Road Pricing in Urban HazMat Transportation: A Practical Assessment

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Why do we ned to move Hazmat?

- Hazmat include: explosives, flammable, oxidant, poisonous, infectious, radioactive, or corrosive substances among others
- Industrial production processes use hazmat as manufacturing components and often generate hazmat by-products.
- Hazmat must be safely transported from their origin to special facilities to be used in a production process, modified to decrease their degree of danger, or properly disposed.

Why is it such a big deal?

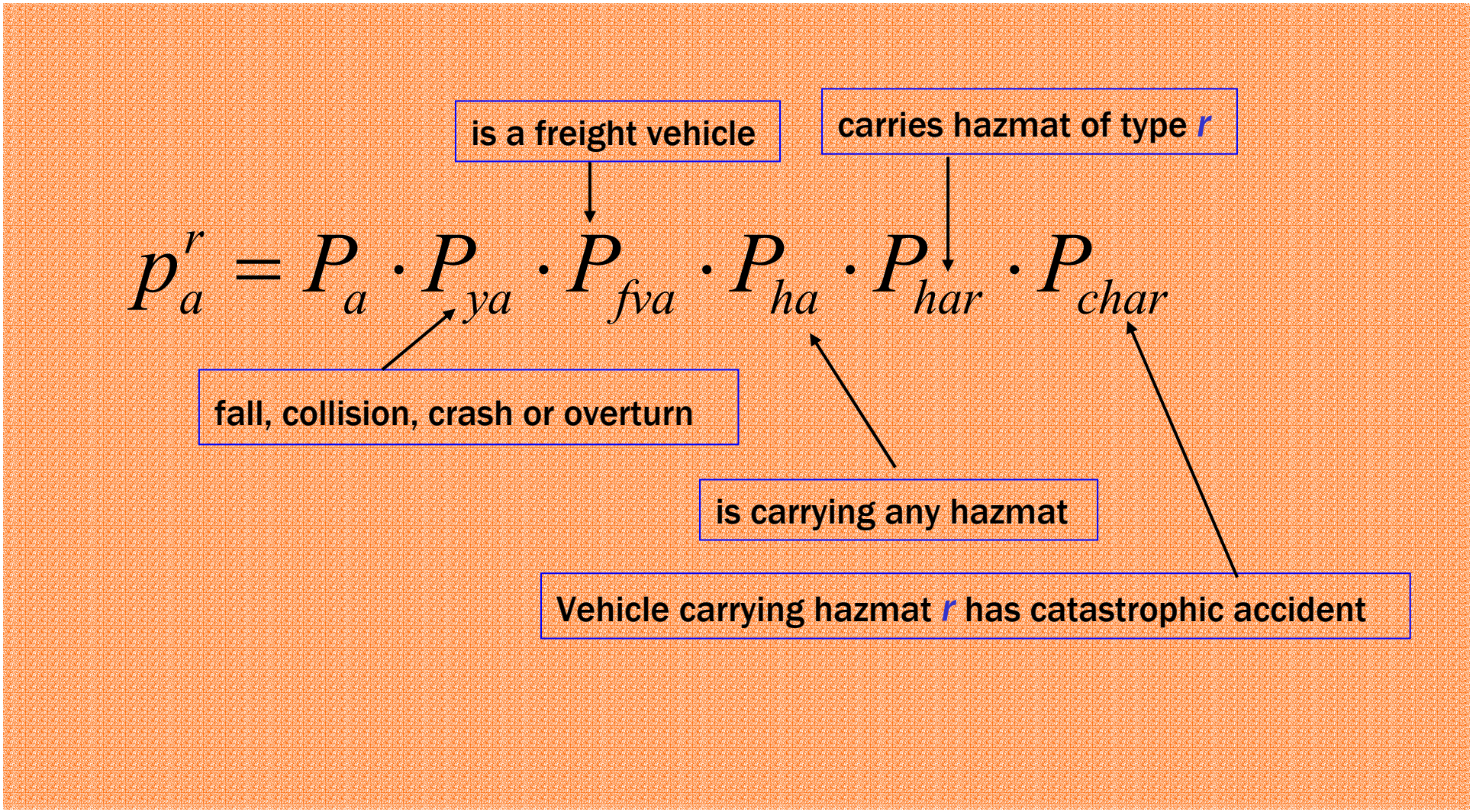
- Enormous social relevance!
- Moving hazmat through populated areas poses a threat to the human health and the environment.
- In spite of the continuous efforts to mitigate harmful effects accidents do occur causing deaths, injuries and losses.
- These effects can be measured in monetary value
- But... these effects are probabilistic in nature

The probability of an accident

- Identify and evaluate scenarios for the occurrence of an incident involving hazmat
- Scenarios can be described as a sequence of events. The events can be represented in a tree structure, showing a sequential progression of branched options: **event tree**

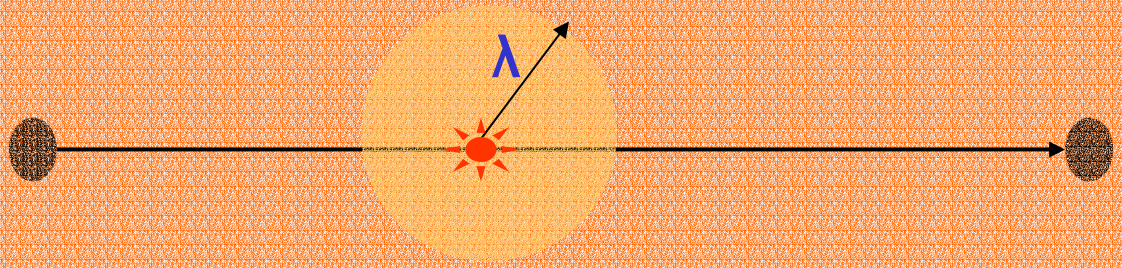
$$p_a^r = P_a \cdot P_{ya} \cdot P_{fva} \cdot P_{ha} \cdot P_{har} \cdot P_{char}$$

Outcome of the event tree:
Prob of a catastrophic accident in arc *a*



What is the consequence of such an accident?

- Measured in terms of its potential to provoke fatalities or injuries to the inhabitants in the vicinity of the event
- Impact area: defined by a dispersion radius λ that depends on physical and chemical properties of relieved substance



Valuating the damages:

Afected population: $AP_a^r = (Psi^r + Pmi^r + Pde^r) \cdot \pi \lambda_r^2 \cdot \delta_a$

Cost at arc ***a*** due to hazmat ***r*** : $c_a^r = \dfrac{AP_a^r \cdot Cost^r}{PA^r}$

Finally, substituting:

$$C_a^r = \frac{(Psi^r + Pmi^r + Pde^r) \cdot \pi \lambda_r^2 \cdot \delta_a \cdot Cost^r}{PA^r}$$

Marginal Cost of Transporting Hazmat

Expected social cost generated by a volume *V* of traffic with hazmat **r** through the arc **a**:

$$SC_a^r = p_a^r \cdot c_a^r \cdot V_a^r$$

Marginal cost of each shipment of hazmat **r** through the arc **a**

$$mgc_a^r = \frac{\partial SC_a^r}{\partial V_a^r} = p_a^r \cdot c_a^r$$

Application: Hazwaste in Santiago Chile

- Santiago is the capital city with about 6 million people and 34 boroughs.
- The main transportation network has 5,790 arcs and 2,030 nodes.
- The National Institute of Statistics keeps records of accidents at the arc level.
- The population density surrounding each arc was available from the Bureau of Census.

- The length of each arc and the borough to which it belongs was obtained from official digital maps
- Four types of industrial solid were considered, and each one was characterized by its level of danger according to international risk classifications
- All the hazwaste types were loaded/unloaded and carried using the same technology, hence only one type of vehicle was considered.

Santiago's Hazwaste Case:
Estimation of Accident Probabilities

- **Summary of estimated conditional probabilities at network level**

		Type of Hazmat (r)	P_{hr}	P_{chr}	p_a^r
P_y =	0,880	1	0,454	0,191	1,40E-05
Pfv =	0,168	2	0,854	0,108	1,50E-05
P_h =	0,001	3	0,073	0,019	2,30E-07
		4	0,480	0,047	3,80E-06

Santiago's Hazwaste Case:
Estimation of the Consequences

- To assess the value of the consequences of a catastrophic accident, we need to determine the impact area.
- No relevant information was available in Chile for this purpose. Therefore, the values were approximated adapting data from the United States' DOT
- The methodology consisted, in identifying the borough to which each arc belonged to and assigning it its population density
- If an arc belonged to more than one borough, its density was computed as a weighted average

Santiago's Hazwaste Case:
Estimation of the Consequences

Impact area for each category of hazmat

Type of hazmat	Dispersion Radius	Impact Area
1	1.2 km	4.52 km2
2	1.9 km	11.34 km2
3	0.8 km	2.01 km2
4	1.9 km	11.34 km2

Santiago's Hazwaste Case:
Estimation of the Consequences

Summary of registered accidents by type of hazmat between years 1993-1999

Type of Hazmat	# of Accidents	Catastrophic Accidents
1	8,588	148
2	16,137	363
3	1,376	26
4	9,074	247

Marginal cost associated to each hazmat in US$

Borough	Hazmat 1	Hazmat 2	Hazmat 3	Hazmat 4
Cerrillos	42,0	56,9	0,8	16,1
Cerro Navia	173,6	234,0	3,5	66,1
Conchalí	162,4	219,0	3,2	61,9
Est. Central	112,0	151,5	2,2	42,9
Huechuraba	16,9	22,8	0,3	6,5
Independenc	113,0	153,0	2,3	43,3
La Cisterna	106,5	144,0	2,1	40,7
La Florida	67,5	91,4	1,4	25,8
La Granja	170,8	229,5	3,4	65,0
La Pintana	89,2	120,5	1,8	34,1
La Reina	49,3	66,6	1,0	18,8
Lo Prado	198,8	268,5	4,0	76,0
Macul	116,2	157,5	2,3	44,5
Maipú	30,2	41,0	0,6	11,6
Ñuñoa	122,1	165,0	2,4	46,7
Peñalolén	43,0	58,2	0,9	16,5
Providencia	87,4	118,1	1,8	33,4
Pudahuel	9,5	12,9	0,2	3,6
Puente Alto	50,3	68,0	1,0	19,2
Quilicura	10,9	14,7	0,2	4,1
Qta Normal	100,7	136,1	2,0	38,4
Recoleta	126,0	171,0	2,5	48,3
Renca	76,0	102,8	1,5	29,0
San Bdo	17,9	24,2	0,4	6,8
San Joaquín	123,9	168,0	2,5	47,5
San Miguel	95,3	129,0	1,9	36,5
Santiago	117,6	159,0	2,4	44,8