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

Human & Goods Mobility

Transport Activities

Generic Damage Agent: Energy

Acoustic (Noise)

Chemical (Pollutants)

Thermal (Dangerous Goods)

Mecanic (Injuries)

Time activity / Population distribution

Exposure

External Exposure

Absorbed Dose

Target Organ Dose

Health Effects

Subclinical Effects

Morbidity

Mortality

[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?

Concentration (K)

Speed (V)
## Time versus distance of exposure

<table>
<thead>
<tr>
<th></th>
<th>Kilometer driven</th>
<th>Time spent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk</td>
<td></td>
<td>✗</td>
</tr>
<tr>
<td>Bicycle</td>
<td></td>
<td>✗</td>
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<tr>
<td>Mopped</td>
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<tr>
<td>Moto</td>
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<tr>
<td>Car</td>
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<td>Lorry</td>
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<td>✗</td>
</tr>
<tr>
<td>Bus</td>
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<td>✗</td>
</tr>
</tbody>
</table>
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

\[ P = \frac{l + vt_c}{d} \]

- \( l \) 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

(Routledge, 1974)
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

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

\[ = k_J \left( 1 - \frac{v}{v_f} \right) \left( \frac{1}{k_J} + t_c v \right) = \left( 1 - \frac{v}{v_f} \right) \left( 1 + t_c k_J v \right) \]

Routledge indicator function of speed (m/s) with \( v_f = 10 \text{ m/s}, l = 5 \text{ m.}, t_c = 3 \text{ s. and } 2[1] \text{ s} \) with a linear function speed/concentration.

[1] These correspond to the crossing of a 3 meters wide at a walking speed of 1 m/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

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

\[ = k t_c v \]

\[ = k_J (1 - \frac{v}{v_f}) t_c v \]

New indicator function of speed (m/s) with \( v_f = 10 \) m/s, \( l = 5 \) m., \( tc = 3 \) s. and 2 s with a linear function speed/concentration.
Combination of exposures and aggregation of accident risks

- Midblocks

\[ \lambda = a_0 T f(P) \]

- One-way streets

\[ \lambda = a_0 \sum_{k} T_k f(P_k) \]

\[ T_{c_1, k_1, v_1} + T_{c_2, k_2, v_2} \]

or

\[ T_{c_1} + T_{c_2, k_{1+2}, v_{1+2}} \]
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)

\[ E(N) = 0.180 SL QT^{0.719} PTSL^{0.435} \exp(-0.070 \text{Oneway}+0.594 \text{Zeb}+...) \]

\[ \frac{E(N)}{365 PT} = A SL^{0.565} QT^{0.719} PT - 0.565 \]

\[ RR = \left( \frac{QT}{QT_0} \right)^{0.719} \left( \frac{PTSL_0}{PTSL} \right)^{0.565} \]
Comparison

\[
\frac{E (N)}{365 \ PT} = A \ SL^{0.565} \ QT^{0.719} \ PT ^ {-0.565}
\]

\[
QT = kv
\]

\[
\lambda = t_c f \left( (1-\frac{V}{v_f}) (t_c k_j v) \right)
\]

\[
\lambda = k_j (1-\frac{V}{v_f})^{0.7} v^{0.7}
\]
Power transformed indicator function of speed (m/s) with $v_f = 10 \text{ m/s}$, $l = 5 \text{ m.}$, $t_c = 3 \text{ s.}$ 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:

![Graph showing the relationship between impact speed (km/h) and probability of fatality (P(fatality))](image-url)
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

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Without red lights

With

Demerging (in)  Merging (out)  Crossing
Combination of the risks (1)

Links

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

\[ = T(f_1(k_t \nu) + \omega^2 k_b L + f_3(k_t \nu)) \]

- 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

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

- or

\[ \lambda = T_c \ast f(P_c) \quad P_c = 1 - \prod_{i=1}^{n} (1 - P_i) \]

\[ P_i = k_i t_r v_i \]
Which form for f?

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

\[ E(N) = 0.131 \, SL \, QT^{0.82} \exp(0.653 \, PTSL^{0.15}) \]

\[ \frac{\lambda}{E(N_{veh})} = \frac{E(N)}{365 SLQT} \]

\[ f = \frac{v^{0.8}}{k_j(1-\frac{v}{v_f})} \]

\[ \lambda \approx AQT^{-0.21} \]
Lessons from empirical risk models (TRL) with speed

\[ E(N) = C V^{2.25} QT^{0.45} \]

\[ \lambda/E(N_{veh}) = C \frac{V^{2.25}}{V^{0.55} (1-V/V_f)^{0.45}} = C \frac{V^{1.7}}{(1-V/V_f)^{0.55}} \]
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 $\lambda_i$ 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