖ Small trucks
 - ❖ Large trucks
- ❖ In terms of:
 - ❖ Contributions to congestion
 - ❖ Environmental impacts



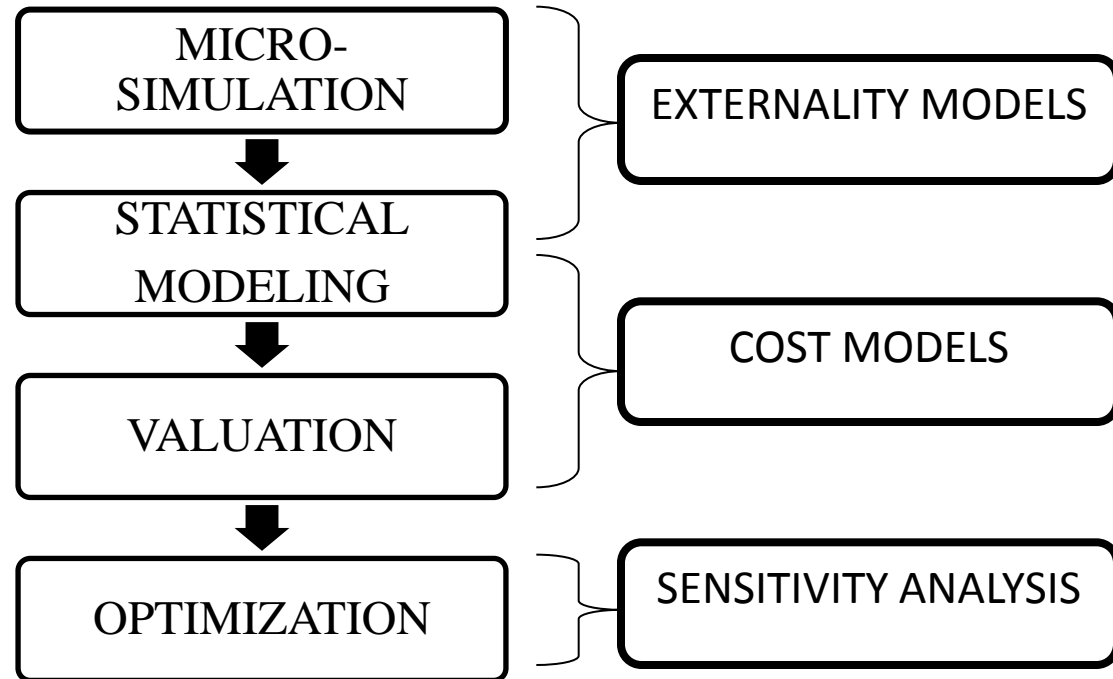
- ❖ In essence, this research aims at finding out what is best for urban areas: Small trucks? or Large trucks?
- ❖ This is an important question for policy makers as it supports the definition of policies and programs to foster the use of the most beneficial vehicle types



- ❖ Holguin-Veras and Cetin (2008) conducted traffic simulations to develop analytical cost functions, used to compute optimal tolls
- ❖ Key insight:
 - ❖ The cost functions developed seemed to indicate that large trucks are more beneficial than small ones
 - ❖ However, since their simulations did not consider urban conditions—as they focused on freeways—no conclusions were made for the urban delivery case



Overall approach



- ❖ Based on the Corridor Management Plan Demonstration conducted by the California Department of Transportation in coordination with the University of Berkeley at California, University of California at Irvine and Systems Metric Group (Madanat and Benuar, 2006; Ban et al., 2007; Ban et al., 2006)
- ❖ It includes a 34 mile urban highway with parallel arterials and cross roads including 143 metered lanes, 157 actuated traffic signals and 25 fixed time signals



- ❖ The calibrated micro-simulation was used to analyze different demand scenarios

Level of Demand	% Cars	% Small Trucks	% Large Trucks
20	100%	0%	0%
40	80%	20%	0%
60	80%	13%	7%
80	80%	7%	13%
100	80%	0%	20%
120	70%	30%	0%
140	70%	20%	10%
160	70%	10%	20%
	70%	0%	30%
	60%	40%	0%
	60%	27%	13%
	60%	13%	27%

- ❖ Performance metrics were collected:
 - ❖ Travel times in the network
 - ❖ Environmental pollutants: NO_x, CO₂, PMs, etc.
- ❖ To facilitate quantitative analyses, these performance metrics were used as dependent variables of regression models
- ❖ The analyses considered:
 - ❖ The entire urban network
 - ❖ The interstate system
 - ❖ Downtown Oakland network



Statistical results: Externality models

		Total Travel Time (seconds)								
Variable	Dependent	Q _C	Q _{ST}	Q _{LT}	Q _C ²	Q _{ST} ²	Q _{LT} ²	Q _C Q _{ST}	Q _C Q _{LT}	Q _{ST} Q _{LT}
Coefficient	t(Q)				6.161E-03			9.666E-03	1.0716E-02	
t-stat					13.35			4.90	5.41	
R ²	0.784									
		Vehicle Miles Traveled (miles)								
Variable	Dependent	Q _C	Q _{ST}	Q _{LT}	Q _C ²	Q _{ST} ²	Q _{LT} ²	Q _C Q _{ST}	Q _C Q _{LT}	Q _{ST} Q _{LT}
Coefficient	V(Q)	10.0178	9.7410	6.2969	-1.996E-05			-3.494E-05		
t-stat										
R ²	0.99	18.22	5.93	10.23	-5.52			-2.29		
		Particulate Matter (mg)								
Variable	Dependent	Q _C	Q _{ST}	Q _{LT}	Q _C ²	Q _{ST} ²	Q _{LT} ²	Q _C Q _{ST}	Q _C Q _{LT}	Q _{ST} Q _{LT}
Coefficient	g _{PM} (Q)	20.401	31.881	39.647	4.481E-05					
t-stat		11.430	25.750	31.680	4.580					
R ²	0.991									
		Volatile Organic Compounds (mg)								
Variable	Dependent	Q _C	Q _{ST}	Q _{LT}	Q _C ²	Q _{ST} ²	Q _{LT} ²	Q _C Q _{ST}	Q _C Q _{LT}	Q _{ST} Q _{LT}
Coefficient	g _{VOC} (Q)				1.3784E-02			2.2609E-02	2.4892E-02	
t-stat					17.95			6.89	7.55	
R ²	0.862									
		Nitrogen Oxide (mg)								
Variable	Dependent	Q _C	Q _{ST}	Q _{LT}	Q _C ²	Q _{ST} ²	Q _{LT} ²	Q _C Q _{ST}	Q _C Q _{LT}	Q _{ST} Q _{LT}
Coefficient	g _{NOX} (Q)	214	1099.4	1490.65	4.0175E-03					
t-stat		2.07	15.37	20.61	7.1					
R ²	0.973									
		Carbon Monoxide (mg)								
Variable	Dependent	Q _C	Q _{ST}	Q _{LT}	Q _C ²	Q _{ST} ²	Q _{LT} ²	Q _C Q _{ST}	Q _C Q _{LT}	Q _{ST} Q _{LT}
Coefficient	g _{CO2} (Q)	123913027	14626	15332	7.8012E-02					
t-stat		3.62	12.4	13.0	32.3					
R ²	0.938									



$$\frac{\partial Q_{ST}}{\partial Q_{LT}} = \frac{\frac{\partial f(Q)}{\partial Q_{LT}}}{\frac{\partial f(Q)}{\partial Q_{ST}}}$$

This measures the tradeoff between small and large trucks, $f(Q)$ is the externality function being considered

Tradeoff Ratios (entire urban area)

Externality Model	$\partial Q_{ST} / \partial Q_{LT}$
Total Travel Time	1.11
Vehicle Miles Traveled	$1/(1.550 - 6.35E-5Q_C)$
Particulate Matter	1.24
Volatile Organic Compounds	1.01
Nitrogen Oxide	1.36
Carbon Monoxide	1.05

In essence, a large truck produces between 1.11 to 1.36 more externalities than a small truck

From externality models → Cost functions

❖ Valuation estimates from the literature were used to convert the externality models into cost functions:

❖ It included time costs, environmental costs, and pavement damage

Pollutant	Low Values (\$)	Medium Values (\$)	High Values (\$)
VOC	0.16	0.99	1.81
CO ₂	0.02	0.08	0.14
NO _x	1.84	14.50	27.15
PM	15.31	112.69	210.06

Vehicle	Low Values (\$)	Medium Values (\$)	High Values (\$)
Car	7	20	50
Small Truck	20	35	65
Large Truck	29	55	120



Optimization formulation

- ❖ While it is true that a large truck does produce more externalities than a small one, such analysis does not take into account that a large truck does carry more cargo
- ❖ This formulation obtains the optimal truck type to transport a set amount of cargo K :

$$C^* = C^C(\mathbf{Q}) + C^{PM}(\mathbf{Q}) + C^{VOC}(\mathbf{Q}) + C^{CO_2}(\mathbf{Q}) + C^{NOX}(\mathbf{Q}) + C^{Pav}(\mathbf{Q})$$

Subject to:

$$\sum_{i=2}^3 \rho_i Q_i \geq K$$

$$Q_i \geq 0$$

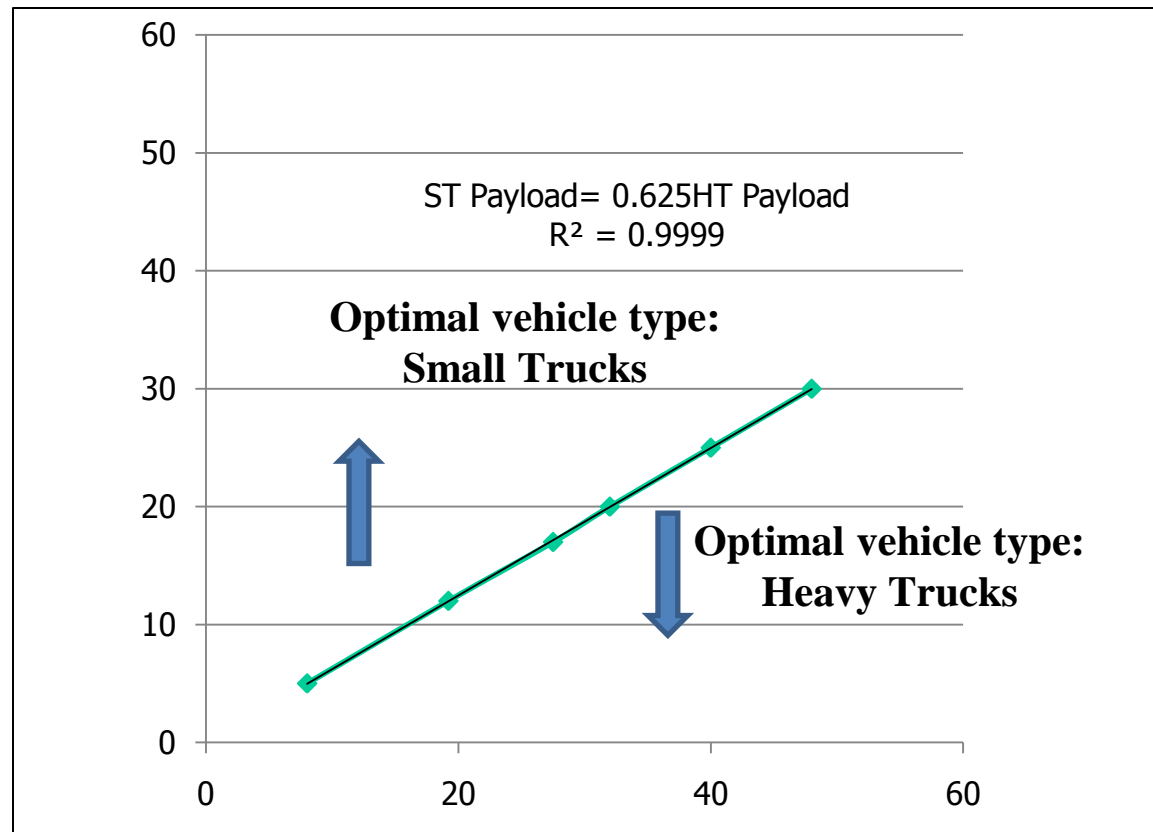
ρ is the average payload for small and large trucks (from the VIUS) (about 6 and 20 tons, respectively)

A lot of sensitivity analyses were conducted...

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❖ Chief finding:

- ❖ For small trucks to be optimal, their average payload must be larger than 62.5% of the one for large trucks
- ❖ Otherwise, large trucks are the most beneficial



- ❖ Since the payloads for small trucks are not likely to reach 62.5% of the ones for large trucks (according to the VIUS are about 30%)
 - ❖ The unavoidable conclusion is that the use of large trucks must be fostered
 - ❖ Once the amount of cargo is taken into account, the small trucks are found to be the most detrimental in terms of externalities (because they generate significantly more truck traffic)



- ❖ Although the findings are expected to hold, some limitations must be acknowledged:
 - ❖ Only two truck types were considered
 - ❖ It was assumed that the truck types were interchangeable and that no major changes would be required in the route structure (using larger trucks may necessitate changing in routes that may increase the externalities produced)



Reactions?

