Transportation networks

Modeling assumptions

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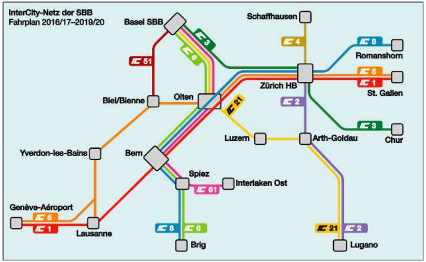
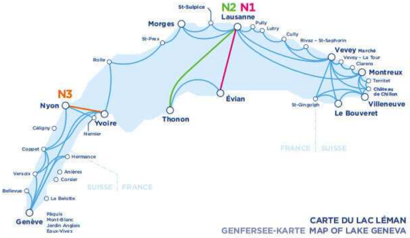
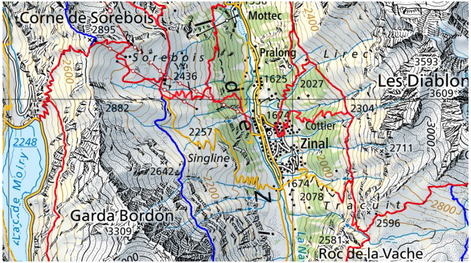
Introduction to transportation systems

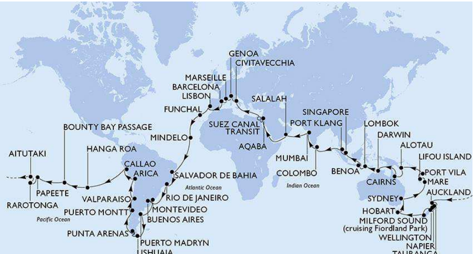
Transportation networks: supply



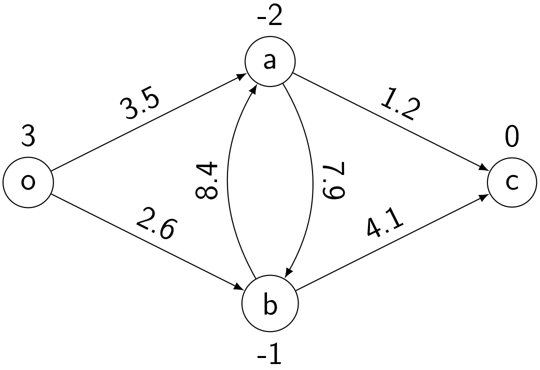


Transportation networks: supply





Network: mathematical model



Networks

- Nodes: $\mathcal{N}$
- Arcs: $\mathcal{A}$
- Incidence function

$$\phi : \mathcal{A} \to \mathcal{N} \times \mathcal{N}$$

- Quantities on nodes
- Quantities on arcs

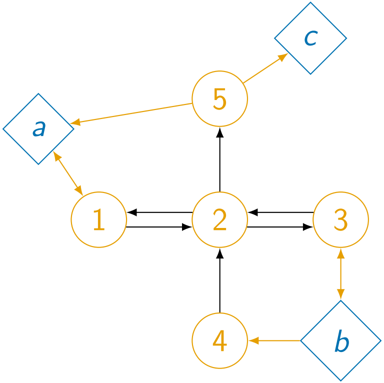
Road networks

Nodes

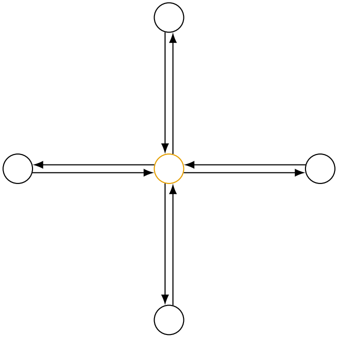
- Geo-coded.
- Centroids: associated with geographical zones.
- Intersections.
- Merging points, capacity changes.

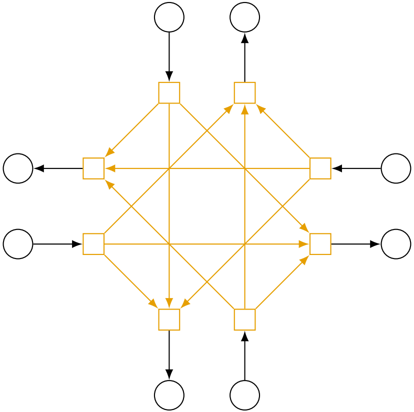
Links

- Centroid connectors.
- Homogenous segments of road.

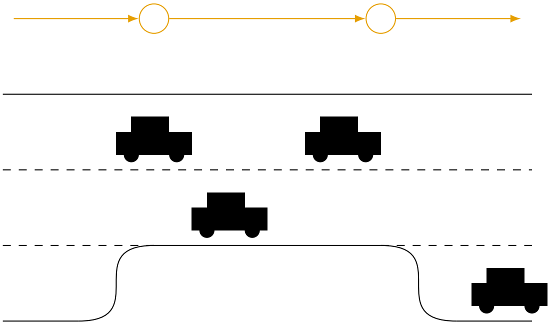


Road networks: intersections





Road networks: capacity changes



Road networks: data

Nodes

- Demand: in-flow, out-flow

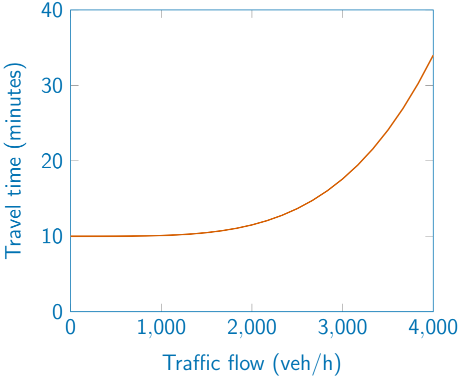
Links

- Flow, capacity (veh/min).
- Travel time, free-flow travel time (min).
- Travel cost, toll (CHF, €).
- Density, jam density (veh/km).

Link performance functions

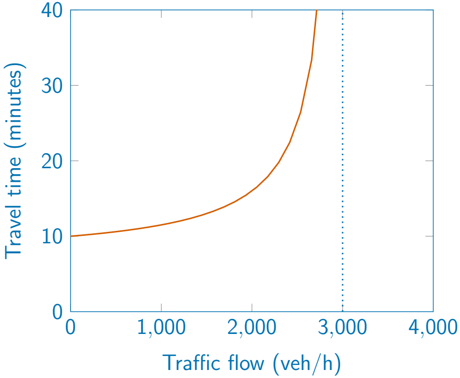
Without upper limit

$$t(x) = t_0 \left(1 + \alpha \left(\frac{x}{\ell}\right)^{\beta}\right)$$



With upper limit

$$t(x) = t_0 \left(1 + \alpha \left(\frac{x}{\ell - x}\right)\right)$$



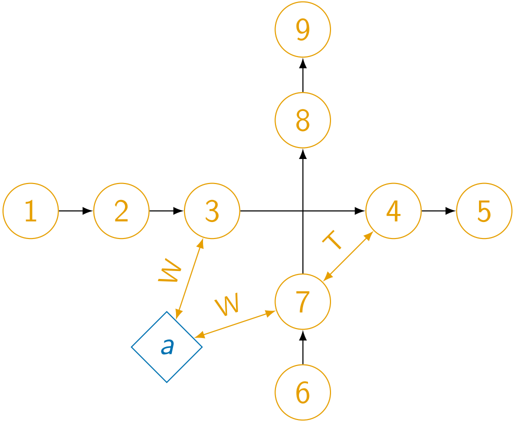
Public transportation

Nodes

- Geo-coded.
- Centroids: associated with geographical zones.
- Stations / stops.

Links

- Line segments.
- Walking, waiting [W].
- Transfer [T].



Public transportation: data

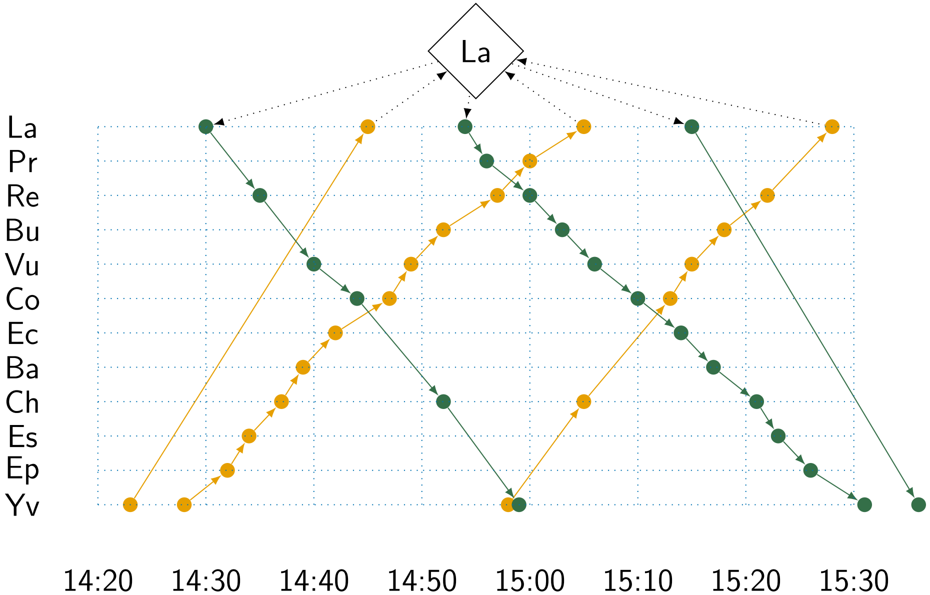
Nodes

- Demand: in-flow, out-flow

Links

- Frequency (veh/hour), headway (min).
- Travel time (min).
- Walking time (min).
- Waiting time (min).
- Transfer time (min).
- Capacity (number of seats).

Scheduled public transportation



Scheduled public transportation

Nodes

- Space and time.
- Centroids.
- Time-table.

Links

- Line segments.
- Walking, waiting.
- Transfer.
- Departure time choice.

Scheduled public transportation: data

Nodes

- Demand: in-flow, out-flow

Links

- Travel time (min).
- Walking time (min).
- Waiting time (min).
- Transfer time (min).
- Capacity (number of seats).

Pedestrians

Difficulties

- Level of granularity (door-to-door).
- No physical network, lane, etc.
- Strong interactions with other modes (feeding mode)

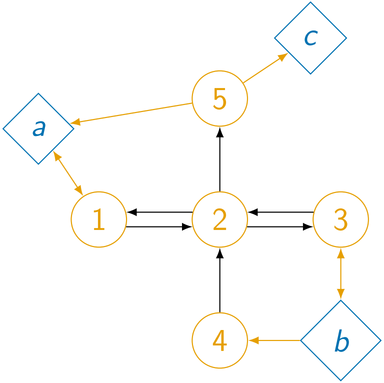
Multi-modal networks

Difficulties

- Superposition of networks for each mode.
- All possible transfers: parkings, stations, airports, etc.

Paths

- $a \to 1 \to 2 \to 3 \to b$
- $a \to 1 \to 2 \to 5 \to c$
- $b \to 3 \to 2 \to 5 \to a$
- $b \to 3 \to 2 \to 1 \to a$
- $b \to 4 \to 2 \to 5 \to a$
- $b \to 4 \to 2 \to 1 \to a$
- $b \to 3 \to 2 \to 5 \to c$
- $b \to 4 \to 2 \to 5 \to c$

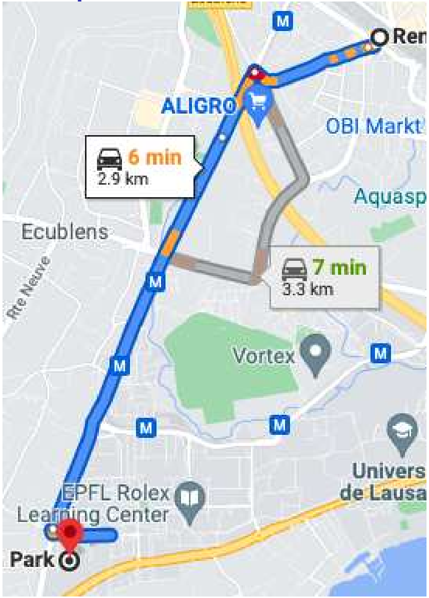


Link-path incidence matrix

1. $a \to 1 \to 2 \to 3 \to b$
2. $a \to 1 \to 2 \to 5 \to c$
3. $b \to 3 \to 2 \to 5 \to a$
4. $b \to 3 \to 2 \to 1 \to a$
5. $b \to 4 \to 2 \to 5 \to a$
6. $b \to 4 \to 2 \to 1 \to a$
7. $b \to 3 \to 2 \to 5 \to c$
8. $b \to 4 \to 2 \to 5 \to c$

	1	2	3	4	5	6	7	8
$(a, 1)$	1	1	0	0	0	0	0	0
$(b, 3)$	0	0	1	1	0	0	1	0
$(b, 4)$	0	0	0	0	1	1	0	1
$(1, a)$	0	0	0	1	0	1	0	0
$(1, 2)$	1	1	0	0	0	0	0	0
$(2, 1)$	0	0	0	1	0	1	0	0
$(2, 3)$	1	0	0	0	0	0	0	0
$(2, 5)$	0	1	1	0	1	0	1	1
$(3, b)$	1	0	0	0	0	0	0	0
$(3, 2)$	0	0	1	1	0	0	1	0
$(4, 2)$	0	0	0	0	1	1	0	1
$(5, a)$	0	0	1	0	1	0	0	0
$(5, c)$	0	1	0	0	0	0	1	1

Path performance



Main assumption

Must be link additive

Examples

- Travel time.
- Distance.
- Travel cost.
- Generalized costs.

Counter-examples

- Speed.
- Flow.

Summary

Networks

- Transportation supply.
- Interface with the demand.

Network models

- Nodes and links.
- Data.

Complexity

- Must be consistent with the needs.
- Too simple: useless.
- Too complex: intractable