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Road, traffic and human factors of pedestrian crossing behaviour: Integrated Choice and Latent Variables models

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Background

- Modelling pedestrian crossing behaviour
  - better understanding of the interaction between pedestrians and the road and traffic environment
  - better design and management of urban networks
- Models on road and traffic factors
  - Gap acceptance
  - Level of service
  - Discrete choice
- Analyses of human factors (psychological, attitudinal, perceptual, motivational)
- Human factors are rarely incorporated in pedestrian behavior models

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Objectives

- To develop choice models of pedestrian crossing behavior, integrating the effect of human factors (i.e. pedestrian attitudes, perceptions, motivations and behavior) together with road and traffic factors

- Analyse data from a survey combining field observations with questionnaire responses
- Develop Integrated Choice and Latent Variables models (ICVL)

Methodology

- A two-step approach
  I. human factors calculated by means of Principal Component Analysis on questionnaire responses
  II. factors introduced as explanatory variables in crossing choice models
  - Tested in Papadimitriou et al. (2015)
  - Known limitations: risk of measurement errors

- ICLV: merging classic choice models with the structural equation approach for latent variables
- Used in the fields of transport economics, activity planning and transport mode choice

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ICLV model

- Latent variables model
- Structural equations

- $Z_{1n} = \alpha_1 W_{in} + \omega_{1n}$
- $Z_{2n} = \alpha_2 W_{in} + \omega_{2n}$

- Measurement equations

- $I_{1n} = \lambda_1 Z_{1n} + \upsilon_{1n}$
- $I_{2n} = \lambda_2 Z_{1n} + \upsilon_{2n}$
- $I_{3n} = \lambda_3 Z_{2n} + \upsilon_{3n}$
- $I_{4n} = \lambda_4 Z_{2n} + \upsilon_{4n}$

- I_{in} are discrete ordered

$$I_i = log\left(\frac{\gamma_i}{1-\gamma_i}\right) = log\left(\frac{Pr(y_i \geq i)}{Pr(y_i < i)}\right)$$

$$\gamma_{ij} = \text{Prob}(y_{ij} \geq i) = \sum_{i}^{I} \pi_{ij}$$

- Choice model
- Structural equations

- $U_{in} = b' X_{in} + b_1 \tilde{Z}_{1n} + b_2 \tilde{Z}_{2n} + \varepsilon_{in}$
- $U_{jn} = b' X_{jn} + \varepsilon_{jn}$

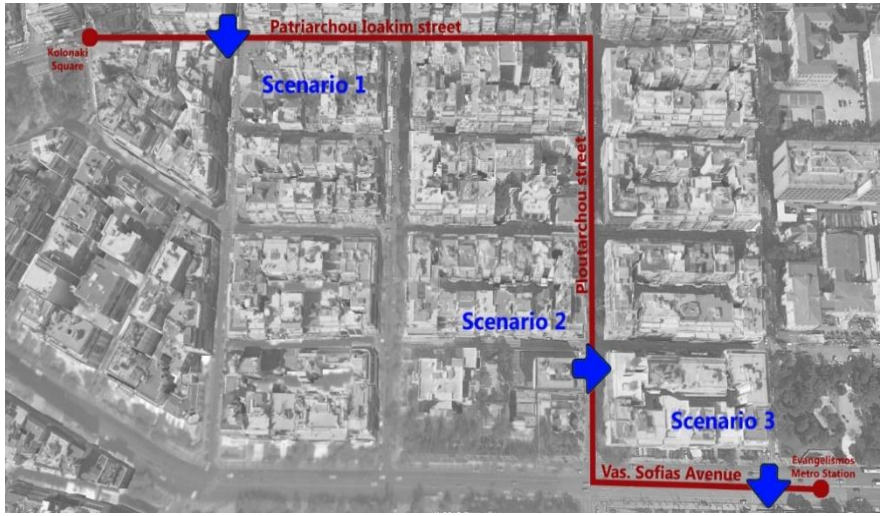
- Measurement equation

- $y_n = \begin{cases} 1, if\ U_{in} > U_{jn} \\ 0, otherwise \end{cases}$

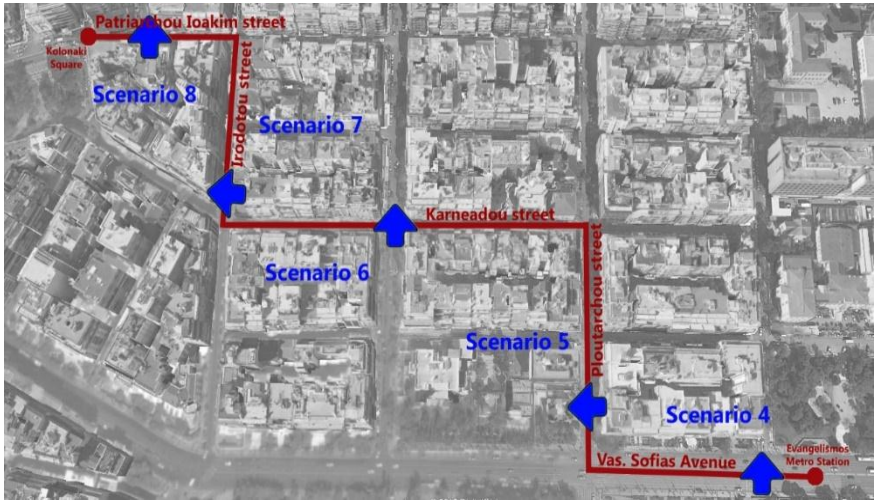
- U_{in}, U_{jn} the utility of each alternative for individual *n*;
- X_{in}, X_{jn} sets of observed variables;
- Z_{1n}, Z_{2n} the latent variables;
- $I_{1n}, I_{2n}, I_{3n}, I_{4n}$ sets of the indicators of the latent variables Z_{1n}, Z_{2n};
- $\tilde{Z}_{1n}, \tilde{Z}_{2n}$ the fitted values of the latent variables, once estimated by the structural equations of the latent variable model;
- W_{1n}, W_{2n} sets of observed variables (characteristics of respondent *n*);
- $\varepsilon_{in}, \varepsilon_{jn}$ extreme value distributed errors; $\omega_{1n}, \omega_{2n}, \upsilon_{1n}, \upsilon_{2n}, \upsilon_{3n}, \upsilon_{4n}$ sets of (multivariate normally distributed) errors;
- $b', b_1, b_2, \alpha_1, \alpha_2, \lambda_1, \lambda_2, \lambda_3, \lambda_4$ unknown parameters to be estimated.

Field survey design

- A trip in the Athens city center, Greece
- From Kolonaki square to Evangelismos metro station and back



- Four walking conditions
  - Major urban arterial
  - Main road
  - Secondary road
  - Minor / residential road
- Eight walking scenarios
- Eight "primary" crossings



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Questionnaire design

B	How many times per week do you travel by each one of the following modes*:
B1_i	Public transport (metro, bus, trolley bus, tramway)
B1_ii	Pedestrian
B1_iii	Passenger car (driver or passenger)
	Last week, how many kilometers did you travel by each one of the following modes**:
B2_i	Passenger car (driver or passenger)
B2_ii	Pedestrian
B2_iii	Public transport (metro, bus, trolley bus, tramway)
	As a pedestrian, how much would you agree with each one of the following statements***:
B3_i.	I walk for the pleasure of it
B3_ii	I walk because it is healthy
B3_iii	In short trips, I prefer to walk
B3_iv	I prefer taking public transportation (buses, metro, tramway, etc.) than my car
B3_iv	I walk because I have no other choice
C	As a pedestrian, how much would you agree with each one of the following statements***:
C1_i.	Crossing roads is difficult
C1_ii.	Crossing roads outside designated locations increases the risk of accident
C1_iii.	Crossing roads outside designated locations is wrong
C1_iv	Crossing roads outside designated locations saves time
C1_v	Crossing roads outside designated locations is acceptable because other people do it
C2_i	I prefer routes with signalized crosswalks
C2_ii	I try to make as few road crossings as possible
C2_iii	I try to take the most direct route to my destination
C2_iv	I prefer to cross diagonally
C2_v	I try to take the route with least traffic to my destination
C2_vi	I am willing to make a detour to find a protected crossing
C2_vii	I am willing to take any opportunity to cross
C2_viii	I am willing to make dangerous actions as a pedestrian to save time

D	Compared to other pedestrians, how much do you agree that***:
D_i	I am less likely to be involved in a road crash than other pedestrians
D_ii	I am faster than other pedestrians
D_iii	I am more careful than other pedestrians
E	As a pedestrian, how often do you adopt each one of the following behaviors****:
E1_i.	I cross diagonally
E1_ii	I cross at midblock at major urban arterials
E1_iii	I cross at midblock at urban roads
E1_iv	I cross at midblock in residential areas
E1_v	I cross at midblock when I am in a hurry
E1_vi	I cross at midblock when there is no oncoming traffic
E1_vii	I cross at midblock when I see other people do it
E1_viii	I cross at midblock when my company prompts me to do it
E1_ix	I prompt my company to cross at midblock
E1_x	I cross at midblock when there is a shop I like on the other side
E1_xi	I cross even though the pedestrian light is red
E1_xii	I walk on the pavement rather than on the sidewalk
E2_i	I cross between vehicles stopped on the roadway in traffic jams
E2_ii	I cross without paying attention to traffic
E2_iii	I am absent-minded while walking
E2_iv	I cross while talking on my cell phone or listing to music on my headphones
E2_v	I cross even though obstacles (parked vehicles, buildings, trees, etc.) obstruct visibility
E2_vi	I cross even though there are oncoming vehicles
F	As a pedestrian, how much would you agree with each one of the following statements***:
F1_i	Drivers are not respectful to pedestrians
F1_ii	Drivers drive too fast
F1_iii	Drivers are aggressive and careless
F1_iv	Drivers should always give way to pedestrians
F1_v	When there is an accident, it is the driver's fault most of the times
F1_vi	I let a car go by, even if I have right-of-way

* (1:never, 2: less than once a week, 3:once a week, 4: more than once a week, 5:every day)
** (1:1-2 km, 2: 3-5 km, 3:5-20 km, 4: 20-50 km, 5: >50 km)
*** (1:strongly disagree, 2: disagree, 3:neither agree nor disagree, 4: agree, 5:strongly agree)
**** (1:never, 2: rarely, 3:sometimes, 4: often, 5:always)

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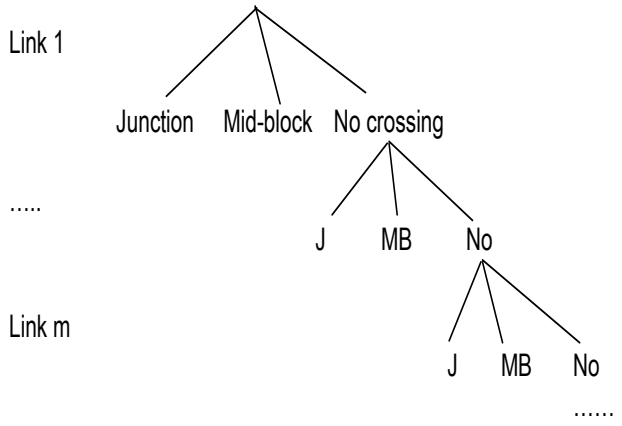
Survey procedures

- July - December 2013
- 75 participants in total
- 53% were males
- 50% were 18-24 years old, 27% were 25-34, 20% were 35-45 and 3% were >45 years old.

- Half of the participants carried out the field experiment after filling in the questionnaire, and half of the participants the other way around
- A trained researcher followed them at a distance of approximately 35 meters and recorded data on each road link by filling-in a form.
  - Static data: road environment, traffic control, obstacles
  - Dynamic data: pedestrian speed, crossing behavior, traffic flow

Models development

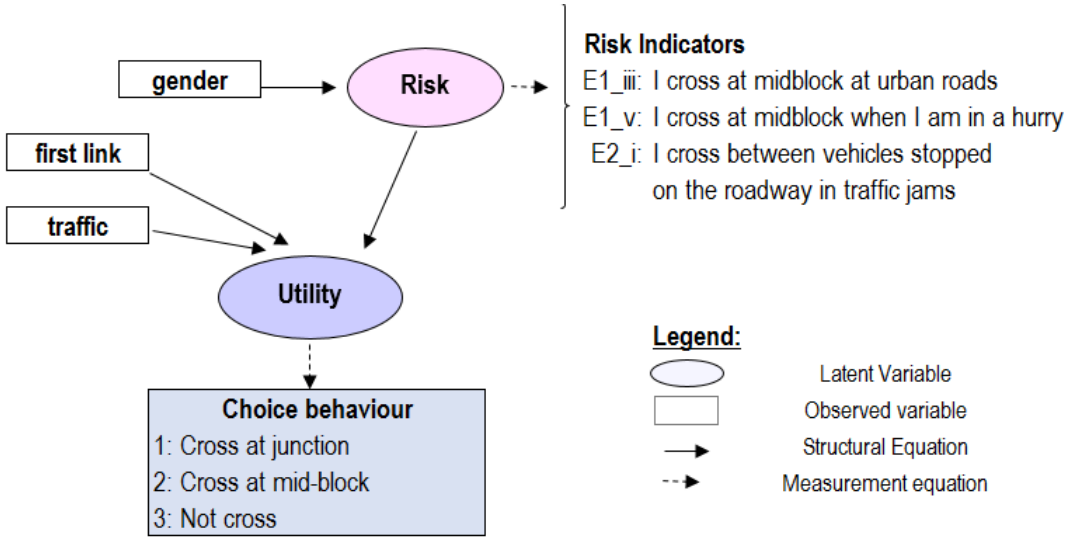
- A probabilistic discrete choice in determining the location of each primary crossing of each scenario
- Sequential choice model
  - Cross at mid-block
  - Cross at junction
  - No crossing



- Exploratory analysis
- A global model for all scenarios unfeasible
- Testing different scenarios separately

Models for main urban roads (1/2)

- Latent variable: "risk"
- Pedestrians with higher "risk" are more likely to report higher scores on indicators
- Pedestrian gender is a significant predictor of "risk" (male pedestrians)
- Pedestrians with higher risk-taking appear to be more likely to cross at mid-block (not statistically significant).
- The first road link has higher probability of being chosen.
- When traffic is low, mid-block crossing probability increases.



Structural model of the latent variable

Risk = -0,55 * gender + ω

Measurement equations: ordered logit

I_E1_iii = 2,78 * risk + u_1

I_E1_v = 3,97 * risk + u_2

I_E2_i = 1,38 * risk + u_3

Utility functions

V1 = -2,74 + 0,466 * first + 1,54 * trafficlow + *0,342* * Risk

V2 = -1,33 + 0,466 * first

V3 = ASC3

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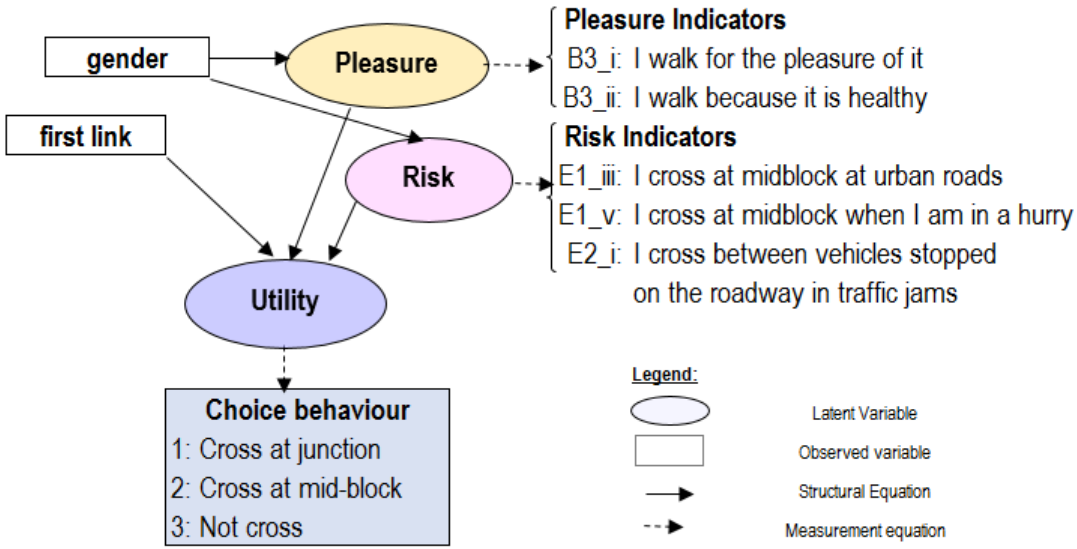
Models for main urban roads (2/2)

- Latent variables: "risk" and "pleasure"
- The presence of the latent variable "pleasure" seems to improve the significance of the latent variable "risk", and the model overall.
- Nevertheless, the latent variable 'pleasure' was not found significant.
- Traffic becomes non significant



Structural models of the latent variables

Risk = 0,538 * gender + ω

Pleasure = -0,375 * gender + ω

Measurement equations: ordered logit

I_E1_iii = -1,34 * risk + u_1 I_B3_i = -1,65 * pleasure + u_4

I_E1_v = -1,89 * risk + u_2 I_B3_ii = -1,32 * pleasure + u_5

I_E2_i = -5,86 * risk + u_3

Utility functions

V1 = -9,44 + 0,427 * first + *-0,410* * Risk *- 0,65* * Pleasure

V2 = -7,23 + 0,427 * first

V3 = ASC3

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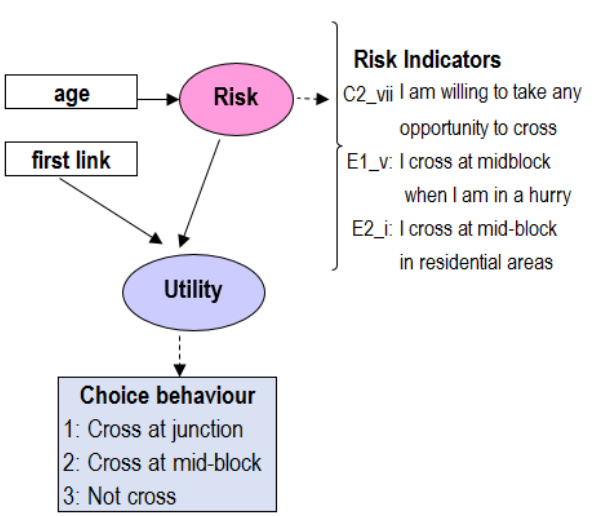
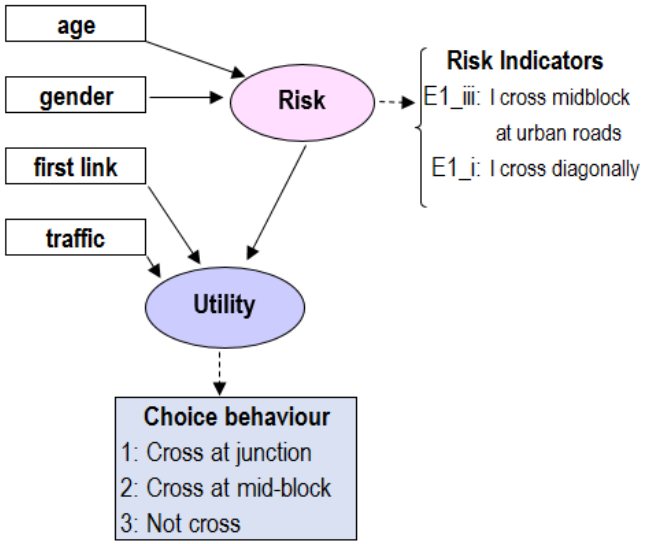
Models for other road types

Major urban arterials



- "Risk": pure risk-taking
- "Risk" significant
- Traffic non singificant

Secondary roads

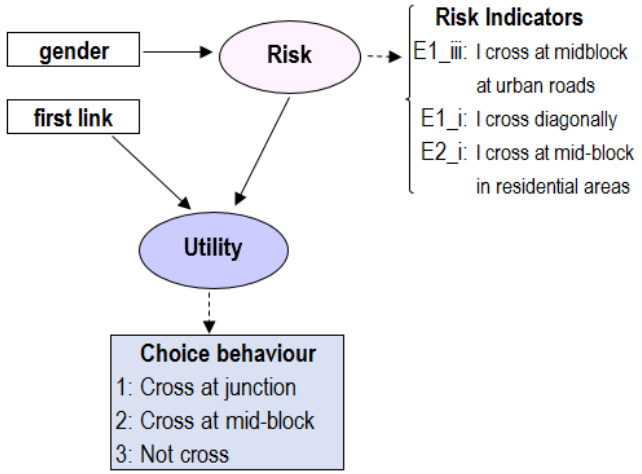


"Risk": trip optimisation

"Risk" non significant

Traffic singificant

Minor/residential roads



"Risk": conformity

"Risk" significant

Traffic non singificant

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Overview of findings

- The effect of traffic volume was non significant on major roads and on minor / residential roads, but was significant on main and secondary roads.
- The effect of risk-taking was significant on major and minor roads, and marginally significant or non-significant on main and secondary roads.
- Overall, "risk-taking" is a key factor for crossing at mid-block when traffic is high, and "trip optimization" is a key factor for crossing at mid-block when traffic is low.
- In none of the ICLV models was 'pleasure' significant (but survey trip not representative of the usual walking motivations)

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Discussion: research hypotheses

- The four ICLV models largely confirm the research hypotheses as per the effects of road and traffic factors of pedestrian behavior.
- The research hypotheses on human factors of pedestrian behavior were not fully confirmed.
- The results do not confirm the structure of the questionnaire and suggest that the underlying dimensions are in fact few

Discussion: methodological

- ICLV models useful for addressing the behavioral aspects of pedestrian trips in urban areas.
- Human factors may be important additional predictors of pedestrian behavior.
- ICLV vs. Two-stage approach
  - ICLV theoretically sounder; however, computationally demanding
  - The measurement error in the two-stage approach appears negligible *in this dataset* as the results of both approaches were similar

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Limitations

- The present sample is not representative of age groups, and the inclusion of older pedestrians in the sample in a future research might reveal additional effects of human factors on crossing behavior.
- The sample size is marginally adequate for a structural equation approach for latent variables.
- Although the model was simplified to enhance validity, more data would be required to generalize the results to different settings.
- Participants knew that they were being observed

"The Anonymous Pedestrians", Wroclaw, Poland

Next steps

- Pedestrian surveys combining field observations and questionnaires appear to be a promising tool.
- The proposed methodology and results need further development, more data and validation before they can be used for practical applications.
- The next steps of the research should address in particular the model's validation, internal and external (i.e. by means of new data collected).
- Allow tackling the question of using such models for prediction.

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