Algorithms for Auto and Transit Route Choice

Potentials and Limitations

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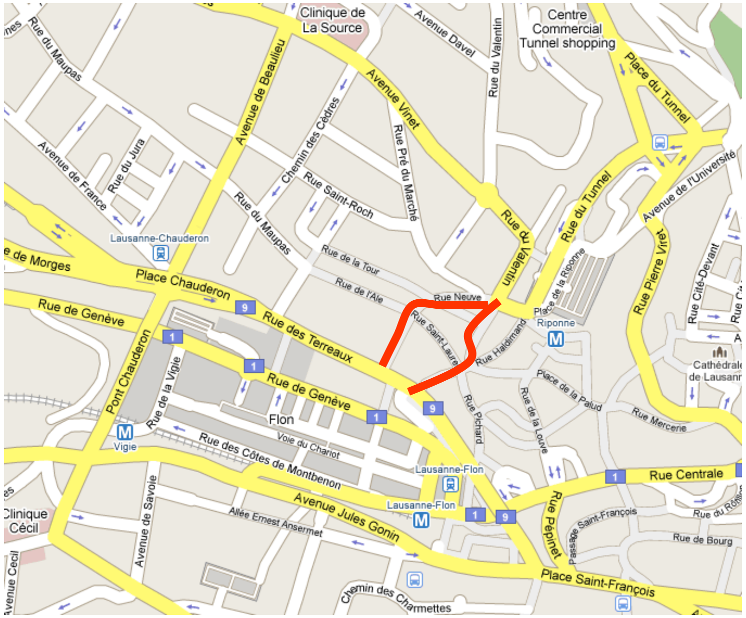
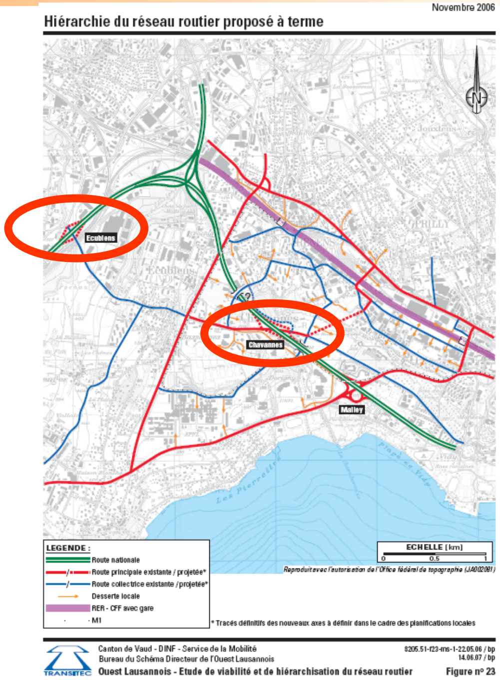
The range of this lecture

- **Models for urban transportation projects assessment**
  - **suited for significant changes in road or transit networks**
  - **e.g. Emme, Visem-Davisum, Transcad, …**
- **How do these models assign travelers**
  - **from their origin to their destination ?**

Examples of projects concerning car traffic



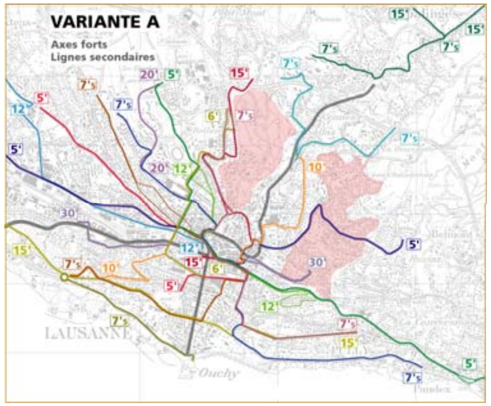


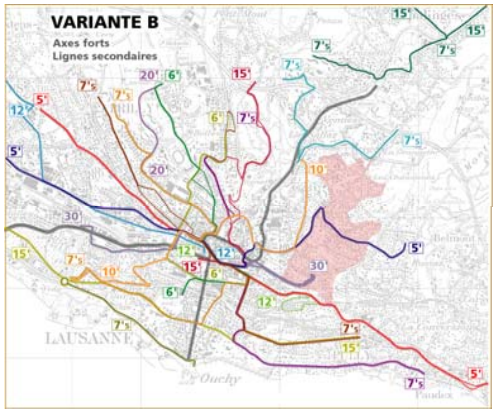
- **roads forbidden to cars**
- **new highway junctions**
- **or building of a new bridge or a new tunnel**

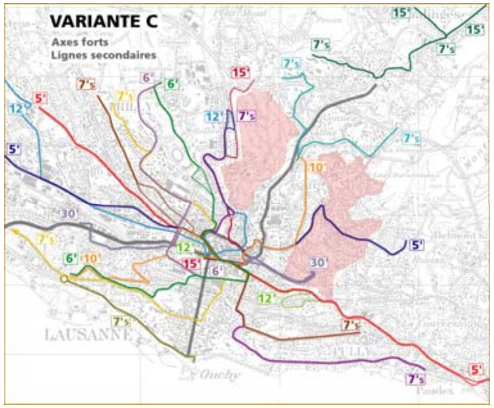
What are the network-wide consequences ?

Example of projects concerning transit

- **A new subway line is created**
  - **Need for adapting the bus network**







But which variant to select ?

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in order to assess a project

it is necessary to predict how people will behave

Trip generation : what trips will be done

Trip distribution : to which destinations

Modal split : with which mode (car, transit, …)

Assignment : through which path ?

In this lecture we will just consider the assignment

A model cannot suit exactly to the reality

- The higher the accuracy requirement,
- the higher the data requirement and the complexity of algorithms

(main difficulty : the data)

- A compromise must be found
- Hence models for project assessment generally use macrosimulation

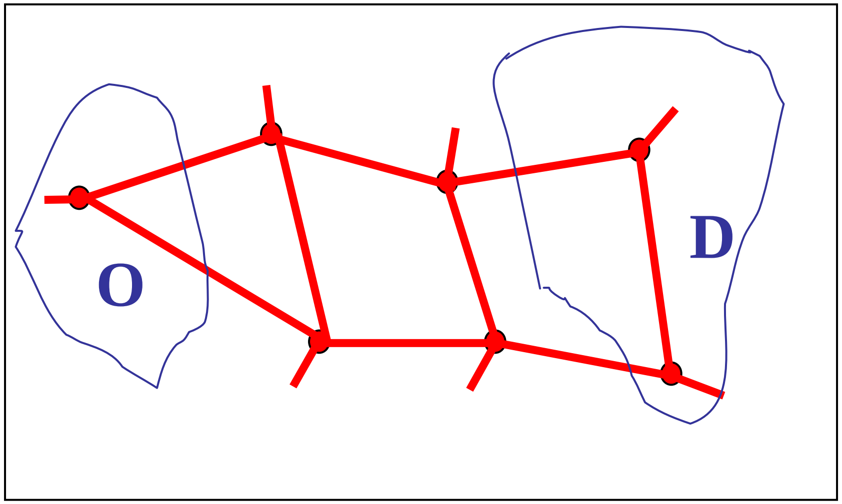
Macrosimulation for assignement

- **The territory is divided into zones**
- **A time period is considered**
  - ➢ **typically an hour**
- **Same (average) travel conditions for all trips which :**
  - ➢ **are perfomed during the considered time period**
  - ➢ **and use the same mode**
  - ➢ **and have both the same origin and same destination zone**
- **Consequence : only global results are available**
  - ➢ **e.g. traffic volume during the considered hour**

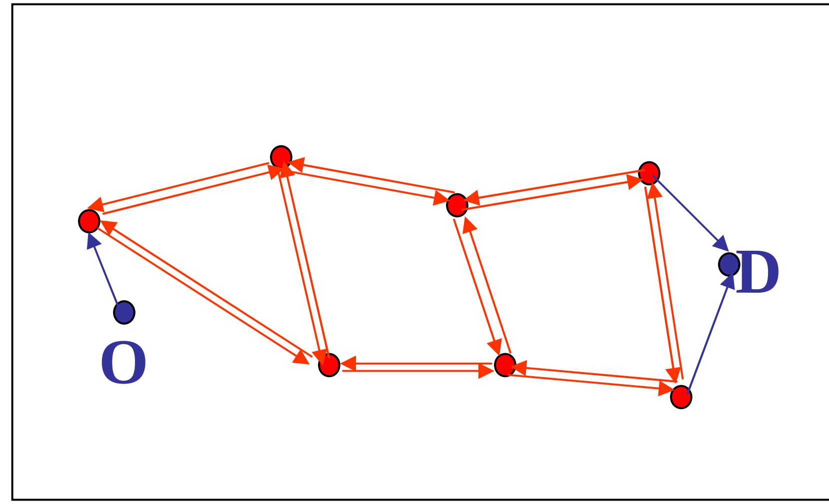
Traffic assignment (cars)

Traffic assignment (cars)

« Real » road network



Coded graph



Zones

Roads

Centroids

Regular nodes

Connectors

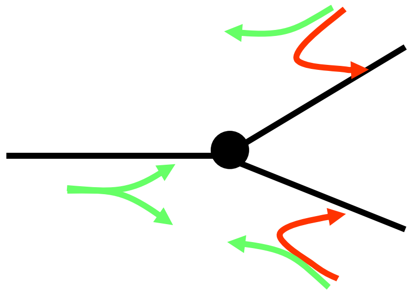
Regular links

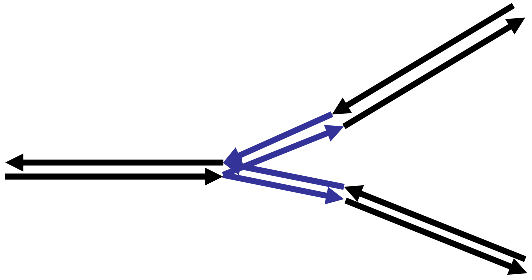
Traffic assignment (cars)

- **Not only nodes and links must be coded,**
- **but also turns in some intersections**
- **Necessary for complex intersections**

➢ **with turn prohibitions**

➢ **or with significant turn delays for some movements**





In what follows, we will just mention link times

➢ **as turn times are treated in the same way**

Traffic assignment (cars)

- **For his route choice a driver may consider**

➢ **the driving time**

➢ **some other objective data (e.g. tolls)**

➢ **some specifically personal criteria**

- **In what follows, we will just mention time, as :**

➢ **a lot of other objective data may be converted into times**

➢ **specifically personal criteria can anyway not be entered explicitely into a model**

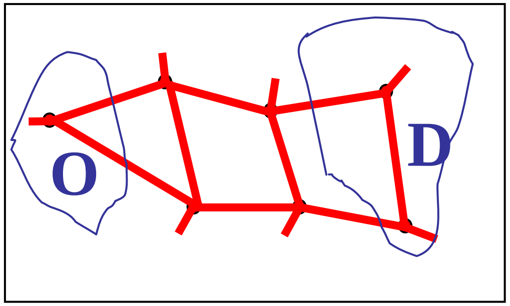
- **In the same way, for us a shortest path to an origin to a destination will mean a path which have the shortest time**

Traffic assignment (cars)

The simplest method : all-or-nothing assignment

- Link times are supposed known a priori
- For each origin-destination, the driver selects a shortest path (the same for everyone)
- Advantage : classic problem, efficient algorithms

Traffic assignment (cars)



- But all-or-nothing assignment is unrealistic when more than one path looks attractive
- For example in the beside case, which route should I select ?
- It may depend e.g. on :

➢ my exact destination in zone D

➢ my knowledge of the network

➢ my preferences (e.g. allergy to traffic lights)

} We are different

➢ what the other drivers are doing (if they congest too much a route, I select the other one)

} We interact

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Traffic assignment (cars)

2 main families of methods

- **Stochastic**

➢ **Times of paths are random variables, due to perception differences amongst drivers**

➢ **Each driver selects a shortest path according to its own perceptions**

- **Including capacity-restraint**

➢ **Times of paths are increasing functions of traffic load**

➢ **Each driver selects a shortest path according to traffic load**

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Traffic assignment (cars)

A classical stochastic method : STOCH of Dial (logit)

From an origin to a destination, only « efficient paths » are considered

- **i.e. paths where every link has its initial node closer to the origin than its final node (no backtrack), this in order to avoid paths with loops**

$$\text{Prob}[\text{path } p_i] \sim e^{-\theta T_i} \; (i = 1,\ldots,n)$$

p_i path, T_i time of p_i and θ coefficient

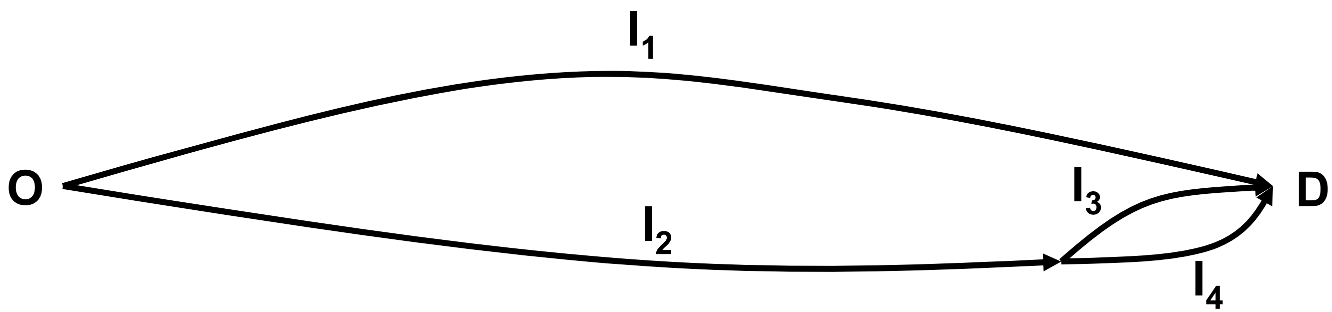
Advantage of this method (due to the form of the function) :

- **quick and efficient algorithm**
- **no need for paths enumeration (algorithm works with links)**
- **no need for explicit simulation**

Drawbacks of STOCH method of Dial

- Efficient paths are mathematically convenient, but not behaviorally motivated

- Independence is assumed amongst alternative routes



$t(l_1) = c$

$t(l_2) = c - \delta$

$t(l_3) = \delta$

$t(l_4) = \delta$

- So for each of the 3 paths above, same probability

➢ unrealistic : the main choice is between using l_1 or l_2

- Too high probabilities for strongly correlated paths

Other stochastic methods

Correction of Dial method (path size logit)

• smaller probabilities for overlapping paths

Methods with explicit simulation

• Links times are random variables

• The demand is divided into slices

➢ e.g. each slice yields 1/10 of the demand of each O-D pair

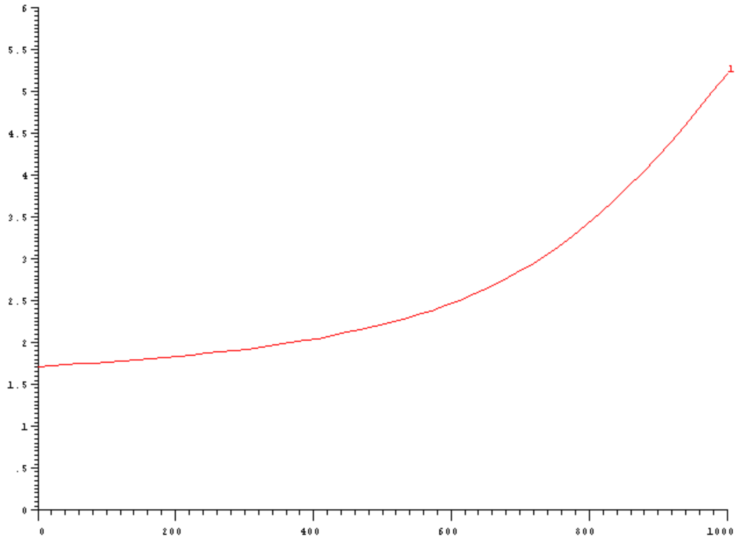
• For each slice, the times are drawn at random

• The demand of the slice is assigned for each O-D pair on a shortest path according to the drawn values

Capacity restraint methods

Link time is a function of traffic volume on the link

t_l (min)



v_l (veh/hr)

$$t_l = s_l(v_l, length_l)$$

Different functions may be used according to the road category and to the number of lanes

A simple method : incremental load

- The demand is divided into slices
- The first slice is assigned on a shortest path under the conditions of zero-traffic
- Each next slice is assigned on a shortest path under the traffic conditions due to the preceding slices
- With this method, some drivers of the first slices may be assigned on paths with too much driving time
- In practice, it could correspond to drivers underestimating the traffic effects

User equilibrium method

Wardrop principle : ***under equilibrium conditions traffic arranges itself in congested networks in such a way that no individual trip maker can reduce his path costs by switching routes***

Consequences :

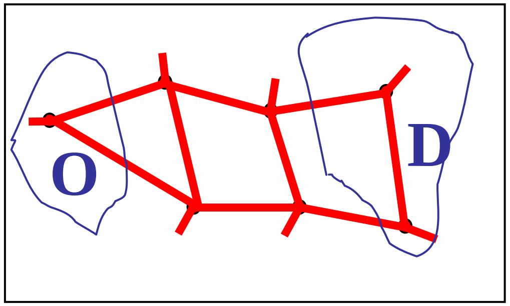
- **for an O-D pair, all the used paths need the same time (equilibrium between used paths)**
- **a non used path cannot have a lower time**

Incremental load ≠ user-equilibrium

User equilibrium algorithm does not assign incrementally, but reassignes a part of the demand at each step

But does a user equilibrium exist ?

- For a simple example with an O-D pair and 2 possible paths, it looks obvious
- But can we have simultaneously a user equilibrium on all the O-D pairs ?

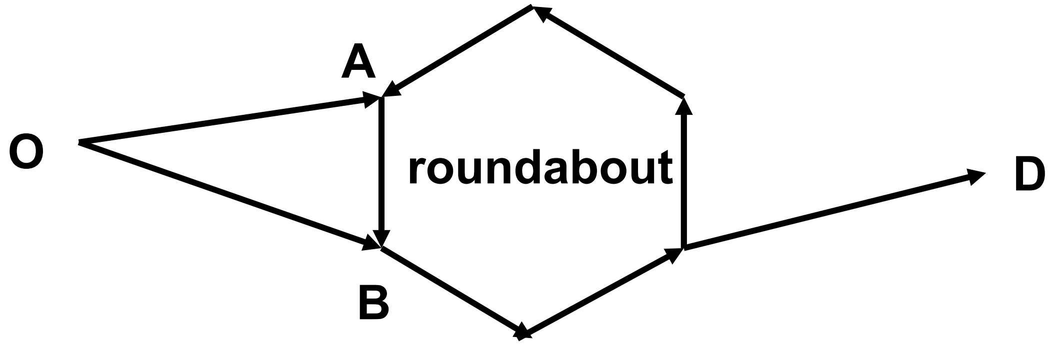


- If each link time is a increasing (non-decreasing) function of the traffic volume on the link itself and does not depend on the traffic volume on other links, then there exists a global user equilibrium

- Moreover, if these functions are strictly increasing, there exists a unique user equilibrium

Traffic assignment (cars)

Problems with some intersections



• In real life, in the case above, the driving time on OB would depend more on the traffic on AB than on the traffic on OB itself

• So the conditions for an user equilibrium would not be satisfied

• And in fact, the more some drivers use OA, the more the others must do the same (instead of using OB) → no equilibrium

• As a conclusion, capacity restraint methods are not suited to a detailed treatment of the intersections with antagonistic movements

➢ microsimulation needed for that

Traffic assignment (cars)

In conclusion

- Stochastic methods are more suited when traffic is low or unknown
- Capacity restraint methods (preferably user equilibrium) are more suited for high traffic
- There exists some experimental iterative methods (stochastic user assignment) where the iterations of user assignment are combined with the drawing of values for link times

Transit assignment

Transit assignment

Data requirements

- **We must not just consider road or rail segments, we must also consider the transit lines using them**
- **These transit lines have :**

➢ **a headway (in a macroscopic model we just consider the headway, not the departure time of every service)**

➢ **a route with stops, with driving and dwell times**

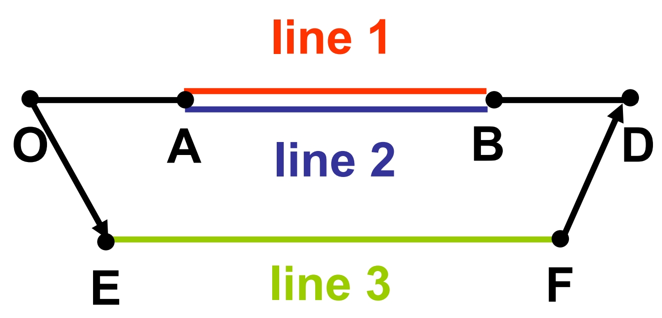
Transit assignment

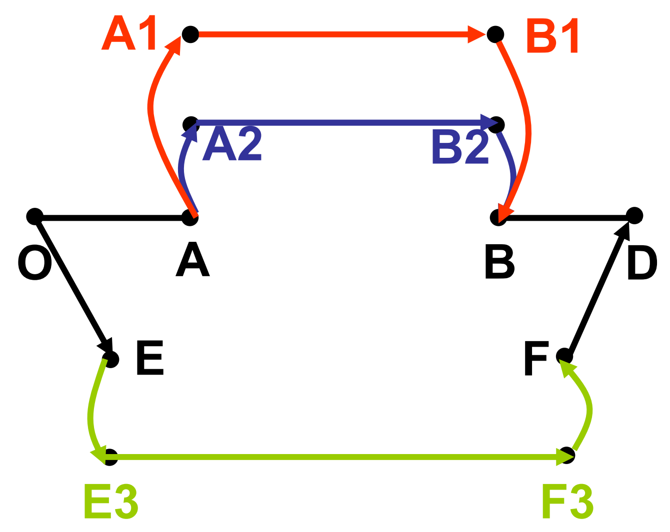
Differences with traffic assignment

- The (transit) vehicles must not be assigned, they already have their route, only the transit users must be assigned
- The transit users perform a lot of different operations : walking, waiting, boarding, riding, alighting
- As these operations are unequally pleasant, the time considered will be a generalized time, each operation being weighted by a different coefficient
- For waiting time, which is random, depending on the arrival time at the stop, only the expectance can be known (typically half of the headway)

Transit assignment

In the algorithms the graphic representation is more complex than just a network



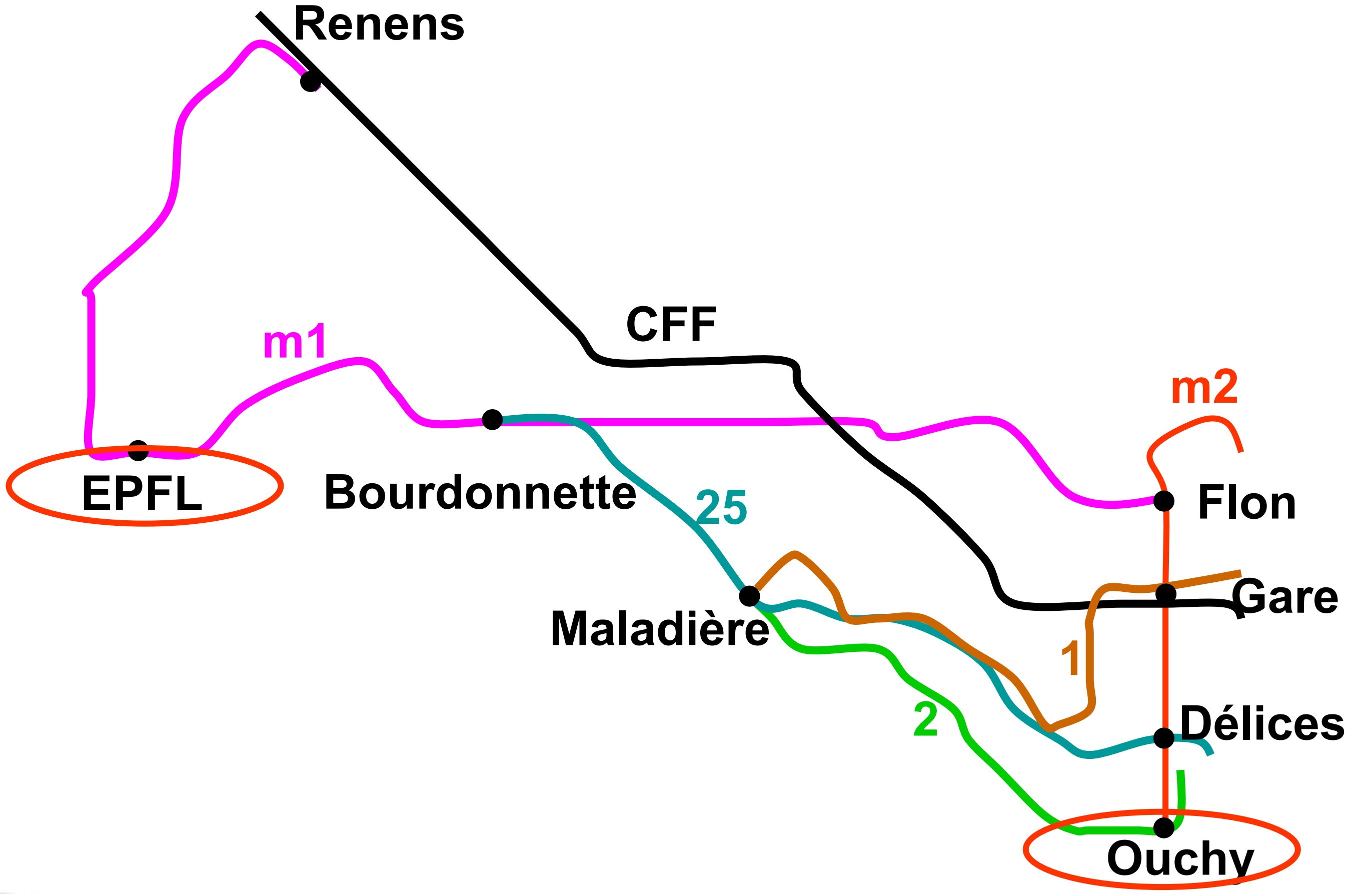


Network **Exploded graph**

Here, the route choice is simple, but some cases may be more complex

Transit assignment

A more complex choice in Lausanne, from Ouchy to EPFL



Transit assignment

All-or-nothing choice on the exploded graph ?

This is unrealistic. Transit users from same origin and same destination can make different choices, depending e.g. on :

- **their exact origin in the origin zone**
- **their exact destination in the destination zone**
- **their knowledge of the network**
- **their preferences (e.g. walking acceptance)**

} **differences between transit users**

- **the exact time they begin their trip**

} **different conditions according to the time**

Hence 2 families of methods to answer repectively to these both problems

Transit assignment

Transit pathfinder method of Dial

Approximately like Dial method for traffic assignment

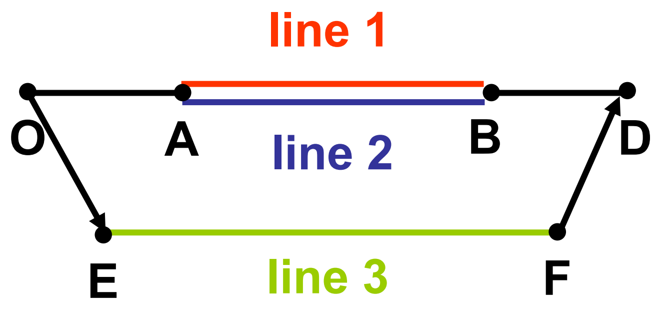
$$\text{Prob}[\text{path } p_i] \sim e^{-\theta T_i} \quad (i = 1,\ldots,n)$$

p_i path, T_i exp. generalized time of p_i and θ coefficient

- **but applied to the exploded graph**
- **and with a special treatment of parallel lines**

Transit assignment

Special treatment for parallel lines



In such a case, one does not consider 2 different paths O-A-B-D, but only one path with the combined line (1+2)

Example if both lines have a frequency of 6 services per hour

Combined frequency of (1+2) = 6 + 6 = 12 services per hour

Combined headway of (1 + 2) = 60/12 = 5 minutes

If the user boards the first vehicle arriving to the stop,

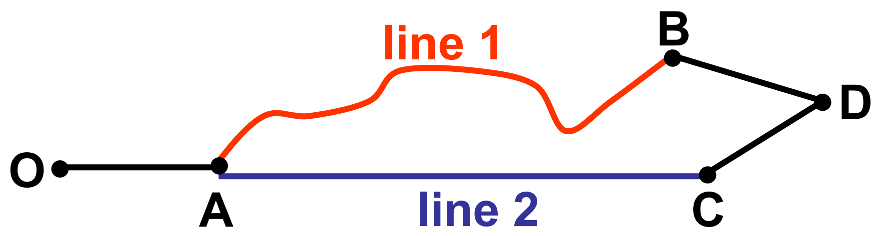
probability of taking line 1 = 6/12 = ½ probability of taking line 2 = 6/12 = ½

Transit assignment

Optimal strategies method (Spiess and Florian)

• Contrary to transit pathfinder method, at a stop the transit user can make a choice between lines with different routes

Example



• For the user arriving in A, 2 possible strategies

➢ take line 2 ; advantage : short riding time

➢ take the first vehicle arriving in A ; advantage : less waiting time

• The user has not selected a priori an itinerary, but just a strategy

Transit assignment

What does a strategy ?

A same strategy is applied to all users going to a same destination.

At a given node (outside a line), the strategy tells the user :

- **whether he must walk to another node or take a transit line**
- **in first case up to which node he must walk**
- **in second case which lines he can consider at this stop**
  - ➢ **he will take the first vehicle performing one of these lines**
- **where he should alight from the line he has boarded**
- **and so on up to the destination**

The selected strategy is the one which minimizes the generalized time expectance

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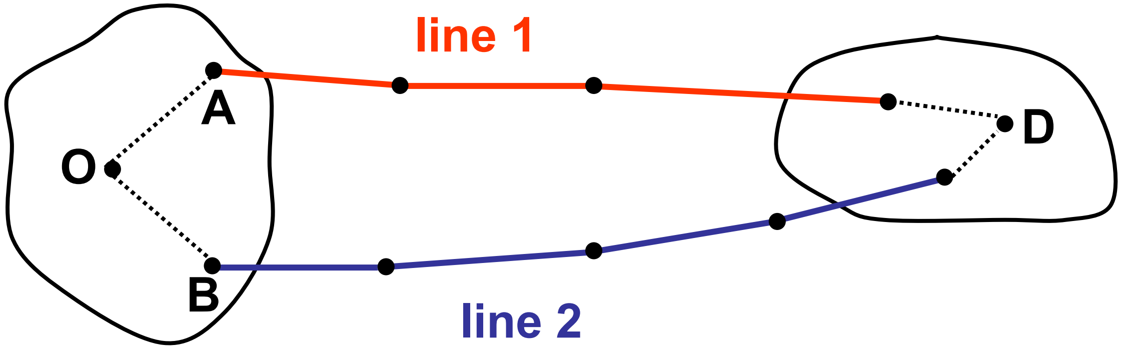
Transit assignment

Comparison between both methods

• Optimal strategies method is better behaviorally motivated

• But it leads to problems in case of large zones with transit lines using different stops



• For the trips from O to D, only one first stop may be considered by the strategy : only A or only B,

• though in reality the choice of the user could depend on it exact origin address in the origin zone

The problem of large headways

- Both methods have problems with large headways
- E.g. if a line headway is 1 hr, do the users wait ½ hr. in average ?
- Probably some users know the time-table and conform their departure time to the time-table
- But some others cannot (especially when they must board a second line after a transfer)
- So, one could imagine to bound the waiting time expectance, but to which limit ?
- Some mesoscopic methods consider the complete time-table, and therefore the connections between lines, but they must also include the wanted departure or arrival times of the different users

Some documentation

- Dial R.B. (1967) *Transit pathfinder algorithm*, Highway Research Record 205, pp. 67-85
- Dial R.B. (1971) *A probabilistic multipath traffic assignm,ent model which obviates path enumeration*, Transportation Research, Vol. 5, pp. 83-111
- Oppenheim N. (1995), *Urban travel demand modeling*, Wiley
- Ortuzar JH.D. and Willumsen L. G. (2002), *Modeling Transport*, Wiley
- Spiess H. and Florian M. (1989), *Optimal strategies : A new assignment model for transit newtwork*, Transportation Research B, 23B(2), pp. 83-102

Thank you for your attention !