Exposure to the risk of accident of car occupants and pedestrians in urban area

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From European project HEARTS

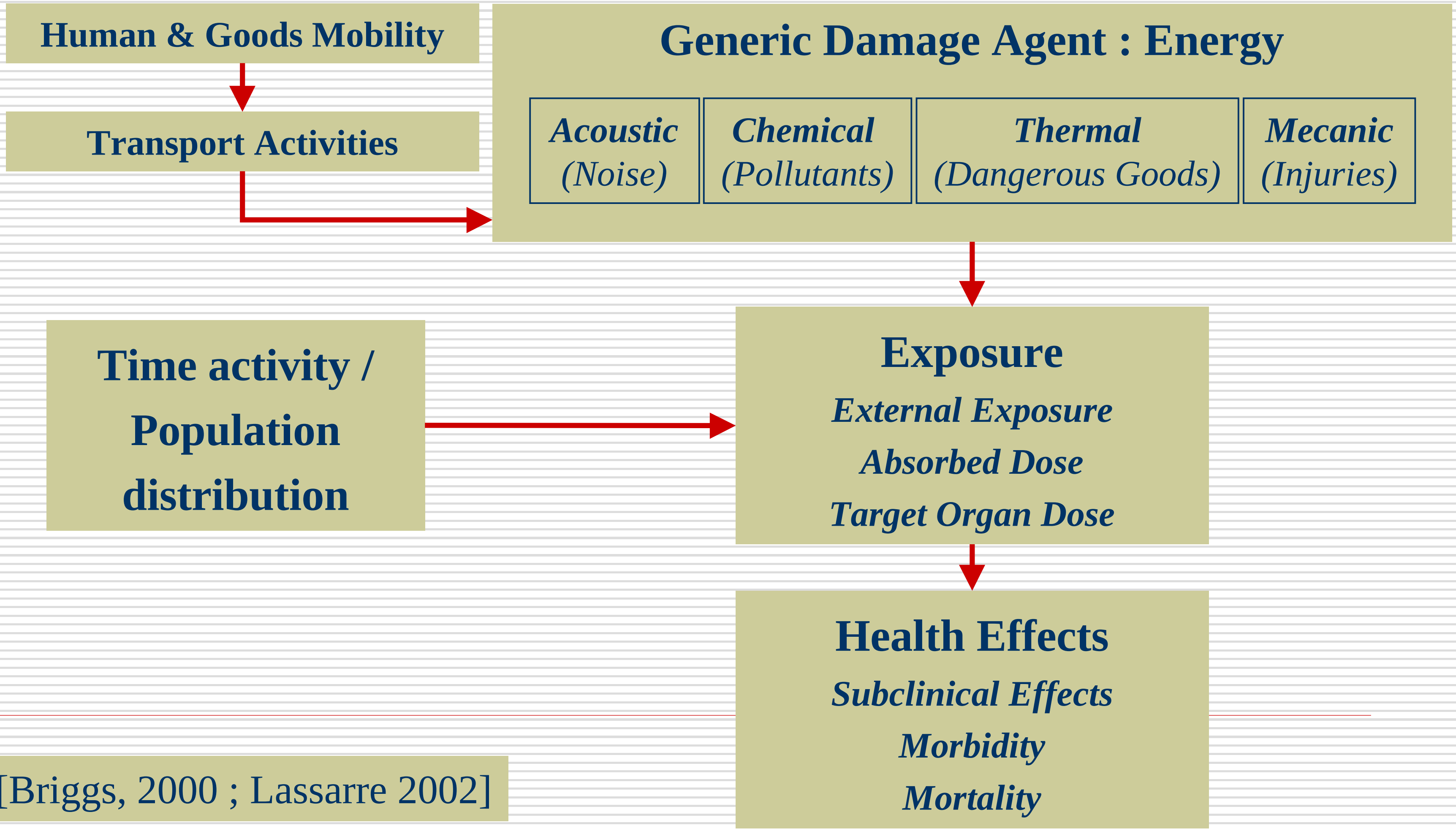
Health Effects and Risk of Transport Systems

Objectives

- Integrated health impact assessment in urban areas

- air pollution
- noise
- accident

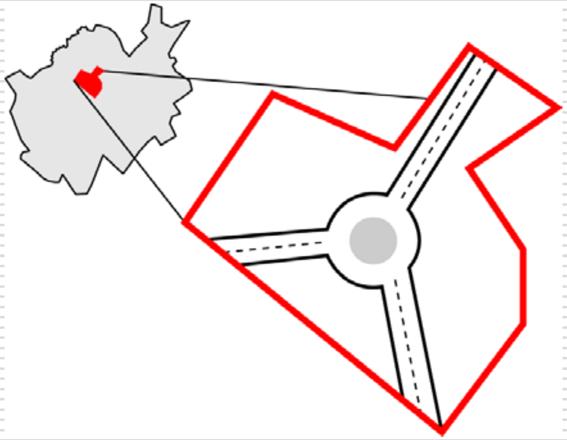
A common risk-exposure chain



[Briggs, 2000 ; Lassarre 2002]

Where a road user is exposed to accident risk ?

Which micro-environments ?



On road segments and junctions where collisions between road users or with obstacles could occur

What is exposure in environmental epidemiology ?

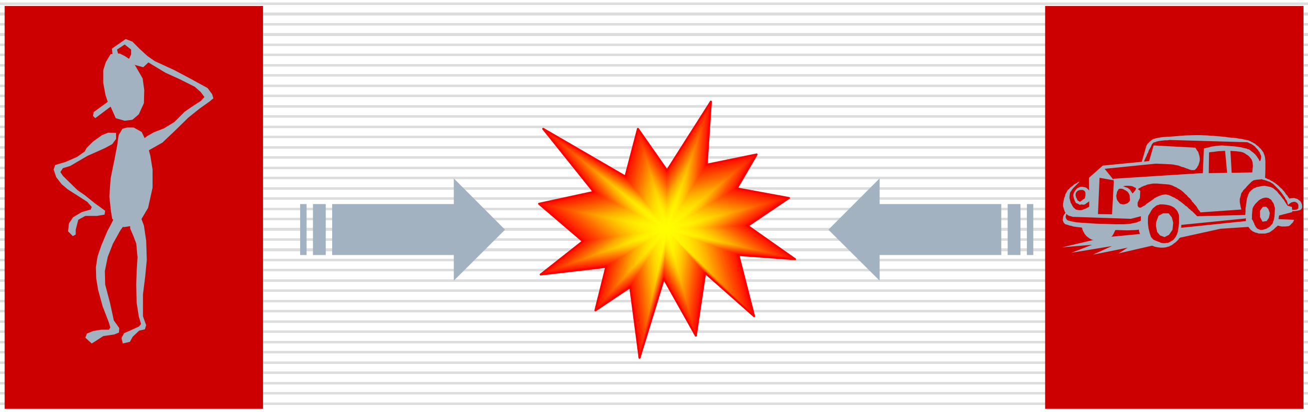
« an event that occurs when there is a contact at the boundary between a human and the environment with a contaminant of a specific concentration for an interval of time»

Used for air pollution and noise

in general and coming from road traffic

In collision

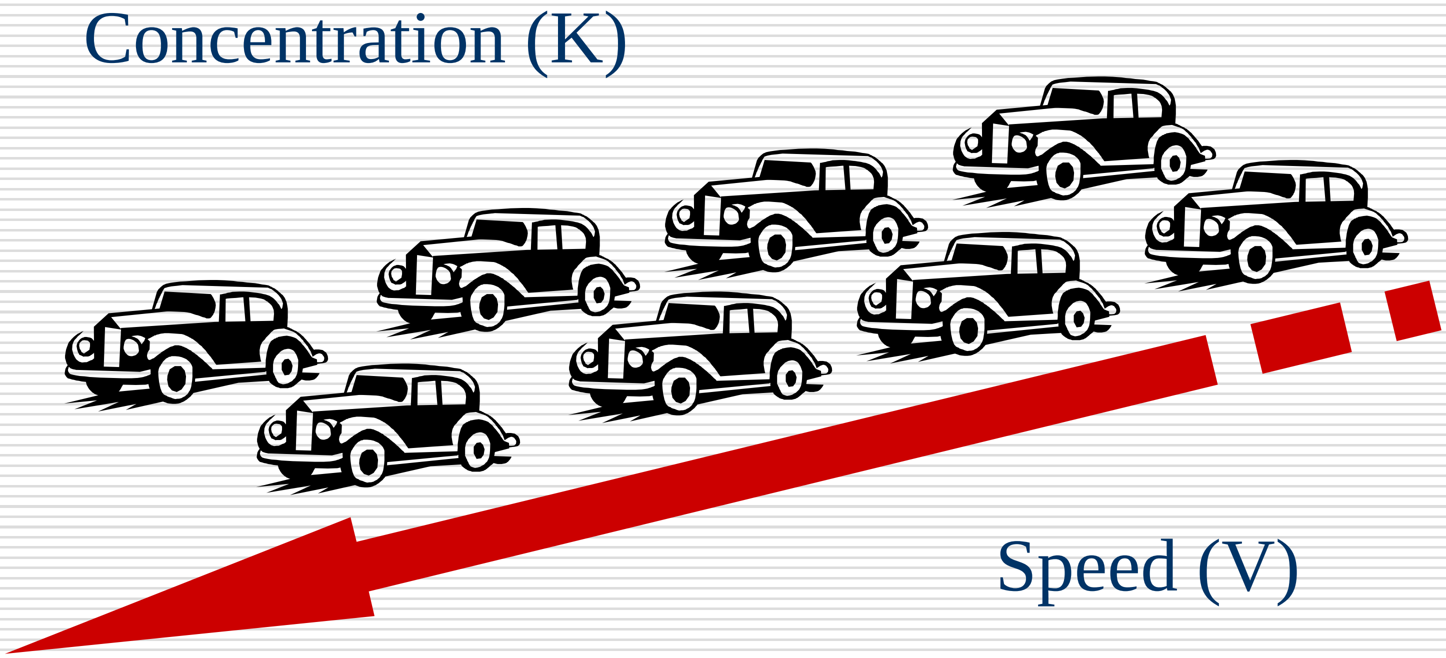
Direct (physical) contact between a road user and a structure with dissipation of mechanical energy which is the agent of the damages



In the street

Virtual contact between a road user and an « atmosphere » generated by the traffic

Which contaminant ?



Time versus distance of exposure

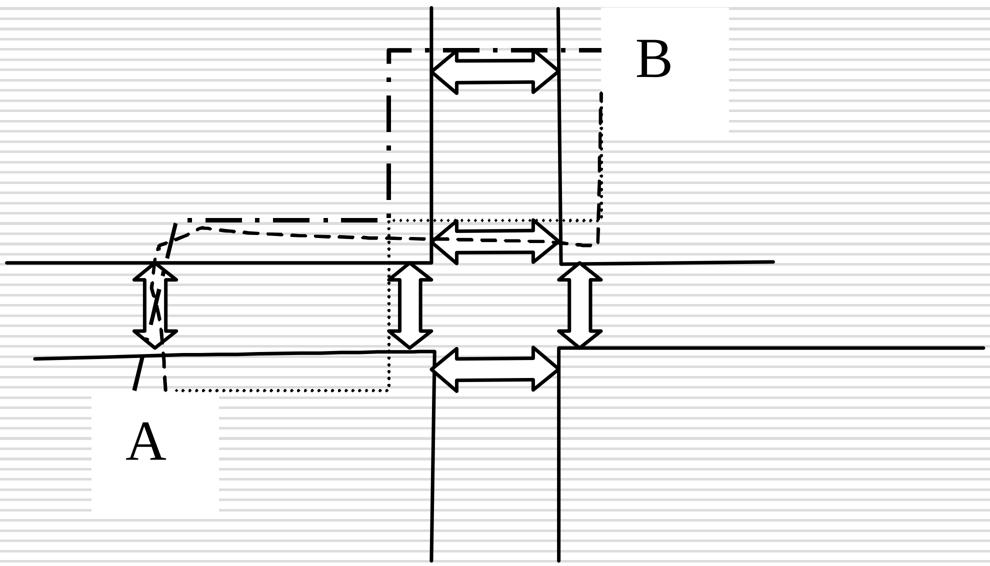
	Kilometer driven	Time spent	
Walk		X	
Bicycle	X	X	
Mopped	X		
Moto	X		
Car	X		
Lorry	X		
Bus	X		

Assessment of accident exposure for pedestrian

Some propositions

Hypothesis

- We suppose that the pedestrian is at risk only when crossing the street

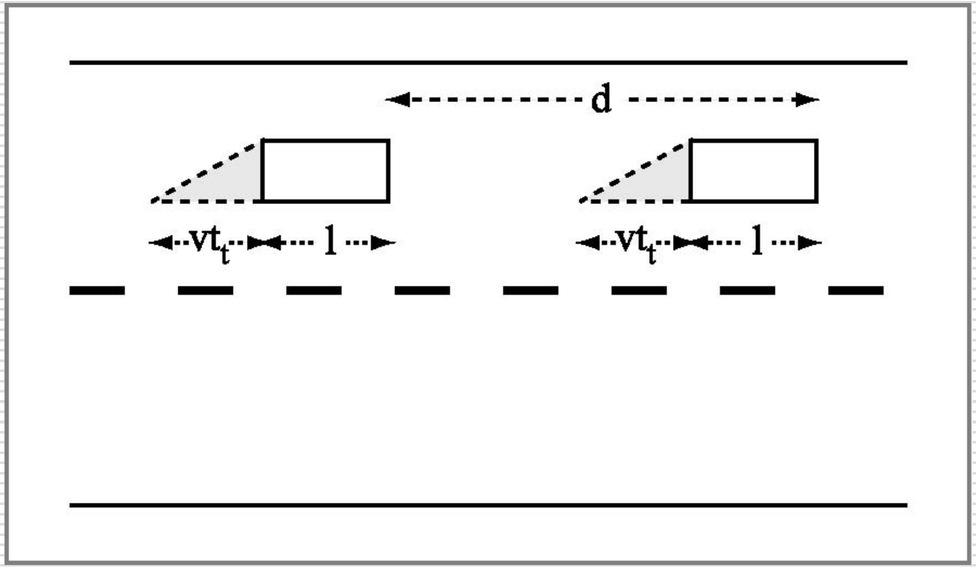


Choice of an exposure indicator

(Routledge, 1974)

$$P = \frac{l + vt_c}{d}$$

- l equal to the average length of the vehicle
- v the average speed of the flow
- d the average gap between vehicle in the flow
- t_c the average crossing time for a pedestrian



Interpretation 2

$$P = k\left(\frac{1}{k_J} + t_c v\right)$$

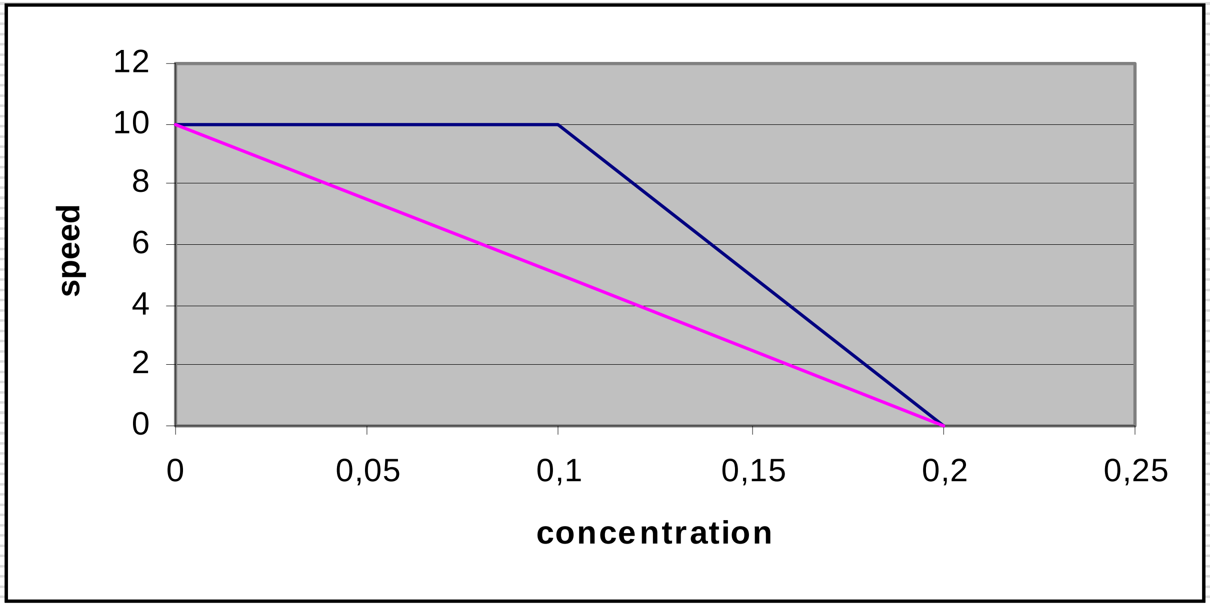
$$= \frac{k}{k_J}(1 + k_J t_c v)$$

- k the concentration of vehicle
- v the average speed of the flow
- k_J the jam concentration
- t_c the average crossing time for a pedestrian

Speed – concentration relationship in a flow of vehicles

$$v = v_f \left(1 - \frac{k}{k_J}\right)$$

- with v_f the free speed when the flow tends to zero, k_J the jam concentration when all vehicles are blocked.

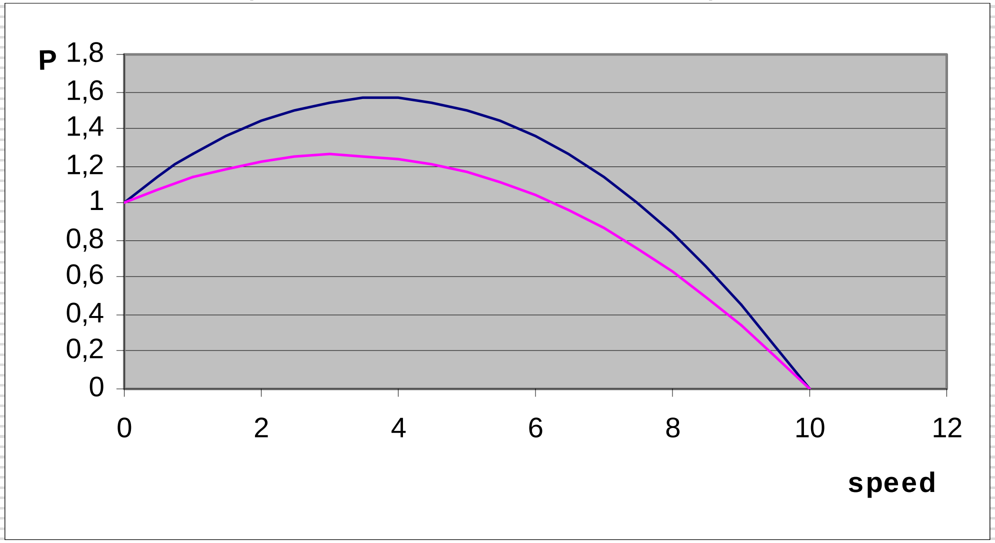


Speed function of concentration : linear and two pieces linear

Variation of P according to speed of the vehicle flow

$$P = k(\frac{1}{k_J} + t_c v)$$

$$= k_J (1 - \frac{v}{v_f})(\frac{1}{k_J} + t_c v) = (1 - \frac{v}{v_f})(1 + t_c k_J v)$$



Routledge indicator function of speed (m/s) with vf= 10 m/s, l = 5 m., tc = 3 s. and 2[1] s with a linear function speed/concentration.

[1] These correspond to the crossing of a 3 meters wide at a walking speed of 1m/s and 1,5 m/s.

Problems in using Routledge's indicator

- **It is not a proportion !**
  - Truncation at 1
- **Asymmetry !**
  - Parabola ?

Conclusion : rather a measure of accessibility

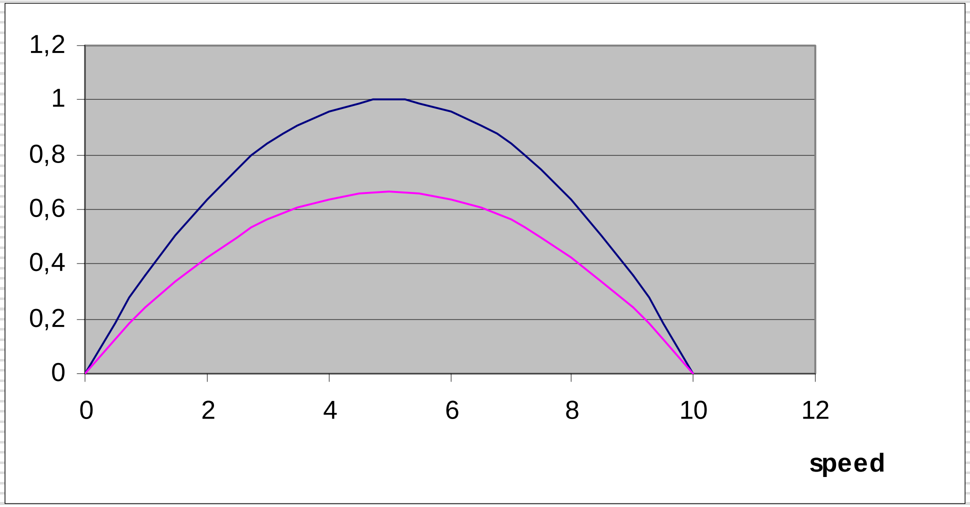
Proposition

- Only the mobile part

$$P = \frac{k}{k_J}(k_J t_c v)$$

$$= k\, t_c v$$

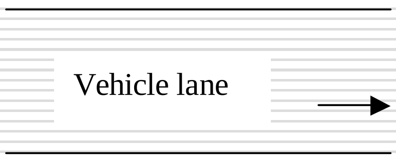
$$= k_J\left(1 - \frac{v}{v_f}\right) t_c v$$

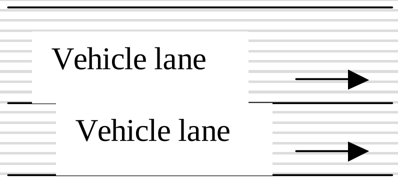


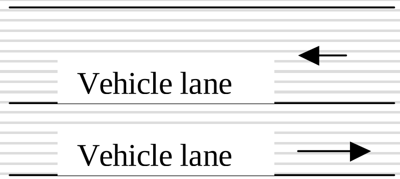
New indicator function of speed (m/s) with vf= 10 m/s, l = 5 m., tc = 3 s. and 2 s with a linear function speed/concentration.

Combination of exposures and aggregation of acccident risks

- Midblocks







$$\lambda = a_0 T f(P)$$

k one–way streets

$$\lambda = a_0 \sum_k T_k f(P_k)$$

$$T_{c1}, k_1, v_1$$

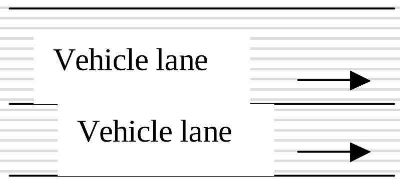
$$+$$

$$T_{c2}, k_2, v_2$$

or

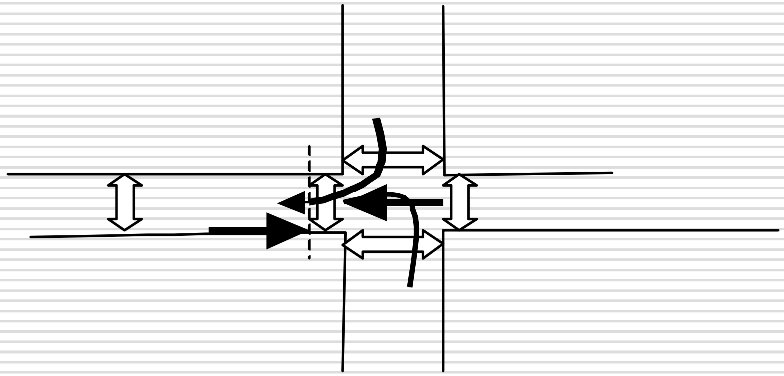
$$T_{c1} + T_{c2}, k_{1+2}, v_{1+2}$$

$$=$$



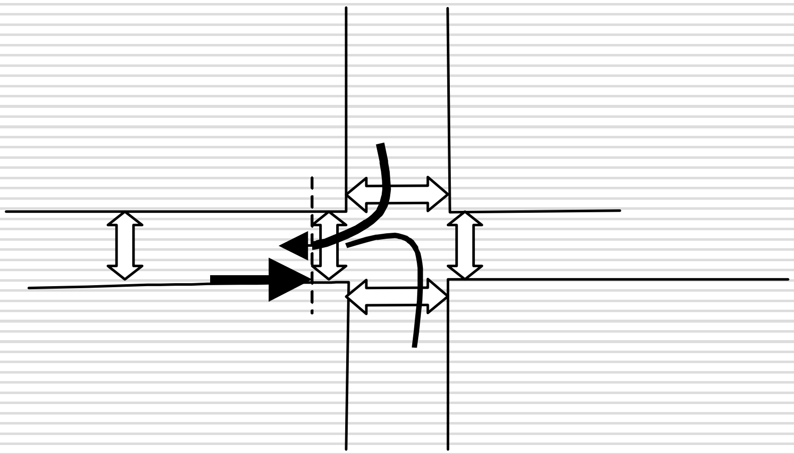
- Junctions

Same formulas and types of microenvironments



Extensions : zebra crossings, red lights...

- Zebra crossing : lower risk + lower speed
- Islands (separated streets)
- Red lights :



Which form for f ?

- Lessons from empirical risk models (TRL)

$$E(N) = 0{,}180\, SL\, QT^{0{,}719}\, PTSL^{0{,}435} \exp(-0{,}070\, Oneway + 0{,}594\, Zeb + \ldots)$$

$$\frac{E(N)}{365\ PT} = A\ SL^{0{,}565}\ QT^{0{,}719}\ PT^{-0{,}565}$$

$$RR = \left(\frac{QT}{QT_0}\right)^{0{,}719} \left(\frac{PTSL_0}{PTSL}\right)^{0{,}565}$$

Comparison

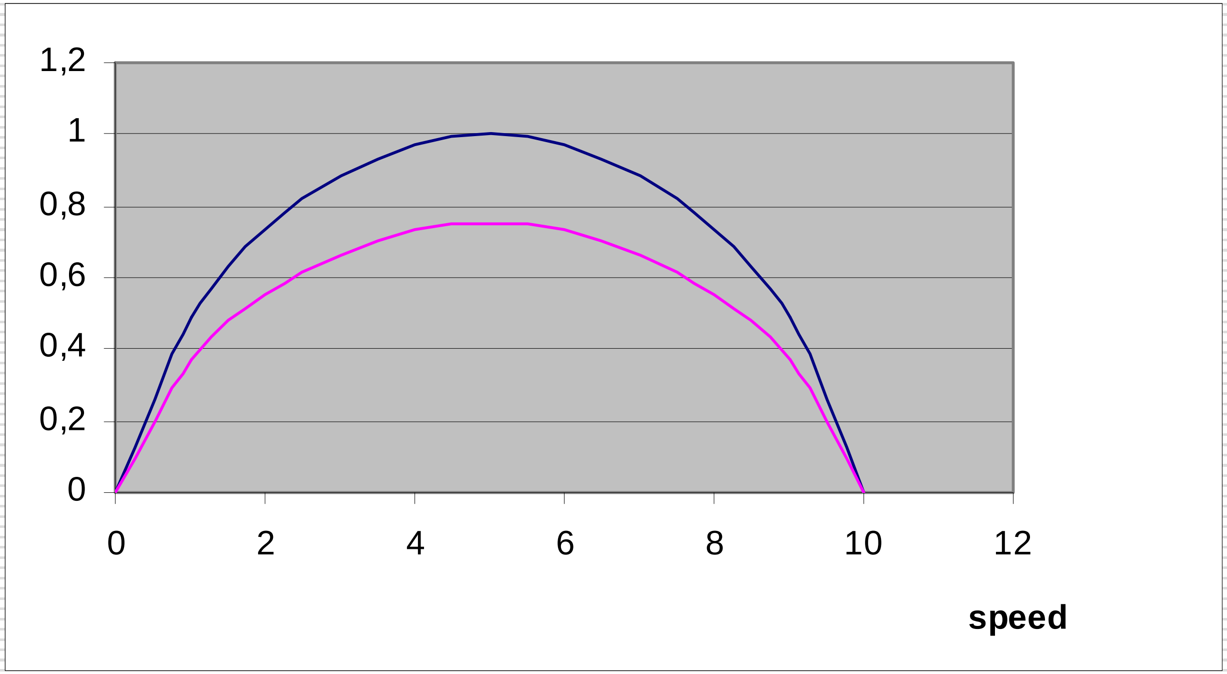
$$\frac{E(N)}{365\ PT} = A\ SL^{0,565}\ QT^{0,719}\ PT^{-0,565}$$

$$QT = kv$$

$$\lambda = t_c f\left((1-\frac{v}{v_f})(t_c k_J v) \right)$$

$$\lambda = k_J (1-\frac{v}{v_f})^{0,7} v^{0,7}$$

Final form



Power transformed indicator function of speed (m/s) with vf= 10 m/s, l = 5 m., tc = 3 s. and 2 s with a linear function speed/concentration.

Assessment of injury exposure for pedestrian

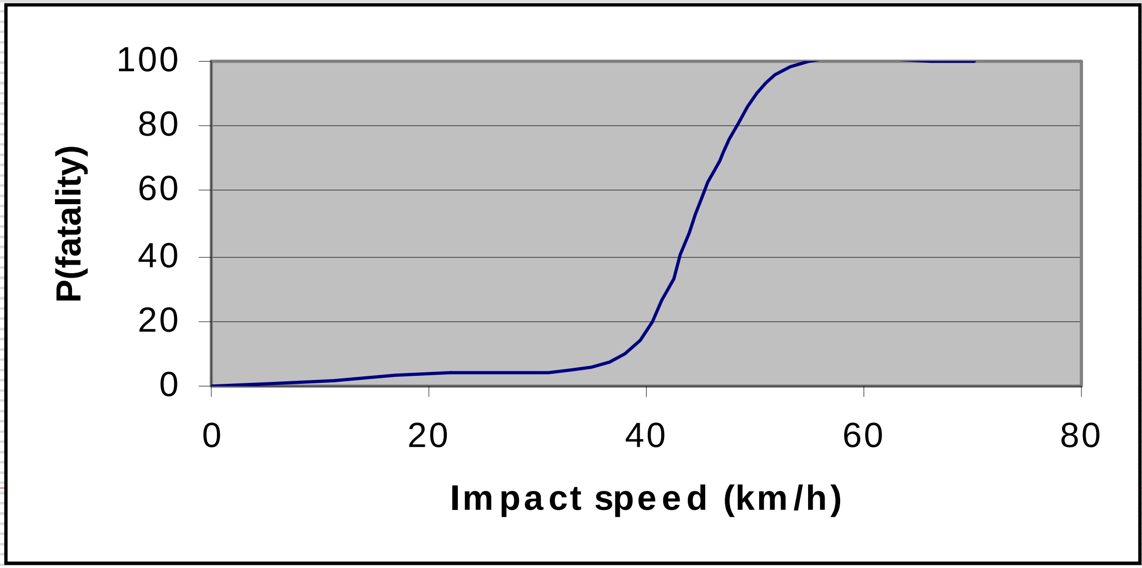
Some propositions

Dose-response modeling

- Involvement rate in injury accident

$$RR_v = \left(\frac{V_{flow}}{V_{flow0}} \right)^2$$

- Severity rate for pedestrians :



BUT

- Transfer from speed of the flow to impact speed ?
- Lack of severity scale
- Problem of interaction between type of junction and speed

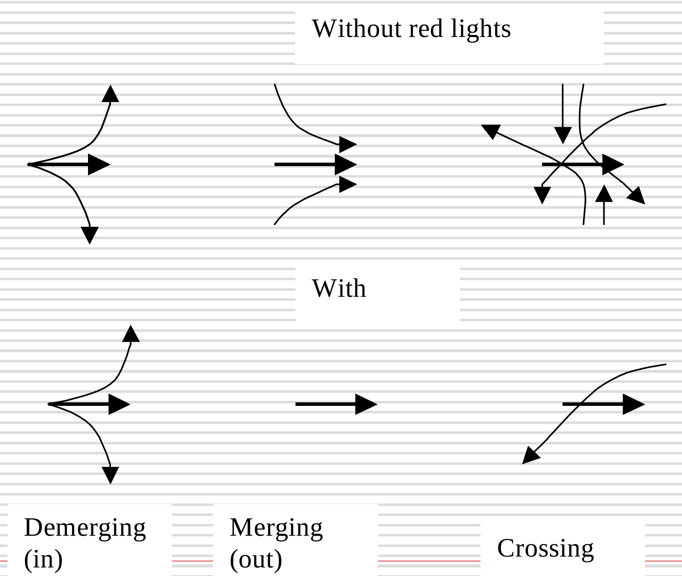
Assessment of accident exposure for car occupant

Some propositions

Combination of exposures and risks

- Links (midblocks)
- three types of accident
  - crash between two or more vehicles in the same direction,
  - collision on a fixed obstacle or a roll-over,
  - crash between two or more vehicles in the opposite direction.

- Junctions
- Merging and crossing conflicts with turning movements



Combination of the risks (1)

- Links

$$\lambda = T(f_1(P_1) + f_2(P_2) + f_3(P_3))$$

$$= T(f_1(k t_r v) + \varpi_2 * k_b L + f_3(k_o t_r v_o))$$

- T duration of the trip
- if travelling speed of the car = v , T=L/v
- t_r reaction time of a car driver

Combination of the risks (2)

- Junctions

$$\lambda = T_c * (f_1(kt_r v) + \sum_{i=1}^{n} f_i(k_i t_r v_i))$$

- or

$$\lambda = T_c * f(P_c)$$

$$P_c = 1 - \prod_{i=1}^{n} (1 - P_i)$$

$$P_i = k_i t_r v_i$$

Which form for f ?

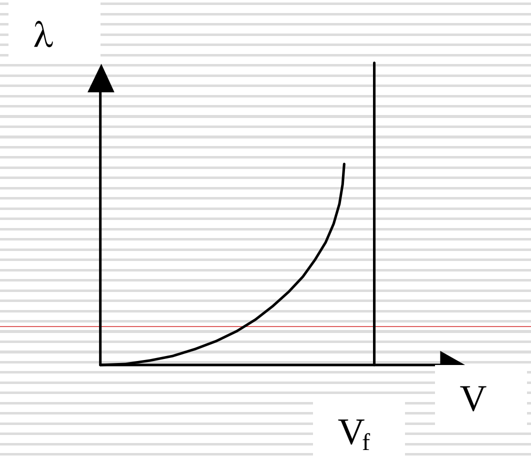
- Lessons from empirical risk models (TRL) without speed on links

$$E(N) = 0{,}131\, SL\, QT^{0{,}82} \exp(0{,}653 PTSL^{0{,}15})$$

$$\lambda / E(N_{veh}) = \frac{E(N)}{365 SLQT}$$

$$\lambda \approx AQT^{-0{,}21}$$

$$f = \frac{v^{0{,}8}}{k_J (1 - \frac{v}{v_f})}$$



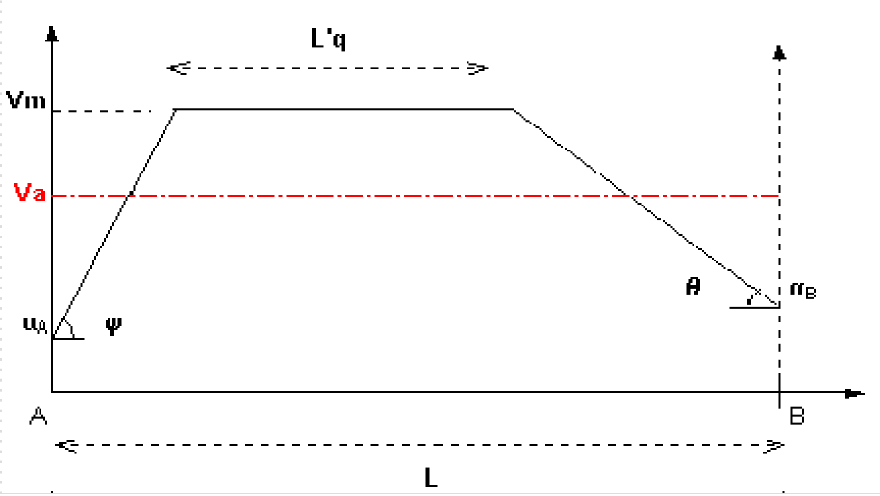
- Lessons from empirical risk models (TRL) with speed

$$E(N) = C\,V^{2,25}\;QT^{0,45}$$

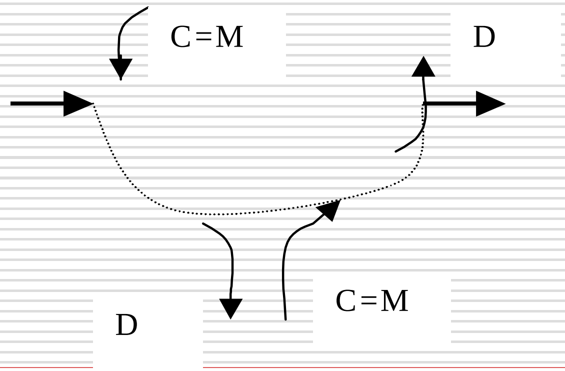
$$\lambda / E(N_{veh}) = C\frac{V^{2,25}}{V^{0,55}\left(1-\frac{V}{V_f}\right)^{0,45}} = C\frac{V^{1,7}}{\left(1-\frac{V}{V_f}\right)^{0,55}}$$

Extension

- Variation of the speed along the link



- Roundabouts



Validation

- By exposure
  - for a sample of n cars or pedestrians, we register their trip continuously and monitor the quality of the micro-environments encountered
- By accident
  - we could compare the aggregated risks at the zones λ_i estimated from the simulation with the number of accidents or better the number of motorised vehicles involved in an injury accident n_i restrained to vehicles carrying residents of the city

Conclusion

- Frequency not fully solved for car
- Severity coming later
- Implementation started into STEMS (software)
- Data acquisition (mobility from surveys and traffic from models (main network))
- Validation in Lille and Leicester on quarters