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Introducing Human Factors in Pedestrian Crossing Behavior Models

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PEDMOD
MODELS OF PEDESTRIAN BEHAVIOUR AND SAFETY

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Abstract

The objective of this research is the development of pedestrian crossing choice models on the basis of road, traffic and human factors. For that purpose, a field survey was carried out, in which a panel of 75 pedestrians were asked to take 8 short walking trips (each one corresponding to a different walking and crossing scenario) in the Athens city centre in Greece, allowing to record their crossing behavior in different road and traffic conditions. The same individuals were asked to fill in a questionnaire on their travel motivations, their mobility characteristics, their risk perceptions and preferences with respect to walking and road crossing, their opinion on drivers etc. The walking and crossing scenarios' data were used to develop mixed sequential logit models of pedestrian behavior on the basis of road and traffic characteristics. The modeling results showed that pedestrian crossing choices are significantly affected by road type, traffic flow and traffic control. The questionnaire data were used to estimate human factors (components) of pedestrian crossing behavior by means of principal component analysis. The results showed that three components of pedestrian crossing behavior emerge, namely a "risk-taking and optimization" component reflecting the tendency to cross at mid-block in order to save time etc., a "conservative" component, concerning individuals with increased perceived risk of mid-block crossing, who also appear to be frequent public transport users, and a "pedestrian for pleasure" component, bringing together frequent pedestrians, walking for health or pleasure etc. The introduction of these components as explanatory variables into the choice models resulted in improvement of the modeling results, indicating that human factors have additional explanatory power over road and traffic factors of pedestrian behavior. Therefore, the development of integrated choice and latent variables models appears to be an appropriate field for further research.

Background & Objectives

- Although signalized junctions provide pedestrians a protected crossing phase, most pedestrians tend to prefer using the available traffic gaps for crossing.
- **Mid-block crossing and diagonal crossing** are common practice among pedestrians aiming to save travel time or distance.
- Existing research on pedestrians crossing behavior in urban areas includes gap acceptance models, level of service models or **choice (utility) models**.
- A distinct part of existing research on pedestrian crossing behavior is devoted to analyses of psychological, attitudinal, perceptual and motivational factors; however, **human factors** are seldom incorporated in pedestrian behavior models

Objectives

the analysis of pedestrians' crossing behavior along entire trips in urban areas, with emphasis on the introduction of human factors in the potential determinants

1. **to identify human factors** of pedestrian crossing choices (pedestrians' attitudes, perceptions, travel motivations and habits etc.)
2. **to develop choice models** for estimating the probability to cross at each location along a pedestrian trip in relation to roadway design, traffic flow and traffic control
3. **to introduce human factors** into the choice models in order to test their explanatory power in the crossing behaviour models

Research hypotheses

❖ Road and traffic factors of pedestrian crossing behavior

Road type:
- ❑ **Residential zones** (minor urban roads): pedestrians will choose the shortest path, due to the lack of constraints and vehicle-pedestrian interaction.
- ❑ **Major urban arterials**: all pedestrians will opt for a protected crossing at junction.
- ❑ **Mixed urban area** (secondary roads): more variation is expected in crossing behavior.

Traffic flow:
- ❑ **No traffic**: pedestrians will choose the shortest path.
- ❑ **Low traffic**: increased probability of crossing at mid-block or diagonally,
- ❑ **High traffic**: increased probability of seeking for a protected crossing at junction.
- ❑ **Congestion**: pedestrians are also likely to cross diagonally, 'in between' stopped vehicles.

Traffic control:
- ❑ **Traffic signal**: leads to increased probability of crossing at junction.

Infrastructure design
- ❑ **Obstacles and barriers**: obstacles (illegally parked vehicles, roadside barriers and guardrails), or **local design elements** may lead pedestrians to a deterministic choice.

❖ Human factors of pedestrian crossing behavior

Demographics:
- ❑ **Younger and male** pedestrians are more risk-taking and less compliant to traffic rules.
- ❑ **Low income**, perceived social inequality and the lack of alternatives to walking may lead pedestrians to more aggressive behavior.

Travel motivations:
- ❑ Positive relationship between **walking frequency / distance travelled** and crossing behavior is assumed.
- ❑ Pedestrians **walking for health / pleasure** are less risk-taking and more safety conscious.

Risk perception and value of time: different types of pedestrians
- ❑ ones that **minimize the number of crossings** and increase the trip length to avoid vehicles
- ❑ others who maximize the number of crossings in order to **minimize the length of the trip**

Interaction with other road users:
- ❑ imitation and **leader / follower** effects
- ❑ **opinion towards drivers** : pedestrians with negative opinion on drivers are more likely to be careful and compliant

Data collection

❖ Survey design

- Pedestrians were followed along urban trips, and their crossing behavior was recorded, together with features of the road environment and the traffic conditions.
- They were also asked to fill in a questionnaire.
- The field survey site is located at the **Athens central area**, from Evangelismos metro station to Kolonaki square.

❖ Survey questionnaire

- Section A: Demographics
- Section B: Mobility and travel motivations
- Section C: Attitudes, perceptions and preferences
- Section D: Self-assessment and identity
- Section E: Behavior, compliance and risk taking
- Section F: Opinion on drivers

❖ Field survey scenarios

- Eight crossing scenarios: fractional factorial design
- ***[road type * traffic flow * traffic control]***
- **Scenarios (i) and (viii)**: Crossing a main urban road with signal controlled and uncontrolled crosswalks
- **Scenarios (ii), (v), (vi) and (vii)**: Crossing a minor (residential) road with or without marked crosswalks:
- **Scenarios (iii) and (iv)**: Crossing a major urban arterial with signal controlled crosswalks

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)

❖ Survey participants

- **75 participants** recruited among students and graduates of the National Technical University of Athens (NTUA)
- 53% of the survey participants were males.
- Age distribution: 50% were 18-24 years old, 27% were 25-34, 20% were 35-45 and 3% were >45 years old.

Analysis methods

❖ Parameterization of pedestrian trips and crossings

- A **topological approach** of urban road networks and pedestrian trips: the number and type of crossings along a pedestrian trip, as well as their choice alternatives can be determined.
- Only one crossing of interest will take place for each scenario, namely a 'primary' crossing.
- **Primary crossings** - defined in previous research - are crossings that take place across the pedestrian trajectory for changing side of the road and their choice is stochastic (i.e. pedestrian may choose from a number of alternative locations).

❖ CATPCA - Categorical Principal Component Analysis

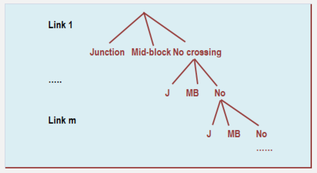
- 'Component' analysis techniques reveal **underlying 'components'** (or 'factors') structured on the basis of a thematically organized set of indicators.
- Categorical Principal Component Analysis (CATPCA): **an optimal scaling technique**
- Converts discrete (nominal and ordinal) variables to **"interval continuous"** variables.
- CATPCA is applied on the optimally scaled variables / indicators, in order to **reduce the dimensionality** of the dataset to a predefined number of dimensions.

❖ Mixed sequential logit models

- A **probabilistic discrete choice** for determining the location of each primary crossing from choice set.
- Sequential choices of a group of individuals (panel data)
- A **Utility function** with systematic component ($\beta_i' X_{in}$), stochastic component (ε_{in}) and individual-specific heterogeneity (α_n) ~ $[0, \sigma^2]$:

$$U_{in} = \beta_i' X_{in} + \alpha_n + \varepsilon_{in}$$

- **Three alternatives** for each road link of each scenario
- 'crossing at junction' (J)
- 'crossing at mid-block' (MB)
- 'no crossing' (No).



Results

❖ Estimation of human factors of pedestrian crossing behaviour

- Optimal scaling was applied on the 51 variables of the questionnaire, which were defined as multiple ordinal
- **3 components** explaining 65% of the total variance from the 51 optimally scaled variables are extracted (eigenvalue>1 criterion).

Component 1: Risk taker & optimizer	Loadings
Crossing roads outside designated locations increases the risk of accident	-0.568
Crossing roads outside designated locations is wrong	-0.509
Crossing roads outside designated locations is acceptable because other people do it	0.418
I prefer to cross diagonally	0.633
I am willing to make a detour to find a protected crossing	-0.564
I am willing to take any opportunity to cross	0.636
I am willing to make dangerous actions as a pedestrian to save time	0.526
I am faster than other pedestrians	0.473
I cross diagonally	0.674
I cross at midblock at major urban arterials	0.579
I cross at midblock at urban roads	0.739
I cross at midblock in residential areas	0.723
I cross at midblock when I am in a hurry	0.825
I cross at midblock when there is no oncoming traffic	0.602
I cross at midblock when I see other people do it	0.467
I cross at midblock when my company prompts me to do it	0.575
I prompt my company to cross at midblock	0.746
I cross even though the pedestrian light is red	0.593
I cross between vehicles stopped on the roadway in traffic jams	0.658
I cross even though obstacles (parked vehicles, buildings, trees, etc.) obstruct visibility	0.548
I cross even though there are oncoming vehicles	0.683

Component 2: Conservative & public transport user	Loadings
Weekly travel by Public transport	0.698
Weekly travel by Pedestrian	0.470
Weekly travel by Passenger car	-0.534
Weekly Km of travel by Passenger car	-0.475
Weekly Km of travel by Public transport	0.724
I prefer taking public transportation than my car	0.493
Crossing roads is difficult	0.558
I try to make as few road crossings as possible	-.463
I prefer to cross diagonally	-.503
I am less likely to be involved in a road crash than other pedestrians	-.452
Component 3: Pedestrian for pleasure	**Loadings**
Weekly travel by Pedestrian	0.570
Weekly travel by Passenger car (driver or passenger)	-0.593
WeeklyKm of travel by Passenger car (driver or passenger)	-0.534
WeeklyKm of travel by Pedestrian	0.583
I walk for the pleasure of it	0.562
I walk because it is healthy	0.628
I prefer routes with singalised crosswalks	0.419
I am willing to make a detour to find a protected crossing	.417
I cross at midblock when there is a shop I like on the other side	.425
When there is an accident, it is the driver's fault most of the times	.478

❖ Development of a crossing choice model with road, traffic and human factors

Utility functions

0 (cross at mid-block)	=	ASC0 * one + B0_first * first + B0_majorroad * majorroad + B0_secondaryroad * secondaryroad + B0_minorroad * minorroad + B0_trafficempty * trafficempty + B0_trafficlow * trafficlow + B0_traffichighcong * traffichighcong + B0_comp1 * Comp1 + B0_comp3 * Comp3 + ZERO [SIGMA] * one
1 (cross at junction)	=	ASC1 * one + B1_first * first + B1_signal * L_signal + B1_barriers * L_barriers + ZERO [SIGMA] * one
2 (no crossing)	=	ASC2 * one

Utility parameters

Name	Value	Std. error	t-test	P-value
ASC0	-3.890	0.457	-8.510	0.000
ASC1	-2.040	0.230	-8.880	0.000
ASC2	0.000	–fixed–		
B0_comp1	0.201	0.107	1.880	0.060
B0_comp3	-0.161	0.114	-1.410	0.160
B0_first	0.893	0.252	3.550	0.000
B0_majorroad	0.000	–fixed–		
B0_minorroad	0.631	0.300	2.100	0.040
B0_secondaryroad	1.630	0.374	4.370	0.000
B0_trafficempty	1.360	0.395	3.450	0.000
B0_traffichighcong	0.000	–fixed–		
B0_trafficlow	0.664	0.317	2.100	0.040
B1_barriers	0.936	0.205	4.570	0.000
B1_first	0.978	0.206	4.750	0.000
B1_signal	0.177	0.177	1.000	0.320
SIGMA	-0.371	0.122	-3.050	0.000
ZERO		–fixed–		

Variance of normal random coefficients

Name	Value	Std.error	t-test
ZERO_SIGMA	0.138	0.104	1.320

Model's fit

Number of estimated parameters	13	Nulllog-likelihood	-1043.86
Number of observations	1048	Finallog-likelihood	-812.475
Numberofindividuals	74	Likelihoodratiotest	461.223

- **'State dependence'** (B0_first, B1_first, B0_skip1): the first road link is more likely to be chosen for crossing compared to not crossing. Moreover, it is slightly more likely to be chosen for a junction crossing than for a mid-block crossing.
- Skipping one crossing opportunity affects the probability of crossing at the next crossing opportunity.

- **Effect of road type on mid-block crossing utility** (B0_majorroad, B0_secondaryroad, B0_minorroad): secondary roads and minor roads are more likely to be chosen for mid-block crossings than major roads.
- **Effect of traffic on mid-block crossing utility** (B0_trafficempty, B0_trafficlow, B0_traffichighcong): pedestrians are more likely to cross at mid-block when traffic is low, and even more likely when there is no traffic, compared to when traffic is high or at congestion.
- **Effect of traffic signal** (B1_signal): traffic signal was found to increase the probability for junction crossing.
- **Effect of barriers** (B1_barriers): the presence of barriers increases the probability of crossing at junction.
- **Effect of pedestrian speed** (B0_speed): a weak tendency of faster pedestrians to cross at mid-block.

- **'Risk-taking pedestrians and optimizers"** (B0_comp1) are more likely than others to cross at mid-block.
- **'Pedestrians for pleasure'** (B0_comp3) are (marginally) correlated with reduced probability for crossing at mid-block, in contrast to those of component 1.

- **Panel effect (**with mean equal to zero, standard deviation equal to 'sigma' and variance equal to 'zero_sigma'): The variance of the random effect is marginally significant.

Discussion

❖ Unlike most existing studies, which either examine only road and traffic parameters and pedestrian demographics, or heavily focus on human factors alone, the present research attempted to **examine the interaction between road factors, traffic factors and human factors (**pedestrian attitudes, perceptions and preferences) in crossing choice modeling.

The basic research hypotheses appear to be largely confirmed.

❖ Both **fixed and random effects of human factors** were found to be significant, although not strongly. However, their contribution to the overall fit of the model is rather small.

❖ The method implemented here is **an intermediate step towards the introduction of human factors** in pedestrian choice models.

❖ **A two-stage approach** was implemented: (i) a principal component analysis to estimate the latent variables "components" and (ii) their scores introduced in the choice model.

❖ Only the mean component scores are introduced (i.e. their variance is not included), some measurement errors and inconsistent estimates may be obtained.

*As a next step, **"integrated choice and latent variables models"** can be estimated.*

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