A short discussion about travel demand models

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Travel demand

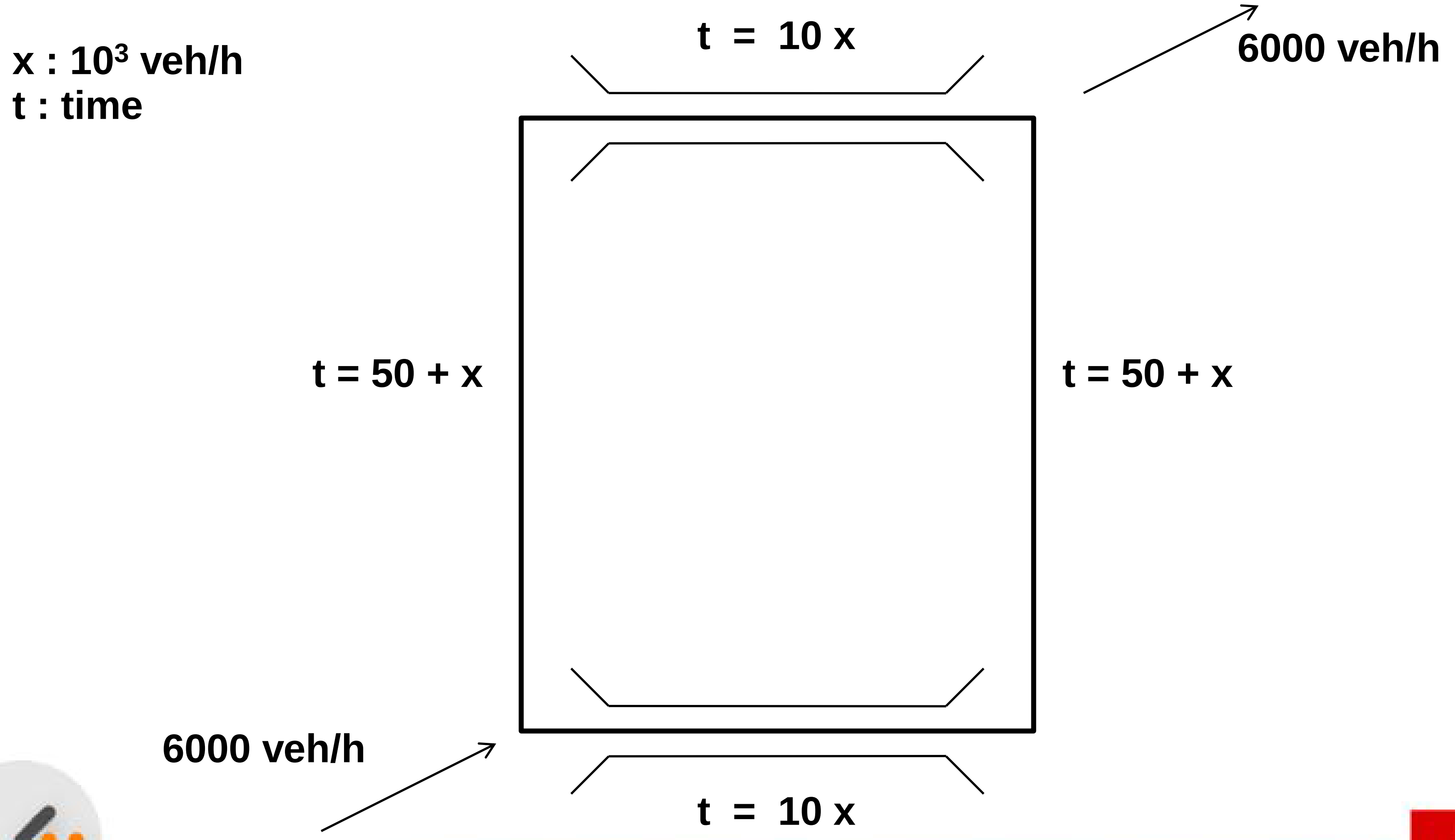
- Most people don't travel for the sake of it
- Travel demand = derived demand
- Results of many choices:
  - Choice of activity
  - Choice of destination
  - Choice of departure time
  - Choice of transportation mode
  - Choice of access point (parking, bus stop)
  - Choice of itinerary
  - Etc…

Route choice for car drivers

Route choice for car drivers

- Assumption #1: drivers prefer the fastest route
- Warning:
  - Their presence affects the other drivers
  - More cars = increased travel time
- So...
  - Travel time influences route choice
  - Route choice influences travel time

A simple example

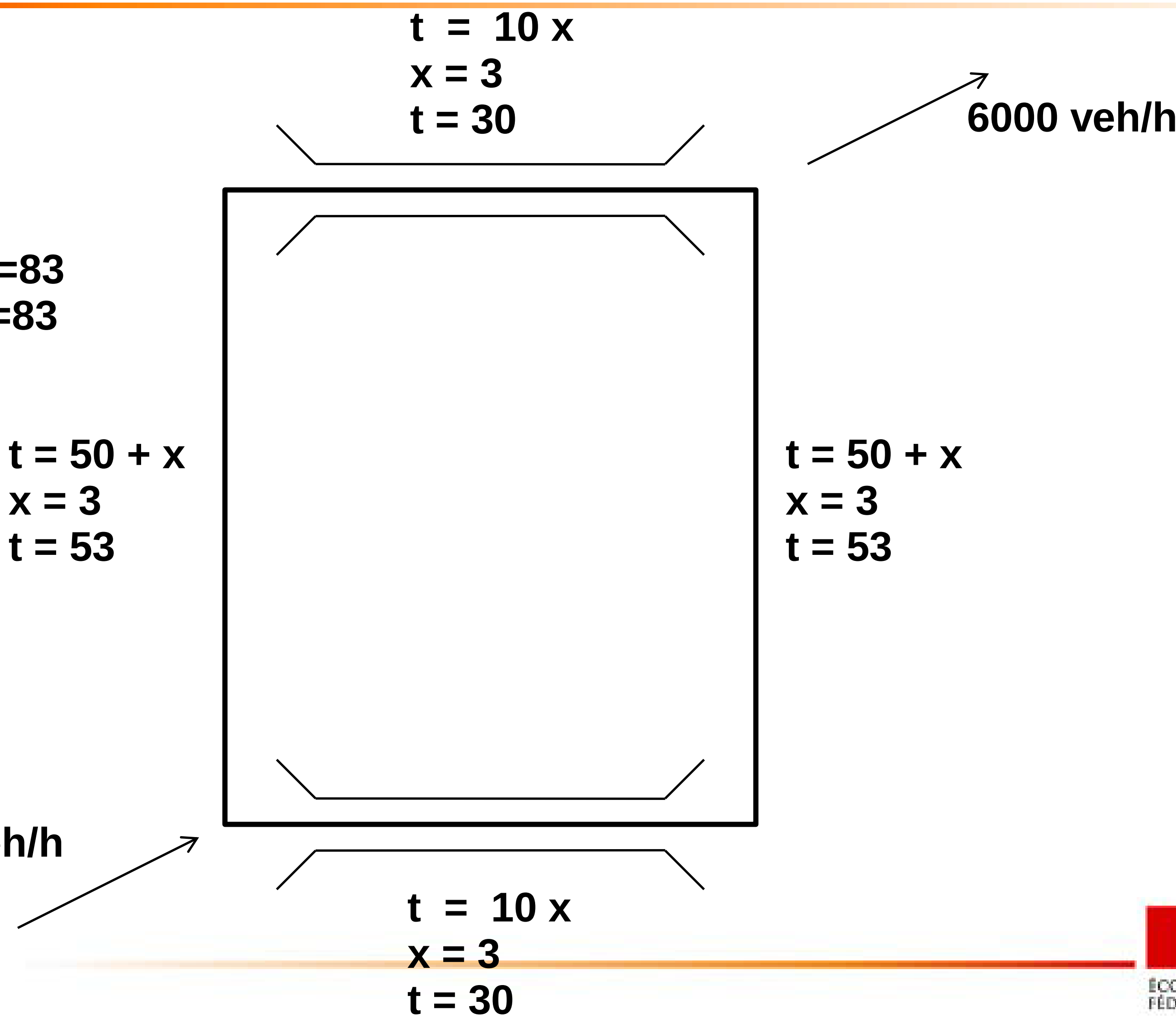


A simple example

x : 10^3 veh/h
t : time

Left-top: t=83
Bottom-right: t=83

Equilibrium



A simple example

x : 10^3 veh/h
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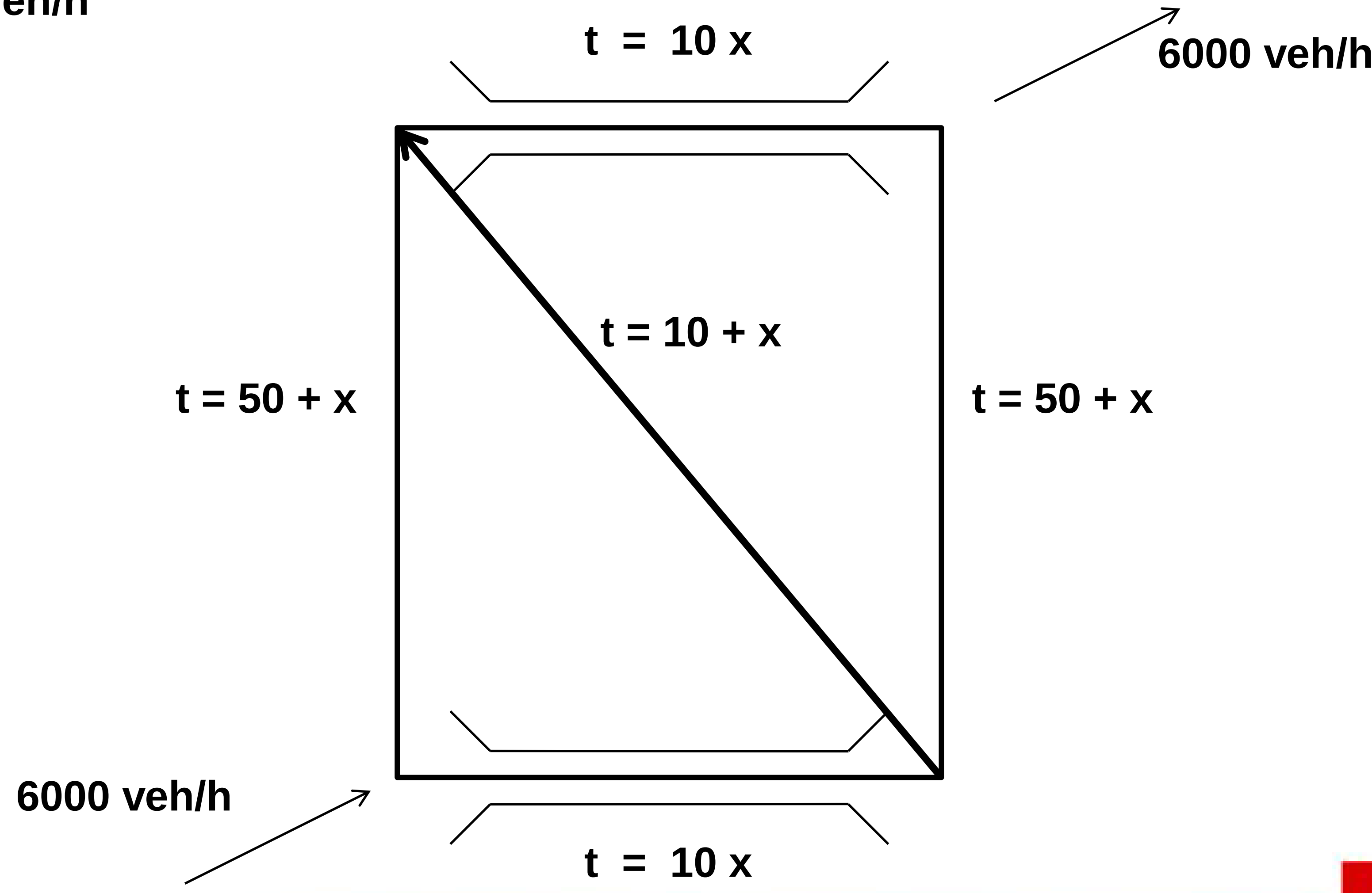

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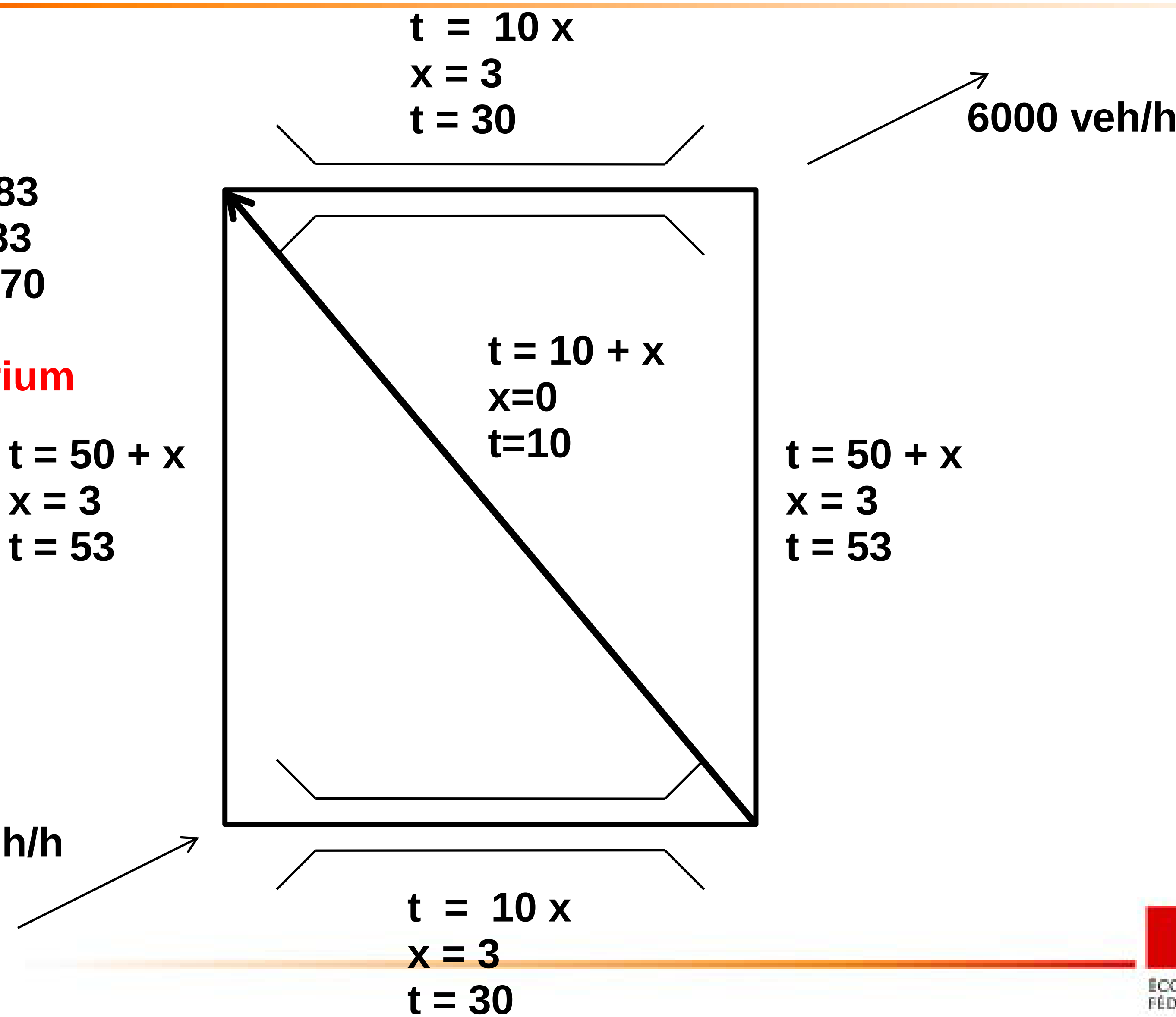
A simple example

x : 10^3 veh/h
t : time

Left-top: t=83
Bottom-right: t=83
New path: t=70

No more equilibrium

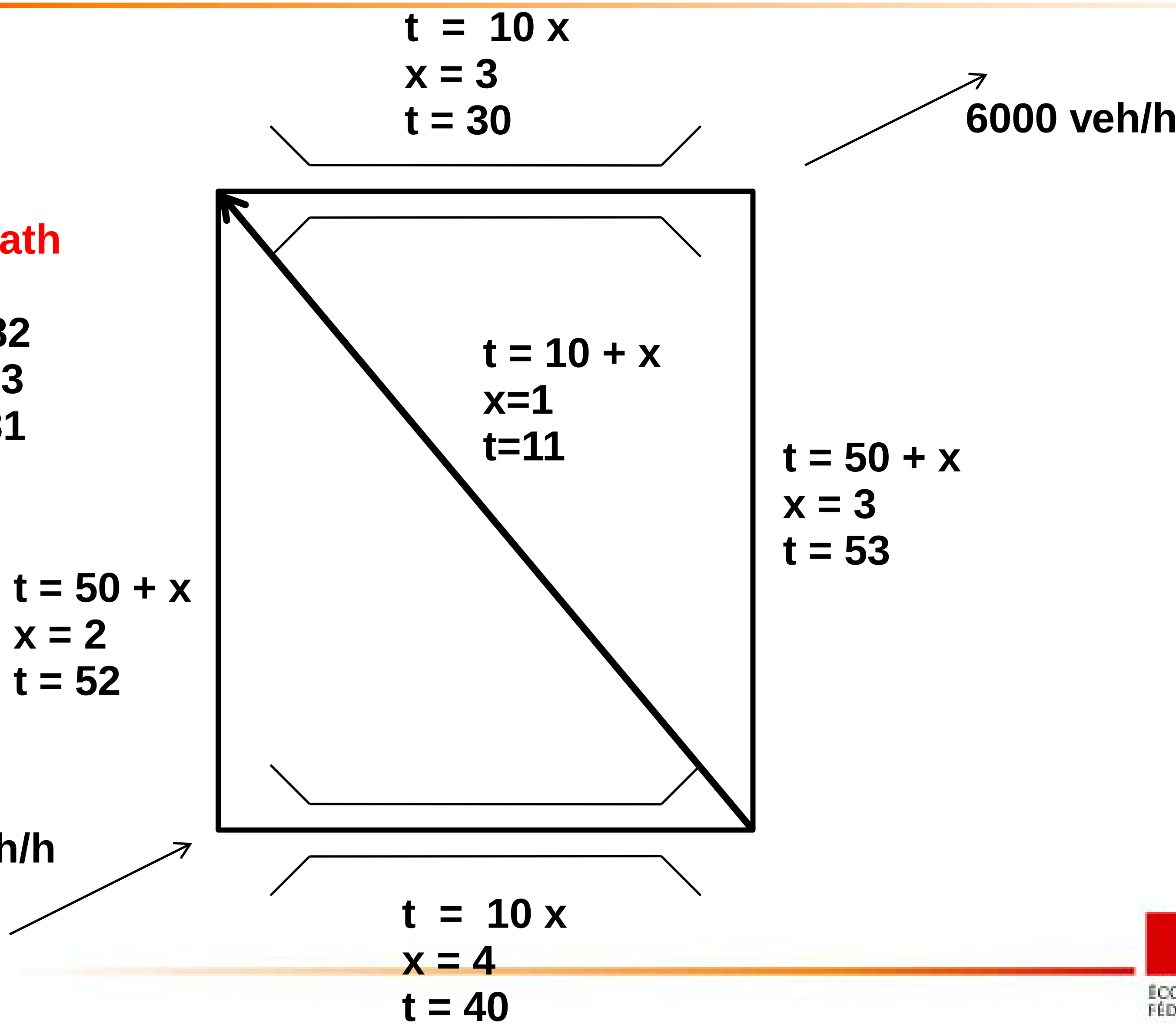


A simple example

x : 10^3 veh/h
t : time

1000 veh change
Left-top → new path

Left-top: t=82
Bottom-right: t=93
New path: t=81



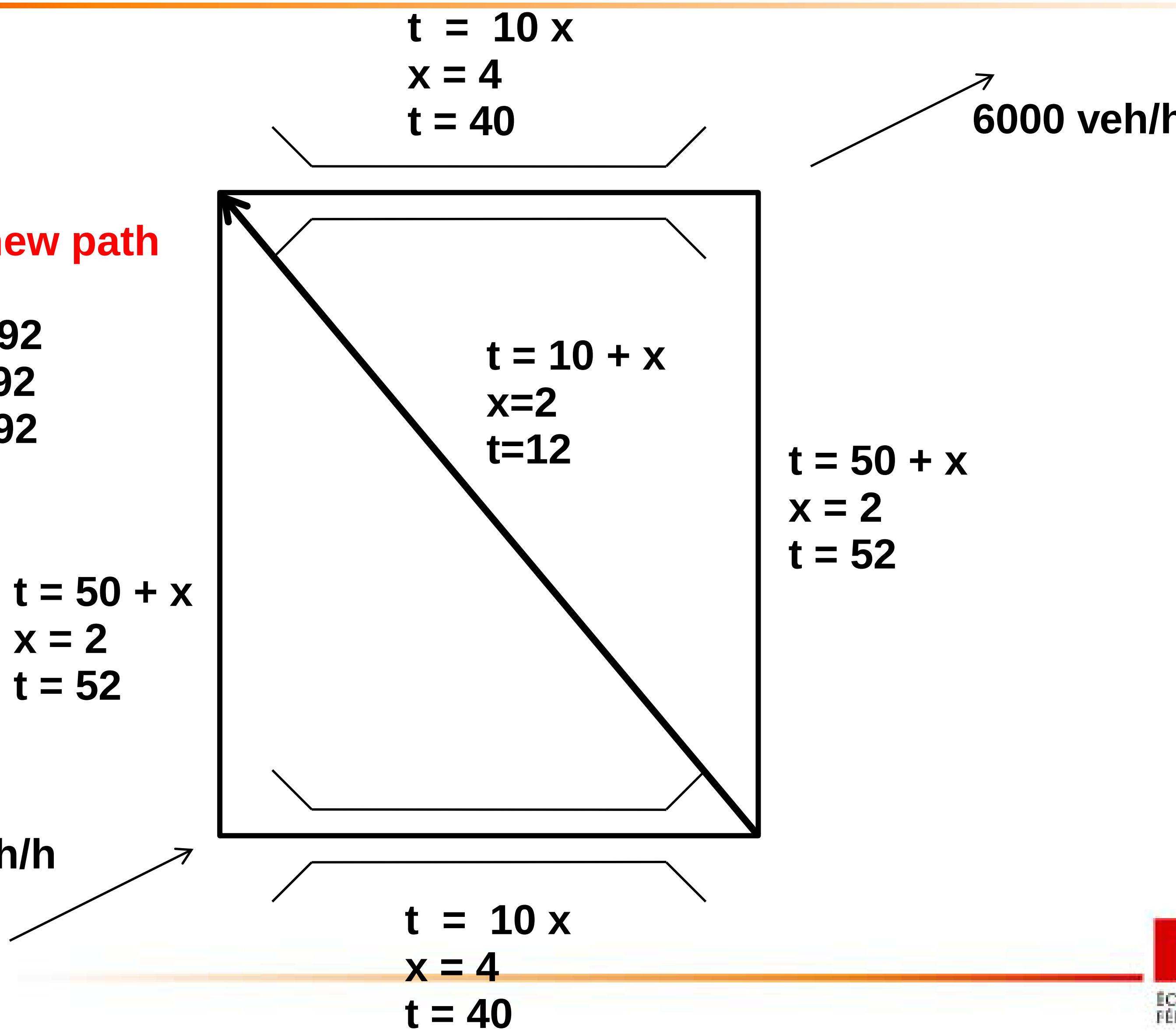
A simple example

x : 10^3 veh/h
t : time

1000 veh change
Bottom-right → new path

Left-top: t=92
Bottom-right: t=92
New path: t=92

Equilibrium



A simple example

- A new infrastructure is built
- Before, travel time = 83 minutes
- After, travel time = 92 minutes

Increasing the physical capacity of the network does not necessarily increase the mobility

- Braess' paradox

Polluters pay principle

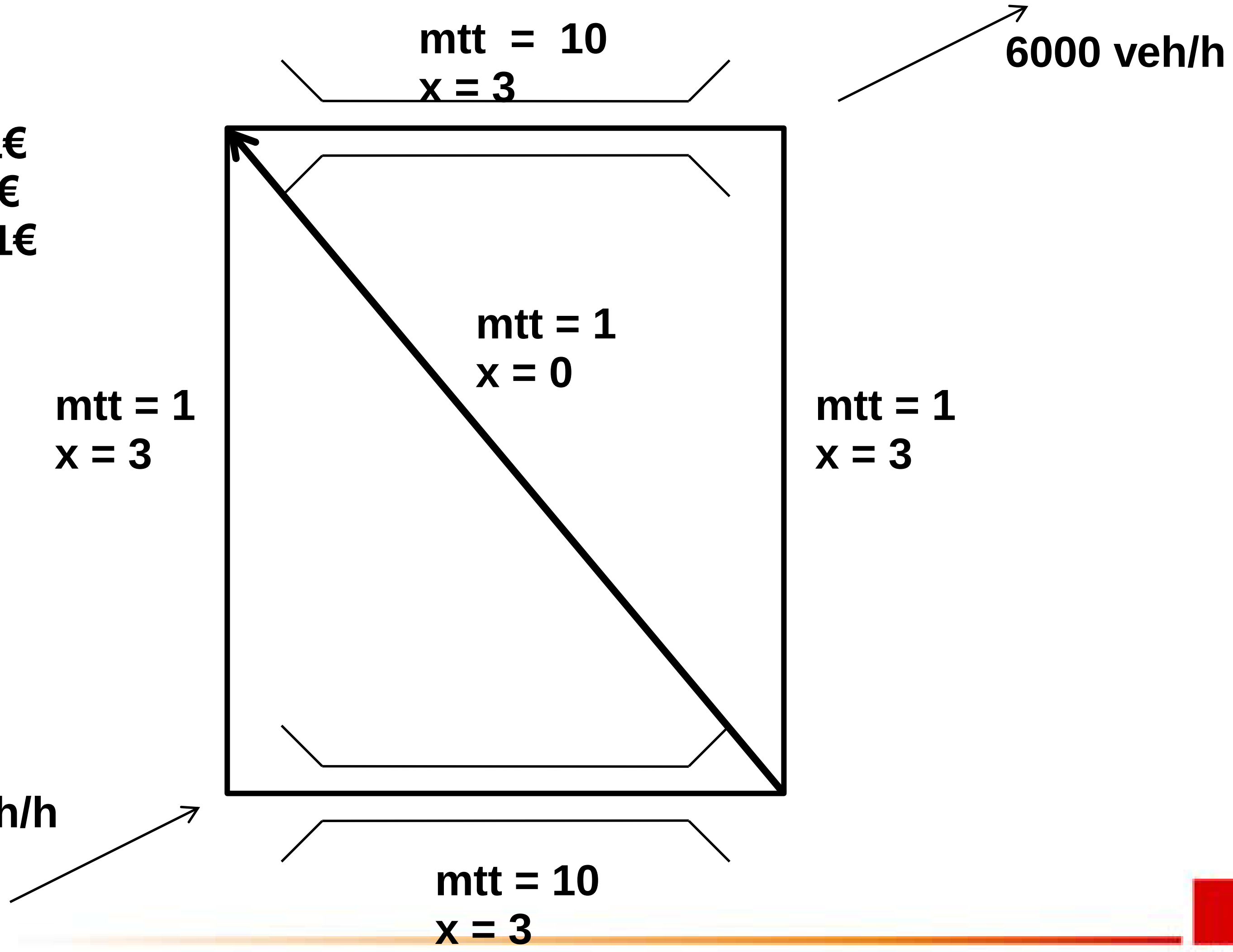
- Concept of marginal travel time
  $t = 50 + x$ Marginal ttime = 1
  $t = 10 + x$ Marginal ttime = 1
  $t = 10\,x$ Marginal ttime = 10
- Drivers are tolled proportionally to the nuisance they produce
- 1 min marginal travel time = 1€
- Assumption #2: drivers prefer the cheapest route

Back to the simple example

x : 10^3 veh/h
t : time

Left-top: 11€
Bottom-right: 11€
New path: 21€

Equilibrium



Behavioral assumption?

- Do people minimize time?
- Do people minimize cost?
- Each assumption gives different results
- Behavior is more complex…

Time is money

- Path 1: 11€ - 83 minutes
- Path 2: 11€ - 83 minutes
- Path 3: 21€ - 70 minutes

- Would you be willing to pay 10€ to save 13 minutes ?
- Assumption #3: drivers consider **both** time and cost
- But how do we identify the best path then?

Random utility models

- Idea : drivers combine cost and time into a number called "utility"
- The selected route is the one with the largest utility.
- Example with two routes:

$$
\begin{aligned}
U_1 &= -\beta t_1 - \gamma c_1 \\
U_2 &= -\beta t_2 - \gamma c_2
\end{aligned}
$$

- $\beta, \gamma > 0$

Random utility models

$$U_1 = -\beta t_1 - \gamma c_1$$
$$U_2 = -\beta t_2 - \gamma c_2$$

- $U_1 > U_2$ if $-\beta t_1 - \gamma c_1 \geq -\beta t_2 - \gamma c_2$

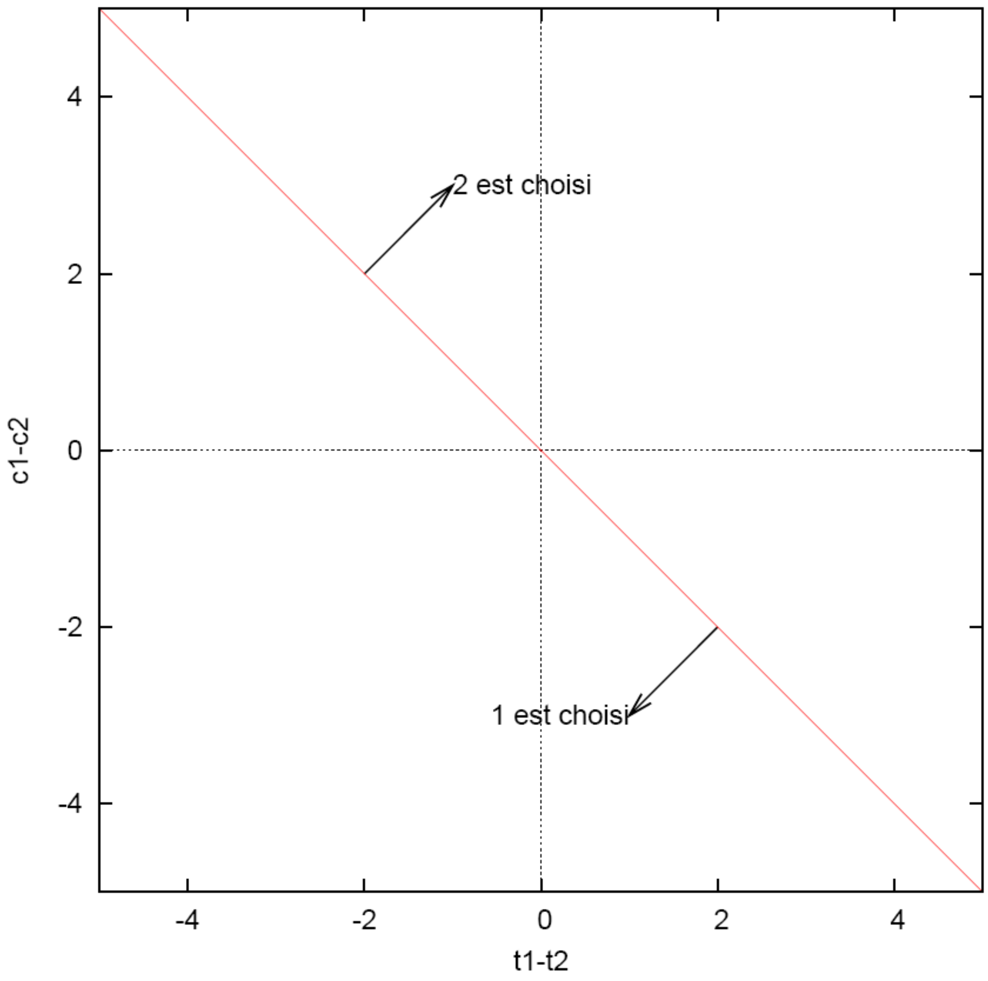
$$-\frac{\beta}{\gamma} t_1 - c_1 \geq -\frac{\beta}{\gamma} t_2 - c_2$$

$$c_1 - c_2 \leq -\frac{\beta}{\gamma}(t_1 - t_2)$$

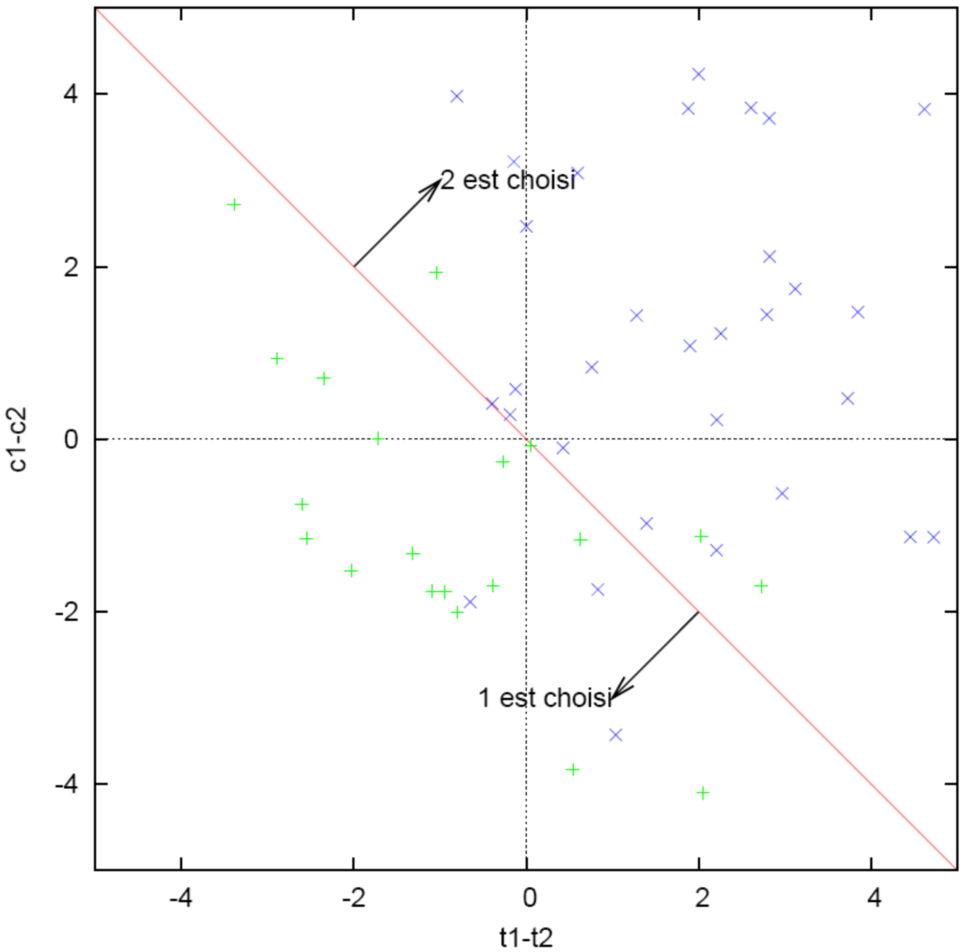
Random utility models

- Dominated cases:
- $c_1 > c_2$ and $t_1 > t_2$: 2 is dominating 1
- $c_2 > c_1$ and $t_2 > t_1$: 1 is dominating 2
- What about the trade-offs for non-dominated cases?

Random utility models



Random utility models



Random utility models

- Need for a random term
- Now, probability must be used

$$
\begin{aligned}
U_1 &= -\beta t_1 - \gamma c_1 + \varepsilon_1 \\
U_2 &= -\beta t_2 - \gamma c_2 + \varepsilon_2
\end{aligned}
$$

- $P(1) = P(U_1 > U_2)$
- Most famous model : the multinomial logit model

Multinomial logit model

$$U_{in} = V_{in} + \varepsilon_{in} = \beta_1 x_{in1} + \beta_2 x_{in2} + \ldots + \varepsilon_{in}$$

- where x include time, cost, number of speed bumps, number of left turns, type of routes, etc.
- $$P_n(i|\mathcal{C}_n) = \Pr(U_{in} \geq U_{jn} \ \forall j \in \mathcal{C}_n)$$

$$P_n(i|\mathcal{C}_n) = \frac{e^{V_{in}}}{\sum_{j \in \mathcal{C}_n} e^{V_{jn}}}$$

Value of time in Switzerland

- We can measure the willingness to pay for travel time savings

- Axhausen, K., Hess, S., Koenig, A., Abay, G., Bates, J., and Bierlaire, M. (to appear). Income and distance elasticities of values of travel time savings: new Swiss results, *Transport Policy*

	Trip purpose			
WTP at sample mean	Business	Commuting	Leisure	Shopping
PT travel time (CHF/hour)	49.57	27.81	21.84	17.73
Car travel time (CHF/hour)	50.23	30.64	29.2	24.32
Headway red.(CHF/hour)	14.88	11.18	13.38	8.48
Interchange red. (CHF/change)	7.85	4.89	7.32	3.52

Value of time in Switzerland

WTP at sample mean	Business	Commuting	Leisure	Shopping
PT Travel time (€/h)	30.2	17.0	13.3	10.8
Car travel time (€/h)	30.6	18.7	17.8	14.8
Headway red. (€/h)	9.1	6.8	8.2	5.2
Interchange red. (€/change)	4.8	3.0	4.5	2.1

Optimal pricing

- Price = z, Population = N
- Choice model:

  P(choosing the train ¦ z)
- Number of people choosing the train:

  N P(choosing the train ¦ z)
- Revenues:

  R(z) = N P(choosing the train ¦ z) z
- Optimal pricing:

  $\mathrm{Max}_z\ R(z)$

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Recent developments in route choice

Route choice modeling difficult because

- Large number of alternatives
- High structural correlation due to the physical overlap of paths
- Difficulty to collect data (reports, GPS)

Solutions we have proposed

- Sampling of alternatives
- Concept of subnetworks
- Measurement equations

Summary

- Travel demand is complex
- Simple assumptions are useful but not sufficient
- Need to analyze the situation as a whole (beware of the Braess paradox)
- Observing and measuring behavior is critical (ex: willingness to pay)
- Random utility models are at the core of disaggregate demand modeling
- Hot topic: route choice models