AGE-DRIVEN PEDESTRIAN MOBILITY IN URBAN ENVIRONMENTS: AN EMPIRICAL STUDY ON CROSSING BEHAVIOR

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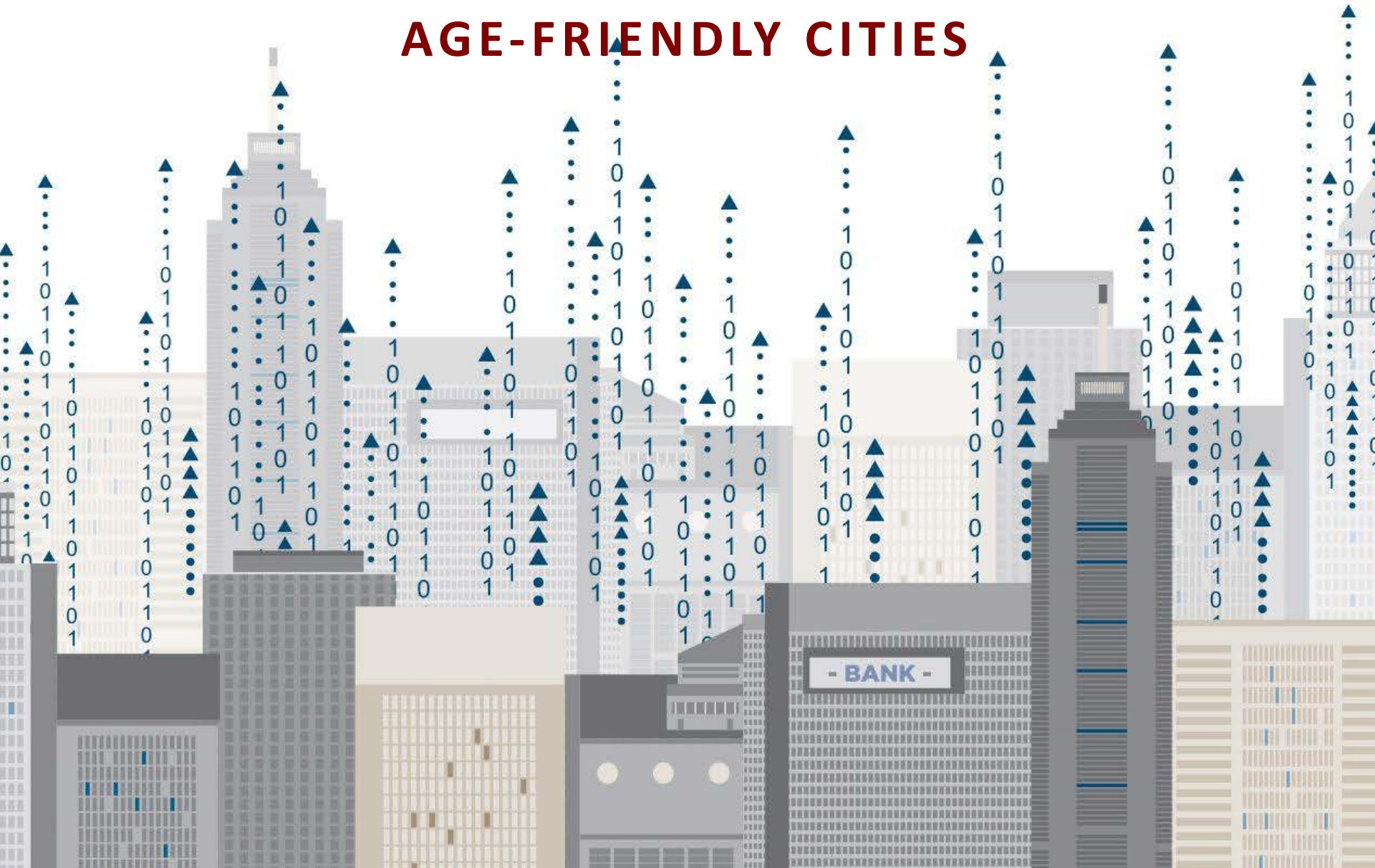
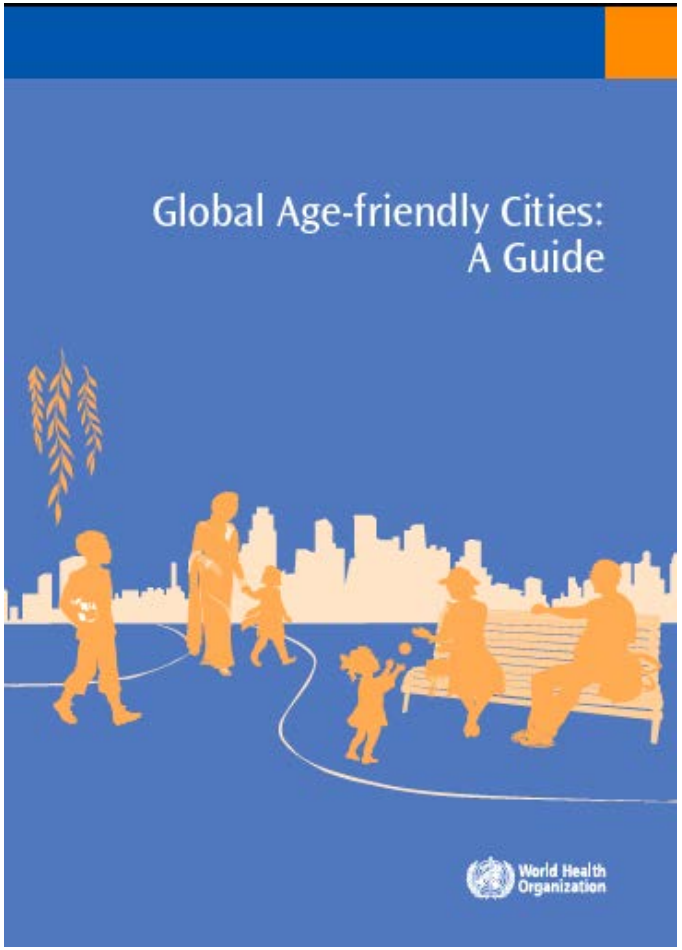
MOBILITY AND THE CITY OF THE FUTURE
VSJF - Association for Social Science Research in Japan, (Duisburg, D)
Annual Meeting, 18.-20. November 2016
Panel 4 - Mobility in the Ageing Society

AGE-FRIENDLY CITIES



The notion of **Age-friendly Cities (WHO – World Health Organization)** offers a framework for the development of urban contexts encouraging the active ageing of the citizens.



Guidelines for assessing and increasing the accessibility and safety of urban facilities for the elderly.

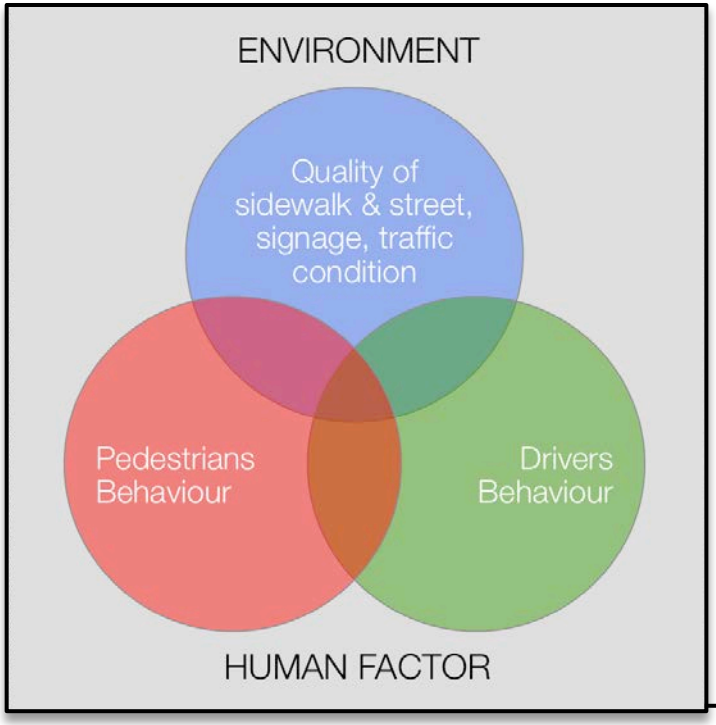
Japan wants us self-driving to the 2020 Tokyo Summer Olympics

Posted on September 9, 2016 in TRANSPORT

Jan 21, 2016 - Japan's first extensive tests of autonomous cars are happening in a sleepy beach town called Suzu. The goal is to give the aging nation's elderly citizens a way to get around. Photo: Kanazawa University

WALKABILITY

MOTIVATIONS



WHY

European Chart of Pedestrians' Rights, 1988

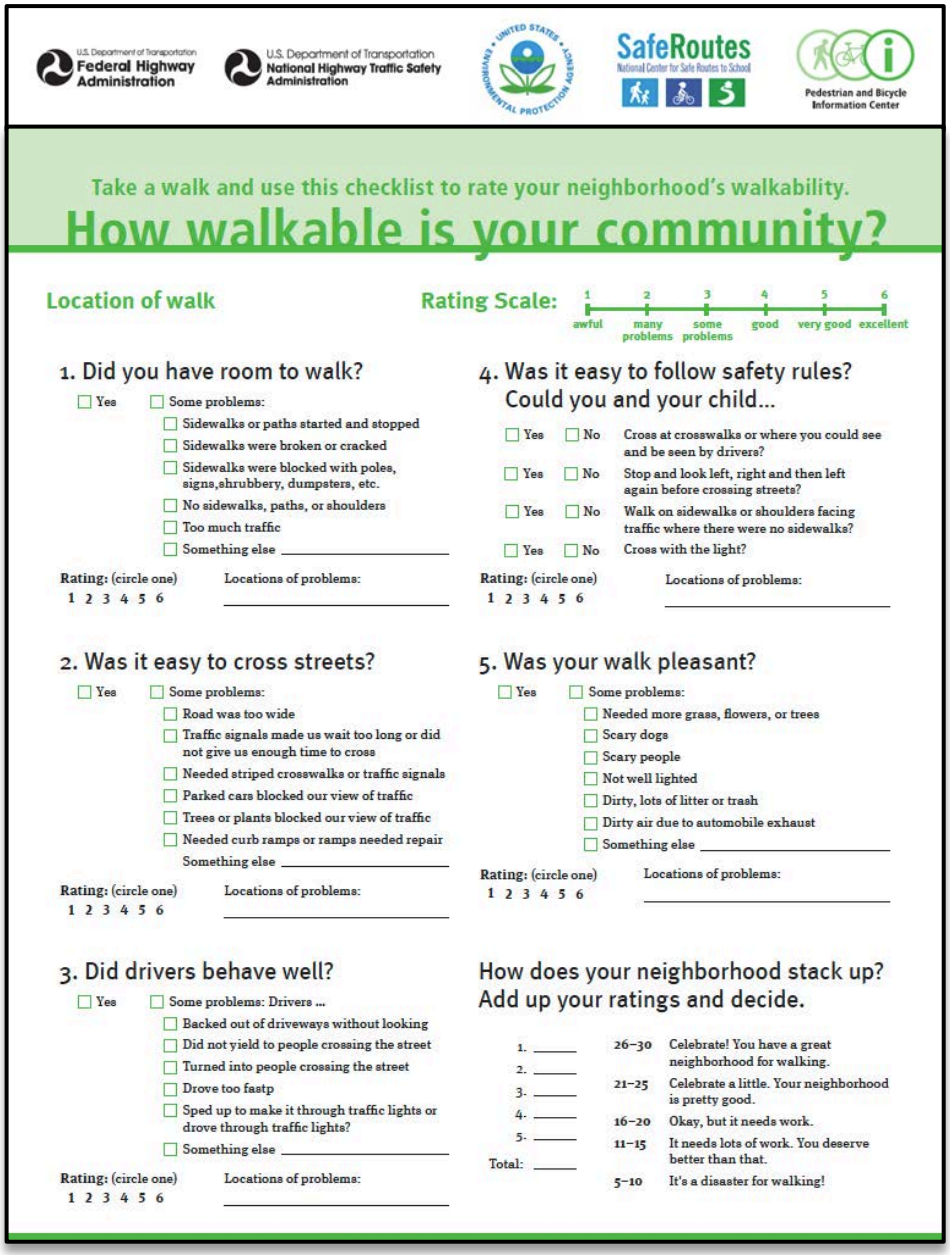
- **Art. No.1:** "The pedestrian has the right to live in a healthy environment and freely to enjoy the amenities offered by public areas under conditions that adequately safeguard his **physical and psychological well-being**"
- **Art. No.3:** "Children, the **elderly** and the disabled have the right to expect towns to be places of easy social contact and not places that aggravate their inherent weakness".

WALKABILITY ASSESSMENT

Walkability: how conducive and friendly the urban environment is for walking (e.g., quality of sidewalks, route navigation, pedestrian-vehicular interaction, architectonic barriers)

Focus on the **comfort** and **safety** of **crossing pedestrians** in urban unsignalized intersections

Reference on **elderlies** as a vulnerable group of the population



U.S. Department of Transportation Federal Highway Administration
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SafeRoutes National Center for Safe Routes to School
Pedestrian and Bicycle Information Center

Take a walk and use this checklist to rate your neighborhood's walkability.

How walkable is your community?

Location of walk

Rating Scale: 1 awful; 2 many problems; 3 some problems; 4 good; 5 very good; 6 excellent

1. Did you have room to walk?

☐ Yes ☐ Some problems:
- ☐ Sidewalks or paths started and stopped
- ☐ Sidewalks were broken or cracked
- ☐ Sidewalks were blocked with poles, signs,shrubbery, dumpsters, etc.
- ☐ No sidewalks, paths, or shoulders
- ☐ Too much traffic
- ☐ Something else _____

Rating: (circle one) 1 2 3 4 5 6 Locations of problems: _____

2. Was it easy to cross streets?

☐ Yes ☐ Some problems:
- ☐ Road was too wide
- ☐ Traffic signals made us wait too long or did not give us enough time to cross
- ☐ Needed striped crosswalks or traffic signals
- ☐ Parked cars blocked our view of traffic
- ☐ Trees or plants blocked our view of traffic
- ☐ Needed curb ramps or ramps needed repair
- Something else _____

Rating: (circle one) 1 2 3 4 5 6 Locations of problems: _____

3. Did drivers behave well?

☐ Yes ☐ Some problems: Drivers ...
- ☐ Backed out of driveways without looking
- ☐ Did not yield to people crossing the street
- ☐ Turned into people crossing the street
- ☐ Drove too fastp
- ☐ Sped up to make it through traffic lights or drove through traffic lights?
- ☐ Something else _____

Rating: (circle one) 1 2 3 4 5 6 Locations of problems: _____

4. Was it easy to follow safety rules? Could you and your child...

☐ Yes	☐ No	Cross at crosswalks or where you could see and be seen by drivers?
☐ Yes	☐ No	Stop and look left, right and then left again before crossing streets?
☐ Yes	☐ No	Walk on sidewalks or shoulders facing traffic where there were no sidewalks?
☐ Yes	☐ No	Cross with the light?

Rating: (circle one) 1 2 3 4 5 6 Locations of problems: _____

5. Was your walk pleasant?

☐ Yes ☐ Some problems:
- ☐ Needed more grass, flowers, or trees
- ☐ Scary dogs
- ☐ Scary people
- ☐ Not well lighted
- ☐ Dirty, lots of litter or trash
- ☐ Dirty air due to automobile exhaust
- ☐ Something else _____

Rating: (circle one) 1 2 3 4 5 6 Locations of problems: _____

How does your neighborhood stack up? Add up your ratings and decide.

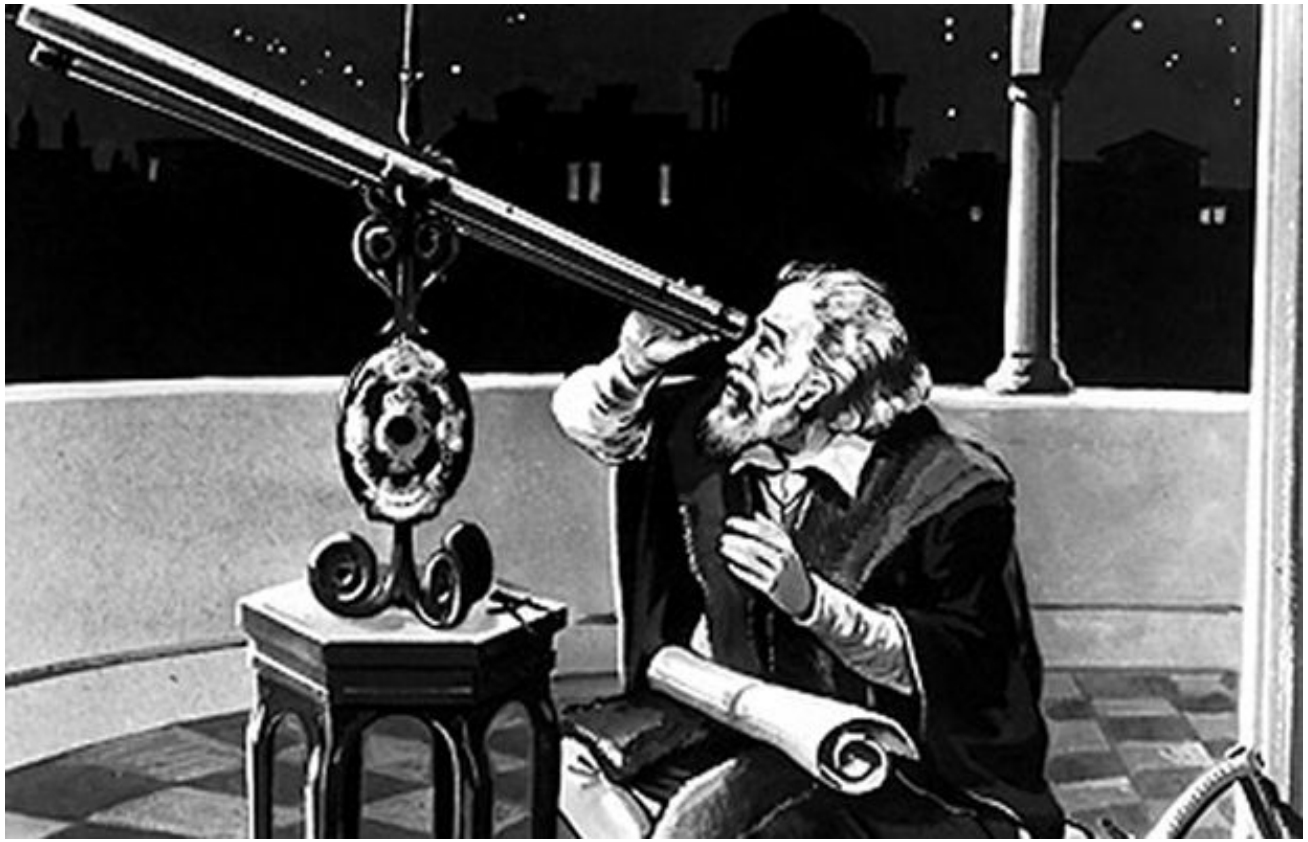
1. _____
2. _____
3. _____
4. _____
5. _____

Total: _____

26–30	Celebrate! You have a great neighborhood for walking.
21–25	Celebrate a little. Your neighborhood is pretty good.
16–20	Okay, but it needs work.
11–15	It needs lots of work. You deserve better than that.
5–10	It's a disaster for walking!

Walkability Assessment

TOWARDS A SCIENTIFIC APPROACH TO WALKABILITY



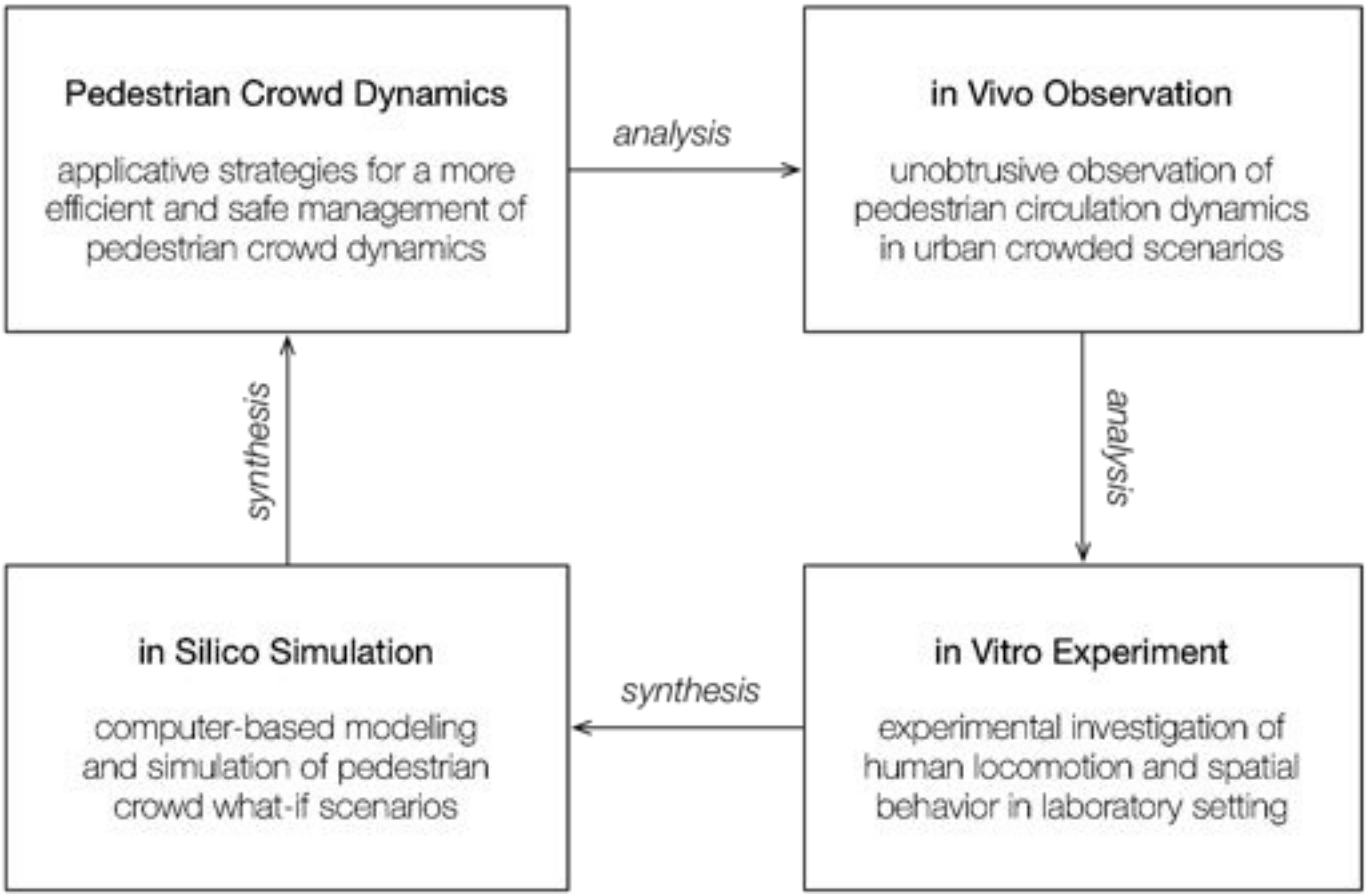
COMPUTER-BASED SIMULATION

Computer-based simulation is a consolidated field of research and application supporting designers and decision makers in the design of transportation networks and **crowd/pedestrian management**.

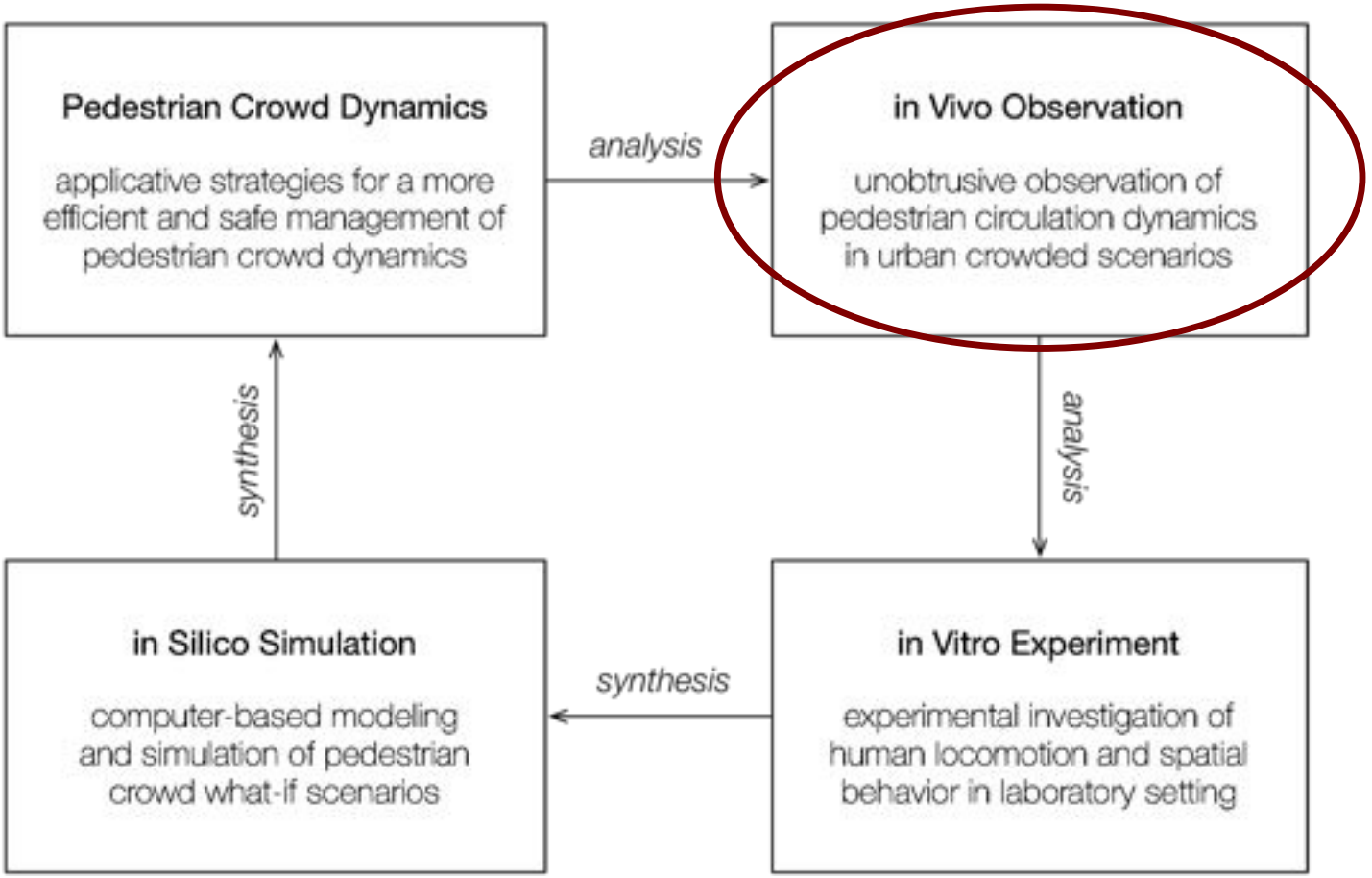
The use of simulations supports the study of pedestrian/vehicle interactions in a predictive and explanatory scheme, to guarantee the **comfort and safety of people** in urban areas and to contrast the **social costs** of pedestrians' injury and death due to car accidents.

The plausibility of simulation results **has to be tested** against empirical data collected by means of video-recorded observations and experiments in order to validate the model.

METHODOLOGICAL CYCLE



METHODOLOGICAL CYCLE



IN VIVO OBSERVATIONS

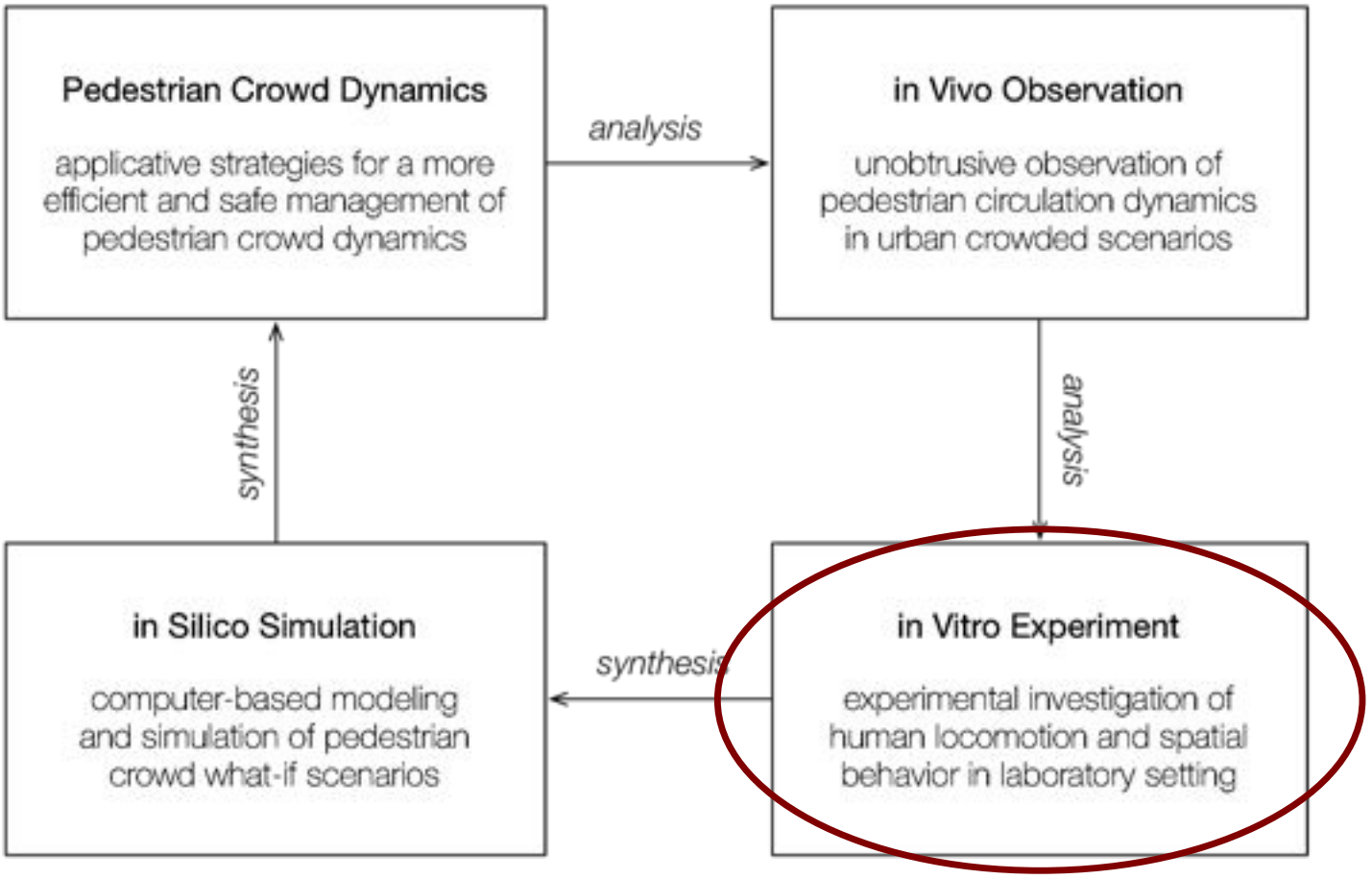
In vivo observations allow collecting empirical data about human behavior, considering the environment and the social context in which the subjects are situated.

This method allow to achieve results about rare phenomena that are difficult to be studied in laboratory setting, due to ethical and practical reasons.

Unobtrusive observation: the privacy of the people participating the study represents a crucial aspect, due to the difficulty to obtain their informed consent beforehand.

Ursus Wehrli

METHODOLOGICAL CYCLE



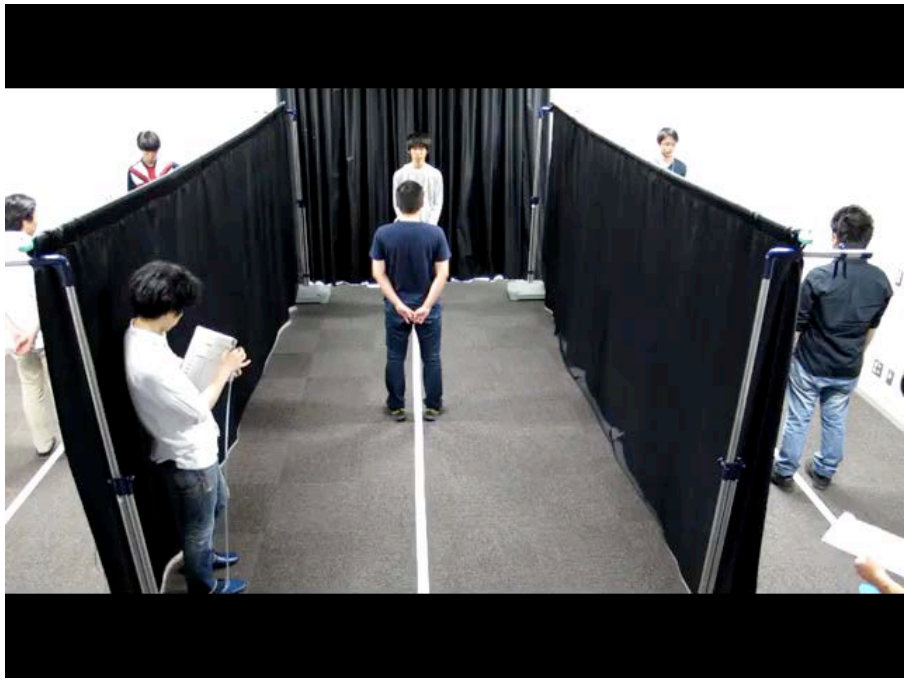
CONTROLLED EXPERIMENTS: *IN VITRO*

Collecting empirical data by measuring the impact of a manipulated stimulus event (independent variable) on subject's behavior (dependent variable) in terms of occurrence, magnitude and persistence.

EXP A: stop-distance

EXP B: approach-distance

EXP C: locomotion-distance

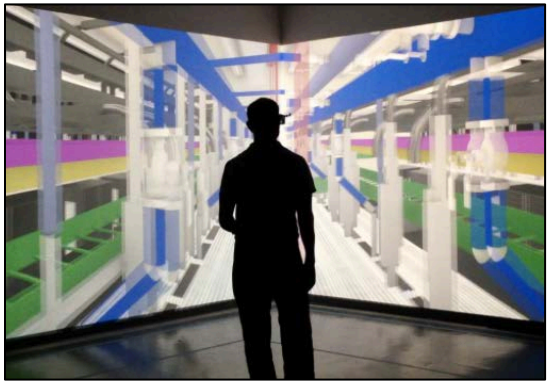


Walking Speed	EXP A – stop distance	EXP B – approach distance	EXP C – locomotion distance
Low (0.93 m/s)	72.15 cm	70.10 cm	71.45 cm
Medium (1.23 m/s)	**94.40 cm**	71.70 cm	68.90 cm
High (1.46 m/s)	**96.00 cm**	68.45 cm	**91.10 cm**

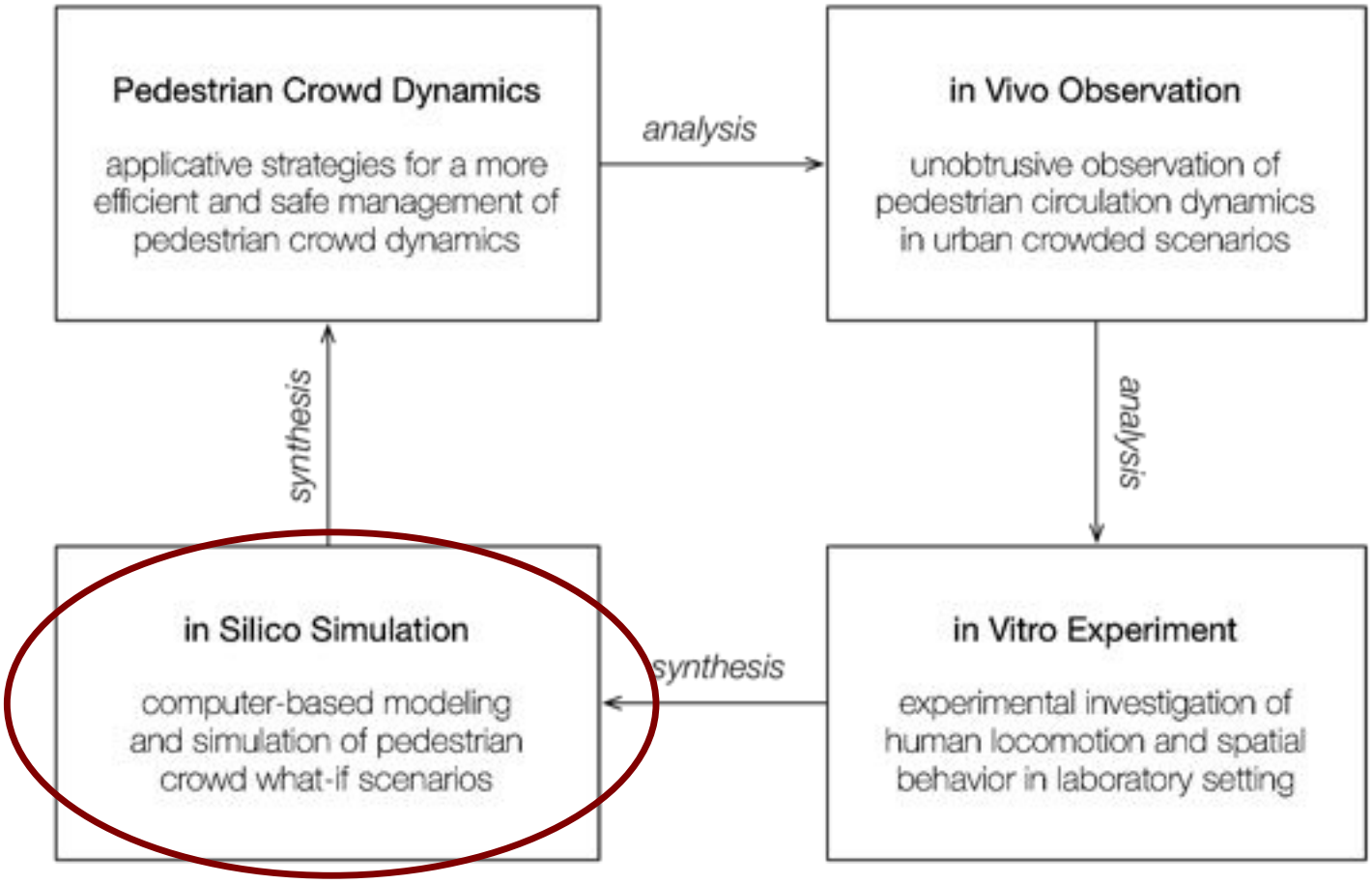
IN VITRO: VIRTUAL REALITY EXPERIMENTS

Virtual reality allows for greater experimental control, improving the possibility to extend results on real world.

Create a **simplified virtual scenario** with similar underlying environmental properties, and compare results with observations and experiments.



METHODOLOGICAL CYCLE

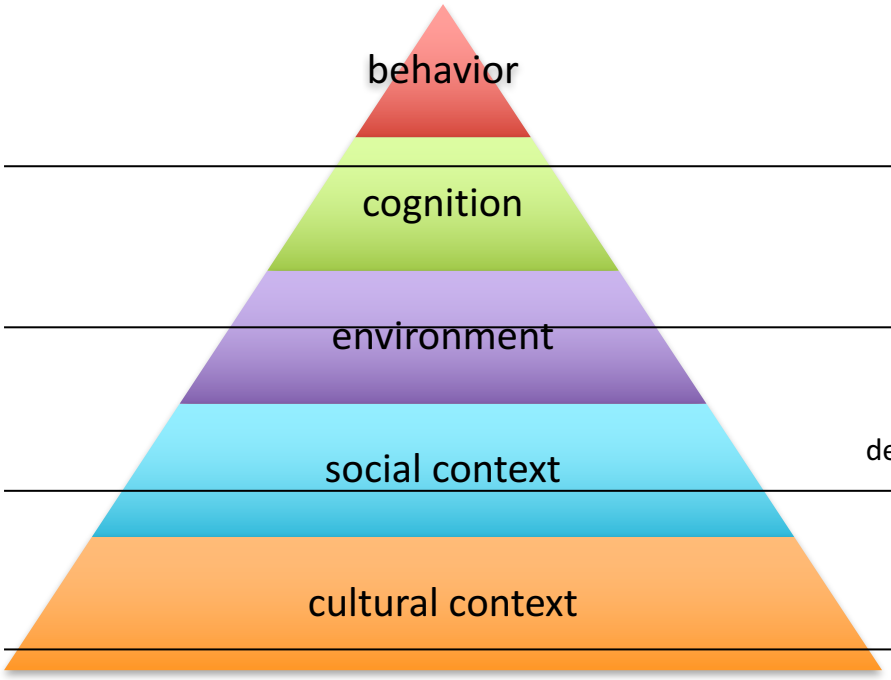


IN SILICO SIMULATIONS

BREAKING DISCIPLINARY BORDERS

Computer-based
modelling and simulation

Social Sciences
empirical studies



crossing behavior

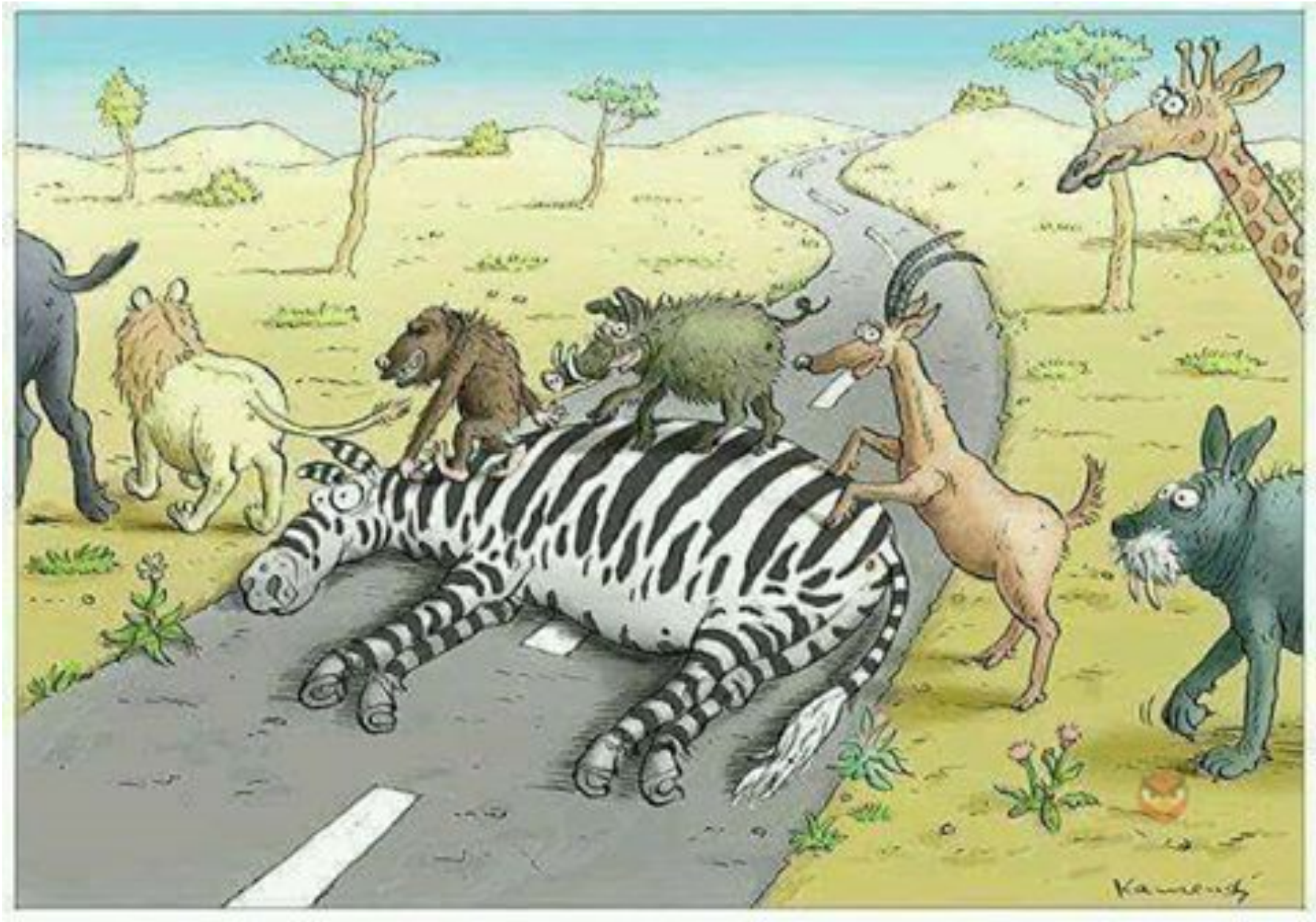
attention, perception, decision making

design of crossing facilities, walkability degree

age profile, grouping

compliance to traffic law

ROAD CROSSING



CULTURAL-DRIVEN CROSSING BEHAVIOR

- Different level of compliance to traffic laws
- Risk perception and motivation towards hazardous situation
- Stress response to traffic condition

Ethiopia

Vietnam

AGE-DRIVEN CROSSING BEHAVIOR

Elderly pedestrians are more likely to die or be seriously injured in road traffic collisions than adult people, due to:

- **limitations in locomotion behavior** (reduced range of motion, loss of muscle strength and coordination, changes in posture, decreased walking speed)

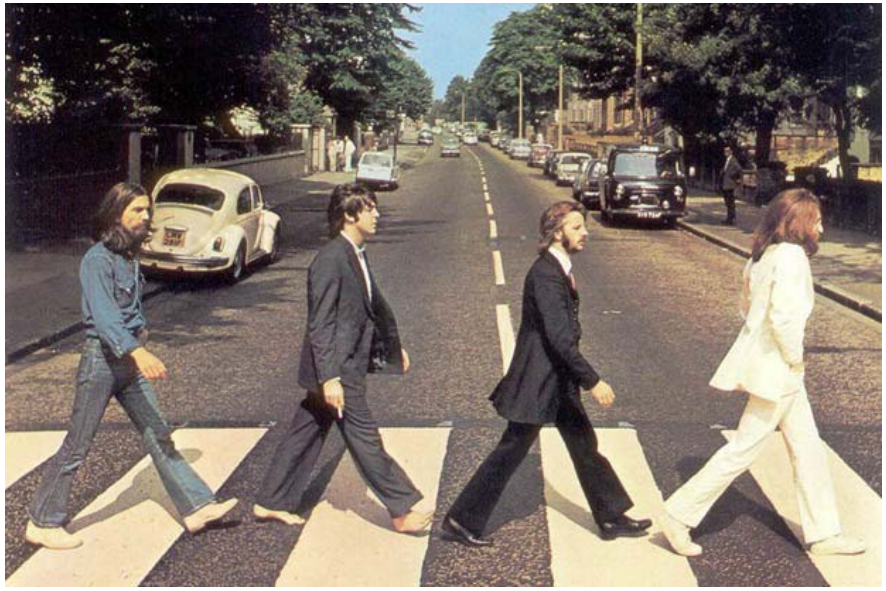
- the progressive **decline in the operation of perceptive sensors and cognitive skills** (limited perception of light and colors, inability to tune out background noise, diminished attention and reaction time, spatial disorientation, slower decision-making)

UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA

日本学術振興会 Japan Society for the Promotion of Science

Univ. Tokyo RCAST 東京大学 先端科学技術研究センター

TOWARDS MODELING PEDESTRIAN-VEHICLE INTERACTIONS: EMPIRICAL STUDY ON URBAN UNSIGNALIZED INTERSECTION



WHAT

Modeling and simulating pedestrian behavioral dynamics

Measuring AGE and GROUP-driven behavior

Assessing the **walkability** of critical areas

WHY

Mobility strategy to face the progressive urbanization (Smart Cities)

Including **vulnerable pedestrians** (Age-friendly Cities)

WHERE

THE CASE: Urban unsignalized intersection

Risky scenario for crossing pedestrians

HOW

Computer-based modeling and simulation

↓

Naturalistic observation

Geographic information system

Questionnaire

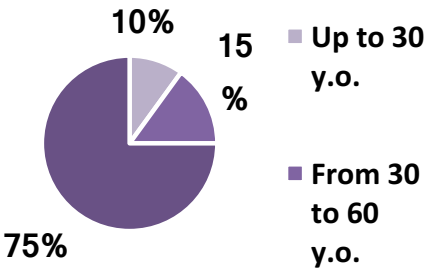
Community areas in Milan with the highest density and percentage of elderly people

Roads with the highest percentage of accidents involving elderly people

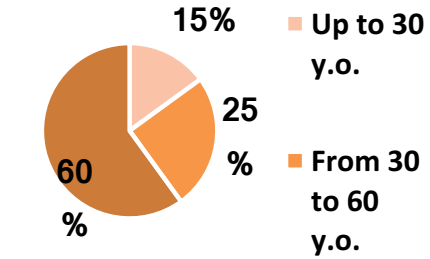
Demographic data for Community Areas of Milan from **ISTAT and the Municipality**

Collecting data from "**Protezione civile**" about road traffic accidents in the city of Milan

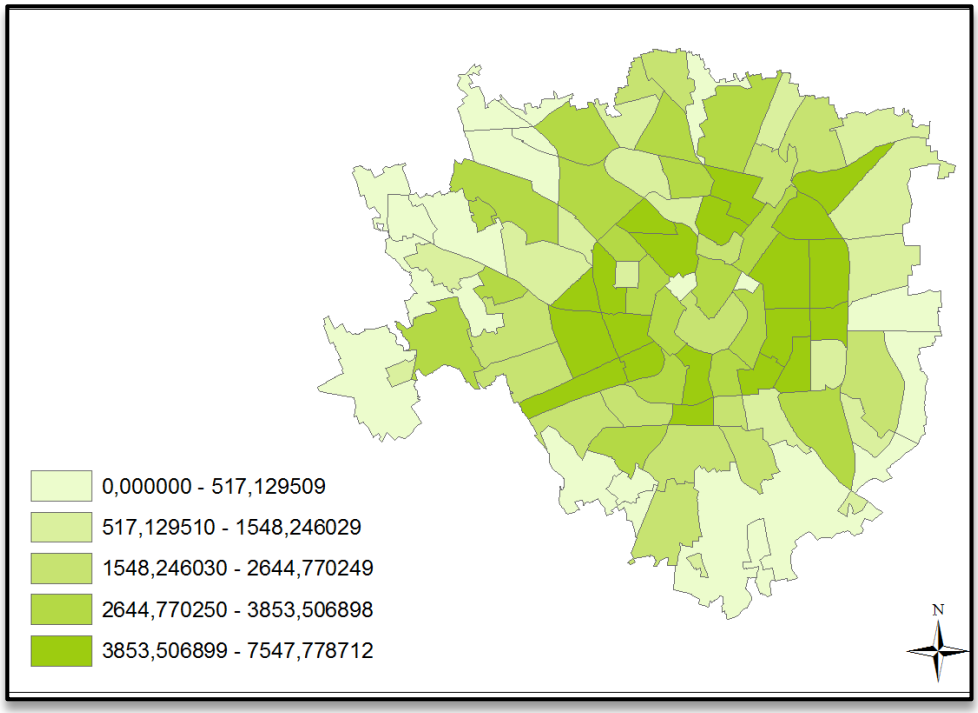
NATIONAL LEVEL



CITY OF MILAN

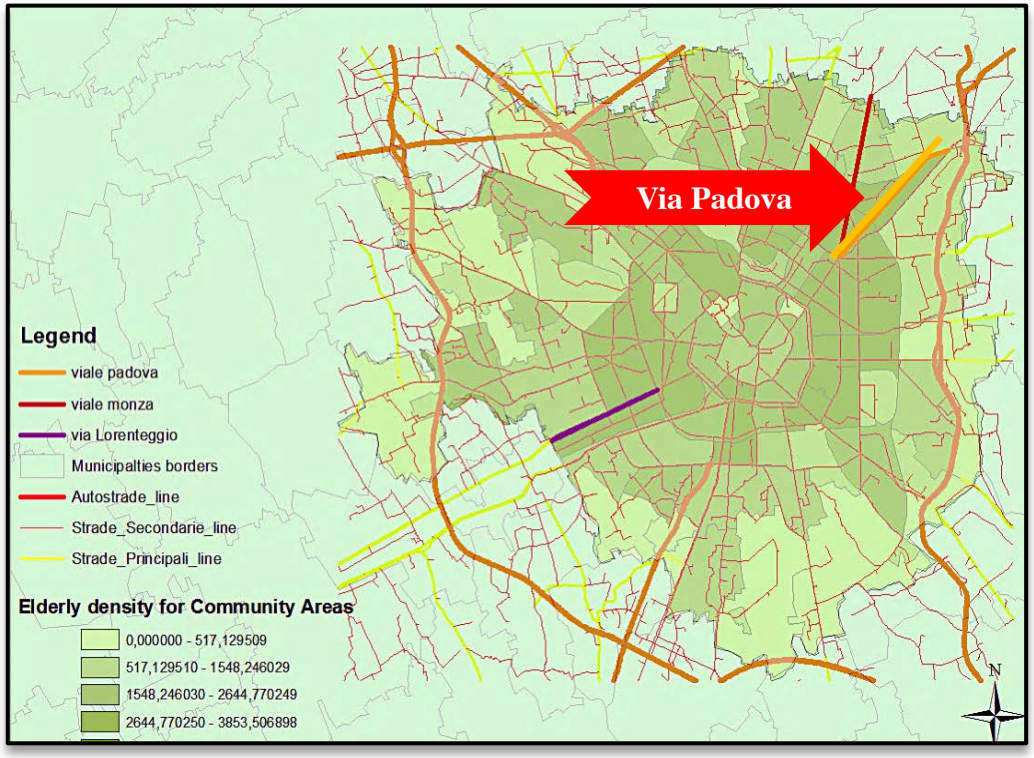


Elderly Resident Population Density for KMQ



GIS ANALYSIS

The highest percentage of accidents involving elderly people **(97 %)** in the city of Milan happens in the **urban roads**



Accidents involving elderly pedestrians

(2006-2010)

Via Padova	No.24	34%
Viale Monza	No.18	25%
Via Lorenteggio	No.29	41%

Via Padova

risky vehicular traffic dynamics

highest presence of elderly inhabitants

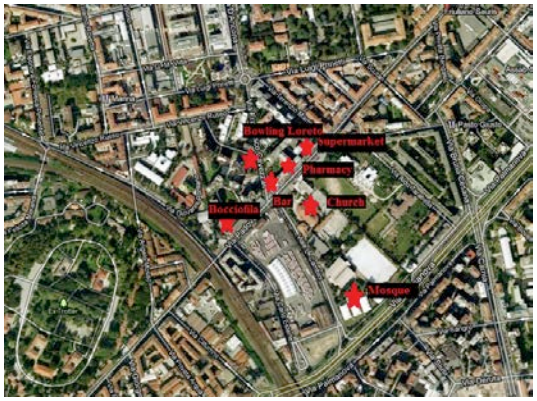
ON SITE INSPECTIONS

Best/most critical scenario

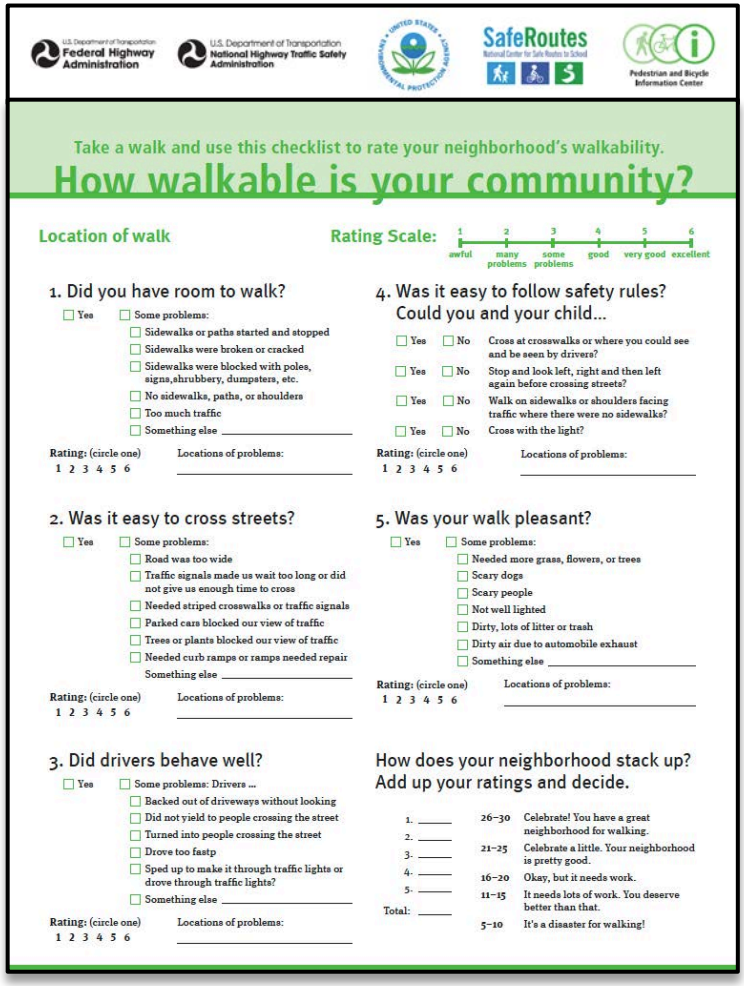
Interactions between vehicles and elderly crossing pedestrians

Unsignalized intersection between Via Padova and Via Cambini

- local market
- pharmacy, public office, bank
- church, Islamic centers



INTERVIEWS



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☐ Scary dogs
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How does your neighborhood stack up? Add up your ratings and decide.

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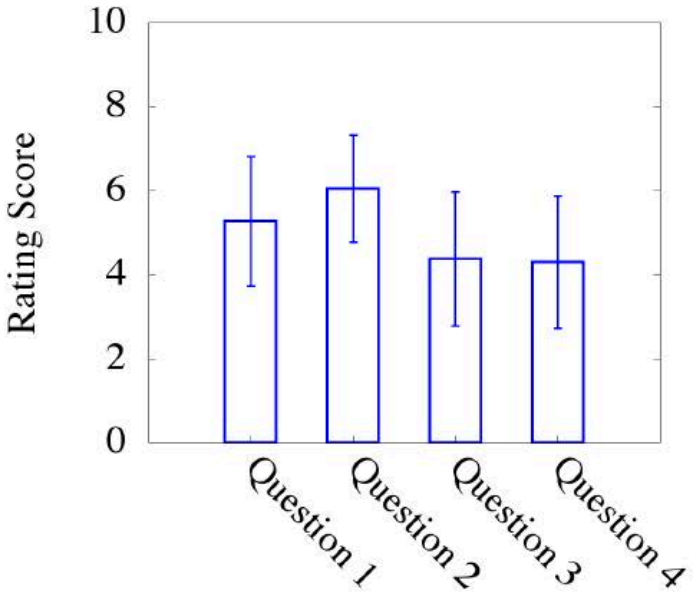
5–10 It's a disaster for walking!

- US Federal Highway Administration walkability checklist
- 120 elderly inhabitant of Via Padova
- Walkability degree: medium-low
- Unsafe interactions with vehicles



COUNTING & PROFILING

- vehicular traffic condition
- pedestrians' profiles
- O-D matrix
- level of service (LOS)
- drivers' compliance at zebra crossing pedestrian-vehicle interactions
  - age
  - gender
  - grouping
  - visibility conditions

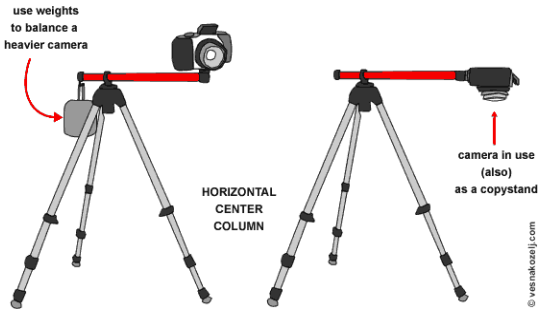
SETTING

Location: two-way street, 50 km/h speed limit, non signalized zebra crossing

Observation: May 18th, 2015 – Monday morning from 11am to 1pm – **local market day**

Equipment: light stands tripod + GoPro Hero 3 camera, ultra wide angle lens, remote screen control (app)

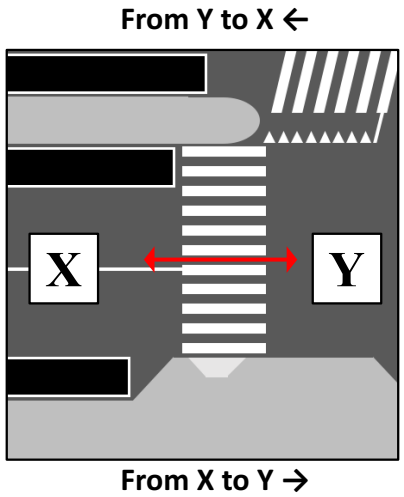
Height: about 25 meter to achieve a zenith point of view

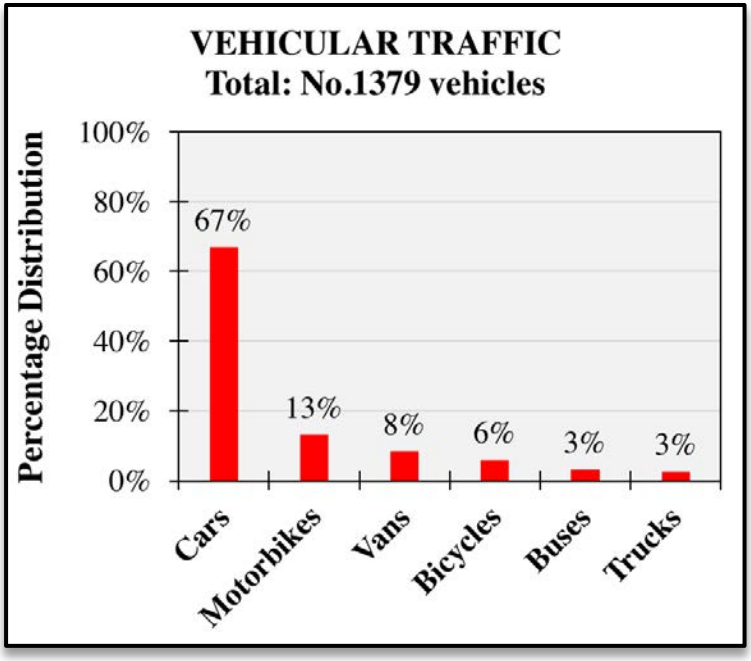


COUNTING AND PROFILING - VEHICLES

Bidirectional flows of **vehicles** passing through the considered portion:

- **counted minute by minute**
- **classified with reference to their characteristics** (type of vehicle)





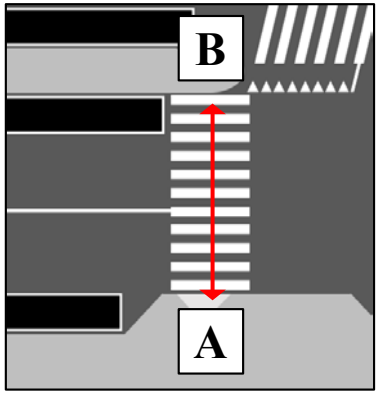
Total No. 1379 vehicles

- 18.89 vehicles in average per minute
- majority of cars (67% of the total)

Time		Cars	Motorbikes	Vans	Bicycles	Buses	Trucks
00:00	00:15	199	37	29	19	7	8
00:15	00:30	233	33	15	16	7	8
00:30	00:45	176	41	18	17	10	8
00:45	01:00	194	48	27	13	11	8
01:00	01:13	120	22	26	17	8	4
Total	**1379**	**922**	**181**	**115**	**82**	**43**	**36**
%	**100%**	**67%**	**13%**	**8%**	**6%**	**3%**	**3%**

COUNTING AND PROFILING - PEDESTRIANS

From B to A ↓



From A to B ↑

Bidirectional flows of **pedestrians** passing through the crosswalk:

counted minute by minute

classified with reference to their characteristics by the checklist:

- pedestrians' age and gender
- size of walking groups

Elderly Detection	
Locomotion Behavior	- regular walking pace - stable trajectories towards the direction of movement - attentive in anticipating oncoming pedestrians by far - unsteady gait and lame posture
Physical Characteristic	- white hair/baldness - clothing (e.g., style, colours, hat) - use of artifact (e.g. stick, tripods)
Dyad Detection	
Locomotion Behavior	- two people walking in the same direction - high spatial cohesion and coordination while walking - waiting dynamics to regroup in case of separation - leader/followers dynamics in sudden changes of direction
Verbal Behavior	- talking while walking
Non Verbal Behavior	- physical contact - body and gaze orientation to the each other - gesticulation while talking and/or indicating

Time		Children/Young	Adults	Elderly
00:00	00:15	5	93	40
00:15	00:30	4	84	48
00:30	00:45	6	114	18
00:45	01:00	9	69	24
01:00	01:13	8	55	8
Total	**585**	**32**	**415**	**138**
%	**100%**	**5%**	**71%**	**24%**

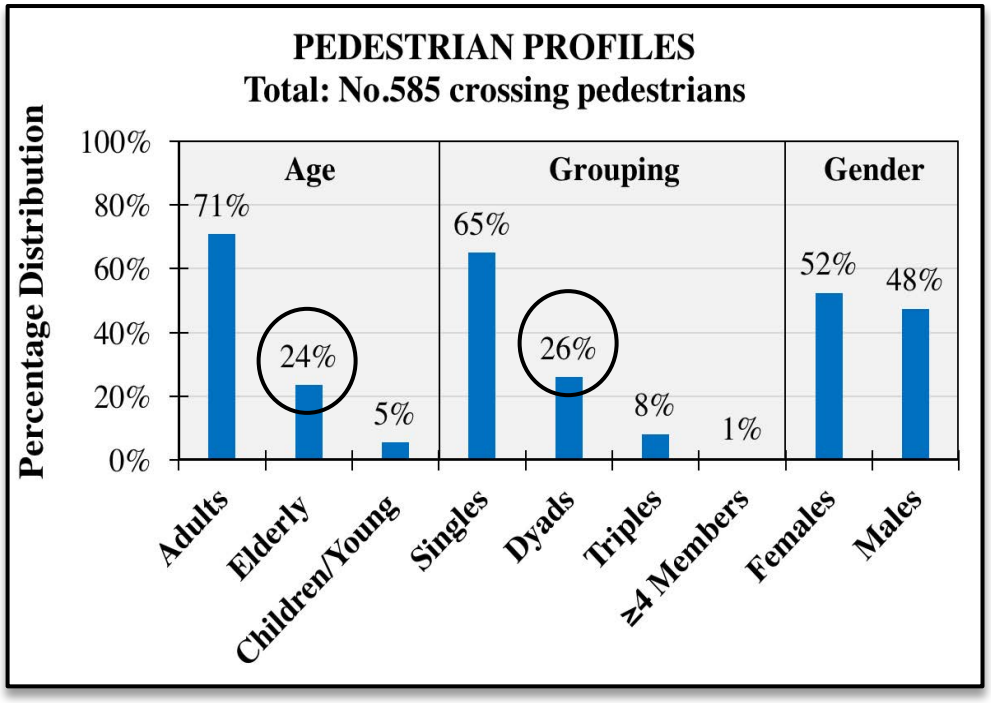
Time		Singletons	Dyads	Triples	≥4 Members
00:00	00:15	101	28	9	0
00:15	00:30	80	34	18	4
00:30	00:45	86	46	6	0
00:45	01:00	64	32	6	0
01:00	01:13	50	12	9	0
Total	**585**	**381**	**152**	**48**	**4**
%	**100%**	**65%**	**26%**	**8%**	**1%**

Time		Males	Females
00:00	00:15	61	77
00:15	00:30	50	86
00:30	00:45	72	66
00:45	01:00	50	52
01:00	01:13	45	26
Total	**585**	**278**	**307**
%	**100%**	**48%**	**52%**

PEDESTRIAN PROFILES

Total No. 585 crossing pedestrians

- 8.01 pedestrians in average per minute
- majority of adults (71%), singles (65%) and female (52%)



Results

- **elderly** pedestrians: significant portion of the observed population (26%);
- 35% of the total pedestrian flows: walking groups, with considerable presence of dyads.

OBJECTIVE

Comparing data among adult and elderly pedestrians, singletons and dyad members

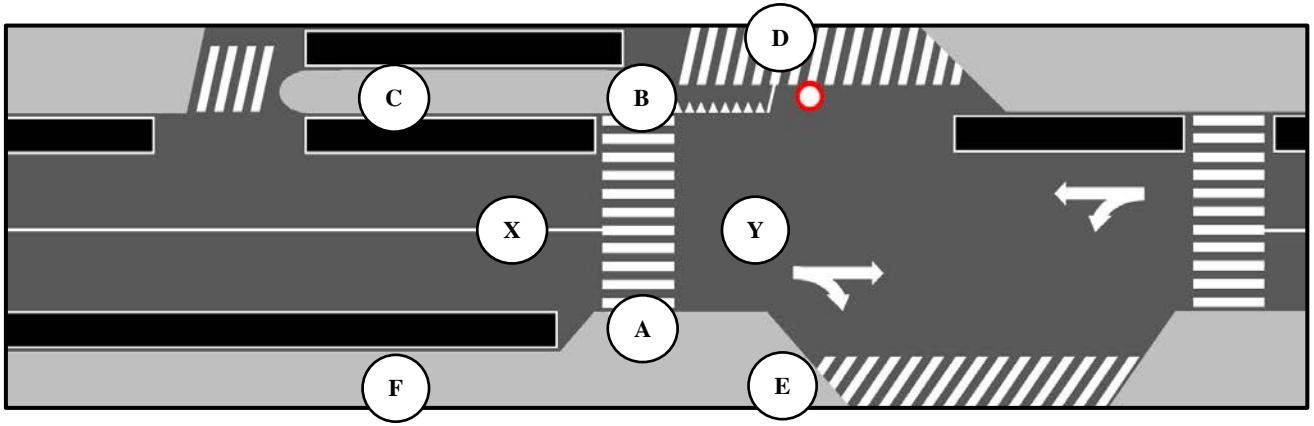
- **Locomotion behavior**
- **Crossing behavior**
- **Spatial behavior**

ORIGIN/DESTINATION

ORIGIN/DESTINATION

Origin and destination of vehicles and pedestrians

From counting activity to **tactical level analysis**



PEDESTRIANS

- A: crossing point
- B: crossing point
- C: Via Padova – church, public office
- D: Via Cambini – **local market area**
- E: Via Padova – bus stop / Via Cavezzali
- F: Via Padova – bus stop

VEHICLES

- X: Milan neighborhood
- Y: Milan city center

ORIGIN/DESTINATION GRAPH

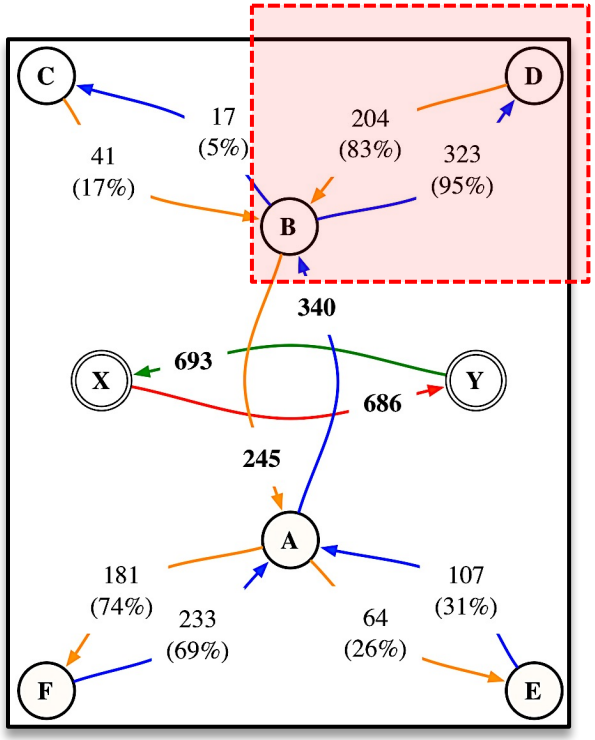
Total No.1379 vehicles

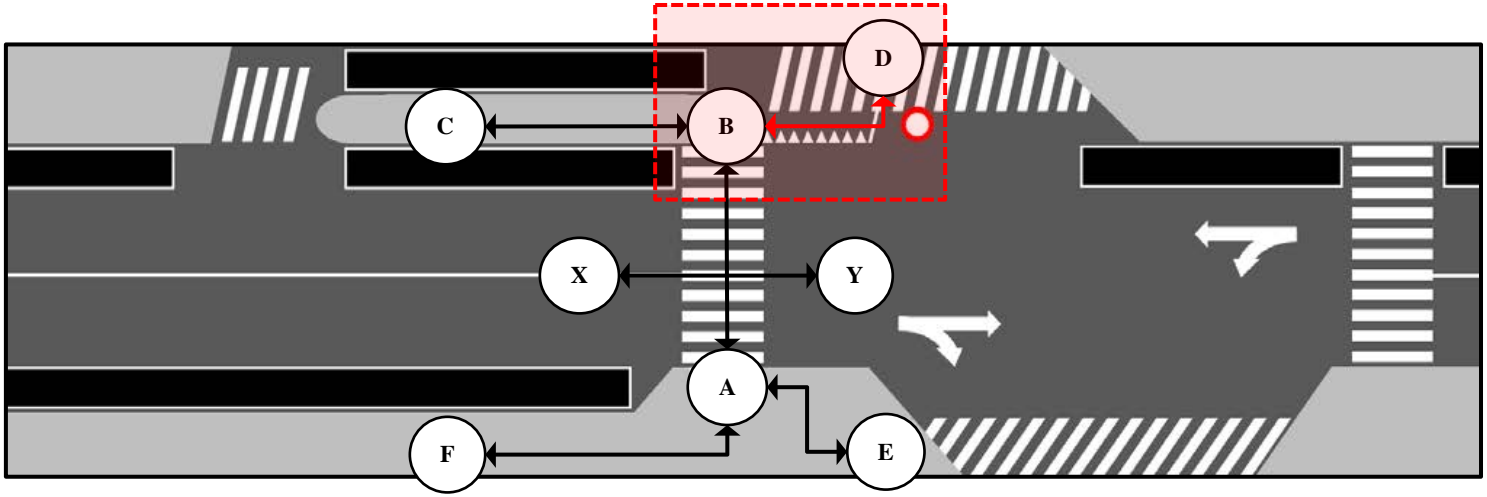
- No. 685 (50%) X → Y (to Milan city center)
- No. 693 (50%) X ← Y (from Milan city center)

Total No.585 pedestrians

- No. 340 (58%) from A → B
- No. 245 (42%) from B → A
- **No. 323: B → D**
- **No. 204: D → B**

The **local market area** in Via Cambini is the main point of interest of crossing pedestrians



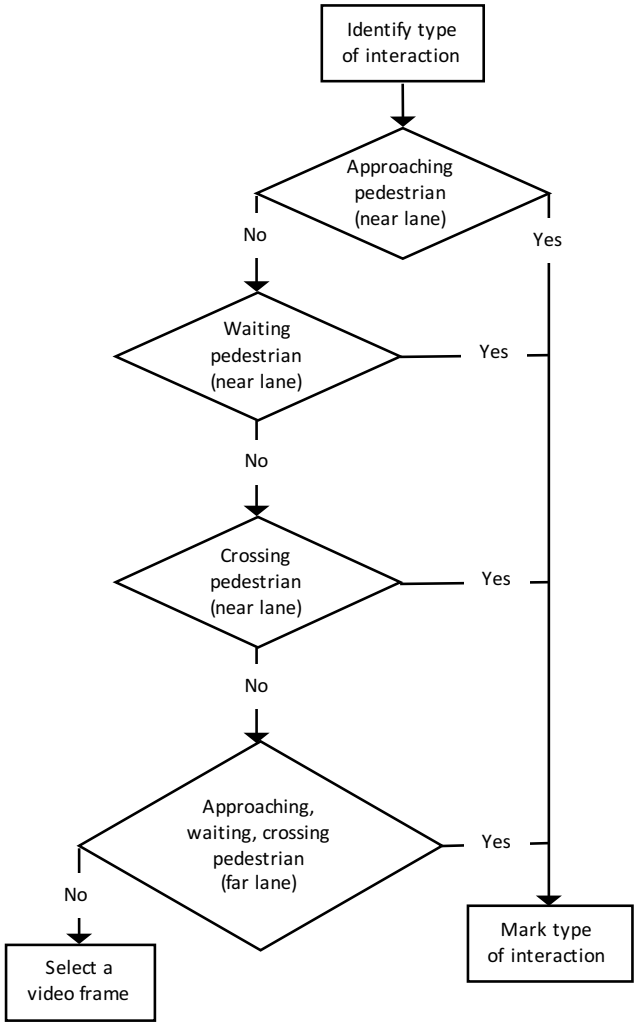


COMPLIANCE

COMPLIANCE OF DRIVERS

How to identify the type of interaction between vehicles and pedestrians?

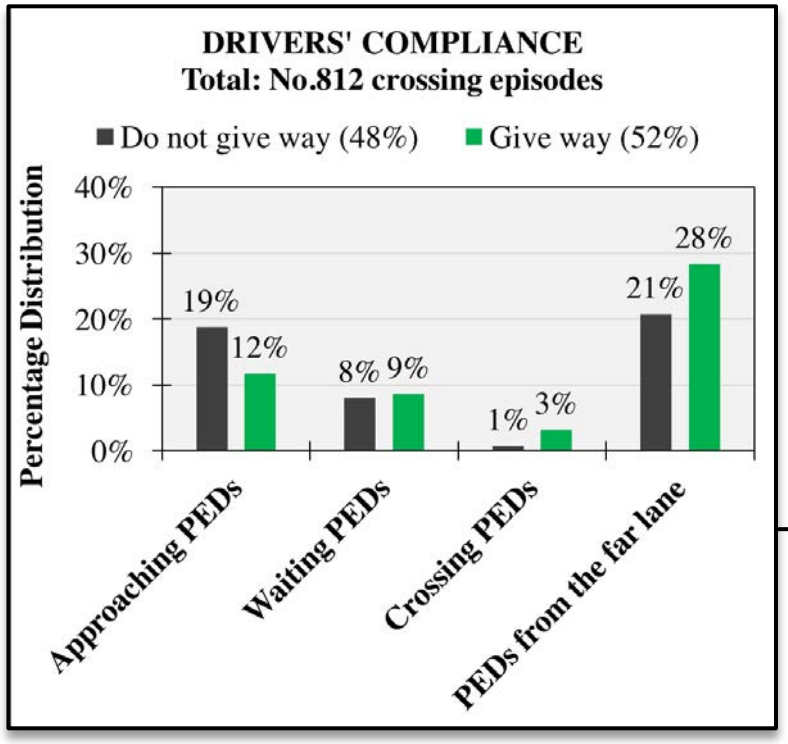
- Approaching or waiting or crossing pedestrians (near lane)
- Approaching and waiting and crossing pedestrians (far lane)



COMPLIANCE OF DRIVERS

Total No. 812 crossing episodes

- 421 (52%) drivers who give way to pedestrians
- 391 (48%) drivers who do not give way to pedestrians



Multiple linear regression to predict drivers' compliance to crossing pedestrians:

- number of vehicles per minute (p = 0.29004, no significance);
- number of crossing pedestrians (p = 0.12853, no significance).

Non significant regression equation:

[F(2,67) = 1.85617, p = 16422], with a R-square of 0.0525.

LEVEL OF SERVICE (LOS)

LEVEL OF SERVICE

Level of Service LOS (Highway Capacity Manual): degree of **comfort and safety** afforded to **drivers and pedestrians** as they travel/walk through an intersection + additional travel time (delay).

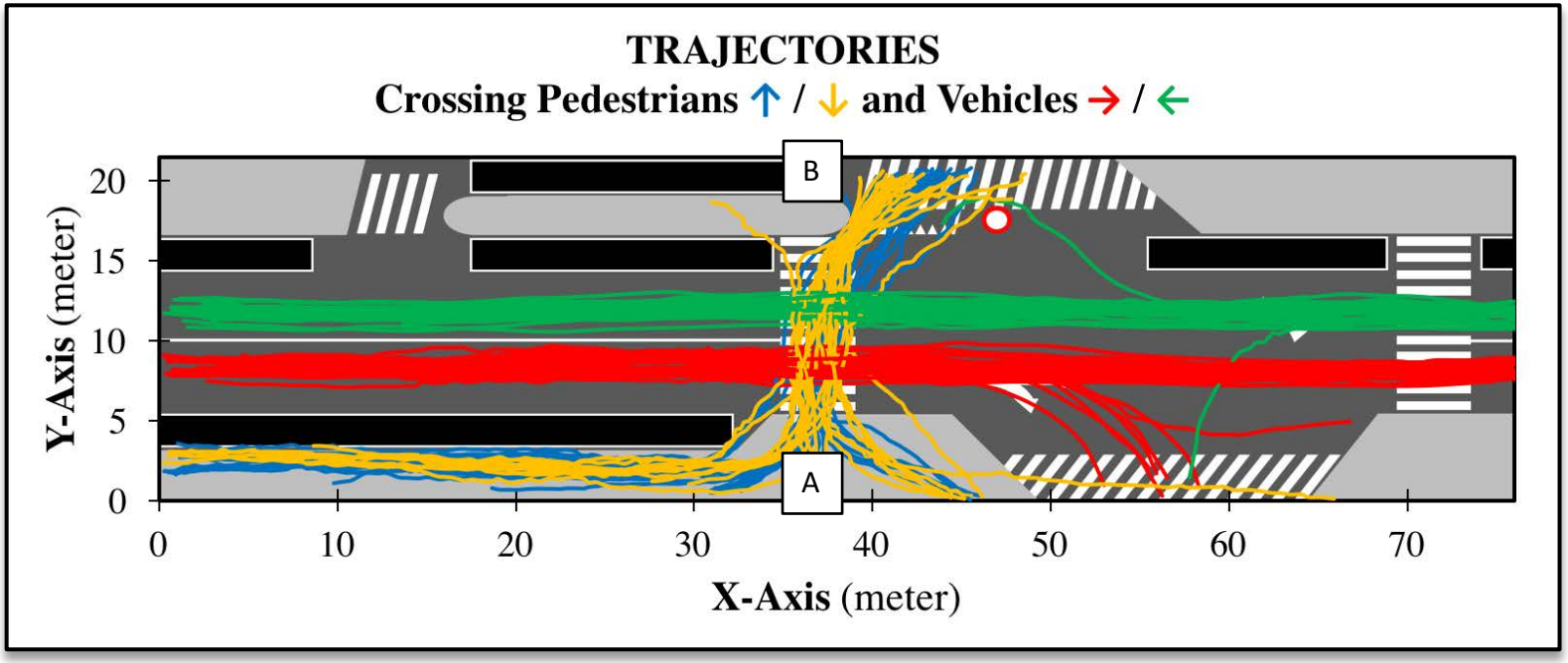
Roadway designers use the LOS value to determine how well a particular intersection accommodates both driver and pedestrian travel. LOS results are necessary for the **validation** of simulation results.

LOS	Description for unsignalized intersections	Pedestrian Delay *(second/pedestrian)*	Vehicle Delay *(second/vehicle)*
LOS A	*Very small delay, none crossing irregularly*	< 5	< 10
LOS B	*Small delay, almost no one cross irregularity*	5-10	10-15
LOS C	*Small delay, very few pedestrian crossing irregularity*	10-20	15-25
LOS D	*Big delay, someone start crossing irregularity*	20-30	25-35
LOS E	***Very big delay, many pedestrians crossing irregularity***	**30-45**	**35-50**
LOS F	*Very big delay, almost every waiting pedestrian crossing irregularity*	> 45	> 50

TRAJECTORIES AND SPEED ANALYSIS

TRAJECTORIES

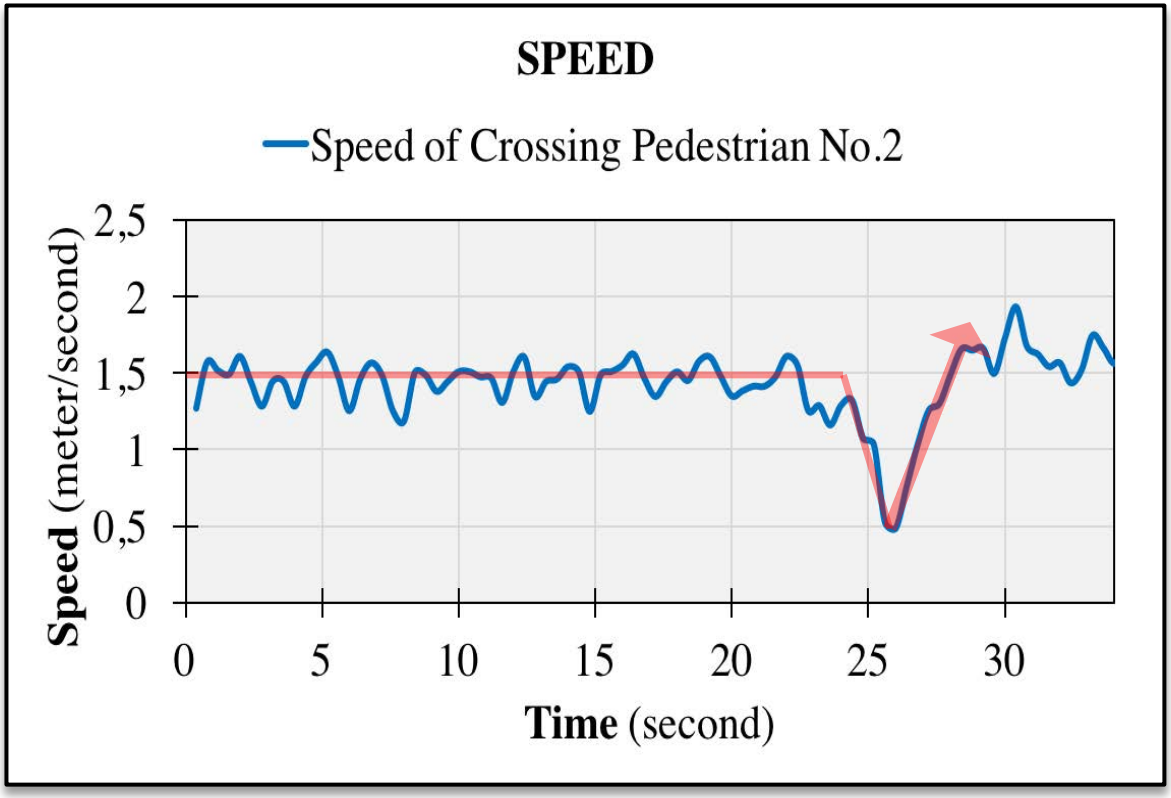
Pedestrians cut off the path on zebra crosswalk directed towards or from the market area, which represents a risky factor of the observed pedestrian-vehicular interactions



SPEED ANALYSIS

Preliminary analysis on the speed of pedestrians:

- stable trend while walking on sidewalks
- deceleration in proximity of the zebra
- acceleration while crossing



CROSSING PHASES

APPROACHING

arrival at the crossing point

APPRAISING

evaluation of the distance and speed of oncoming vehicles

CROSSING

cross the road following the zebras patterns

1. APPROACHING

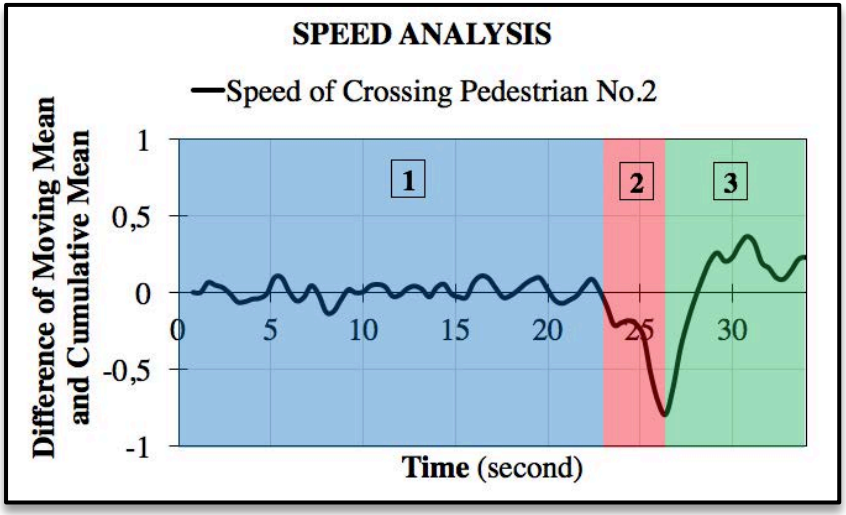
- pedestrian walking on sidewalk
- constant speed

2. APPRAISING

- approaching the zebra crosswalk
- slow down or stop to evaluate the distance and speed of vehicles

3. CROSSING

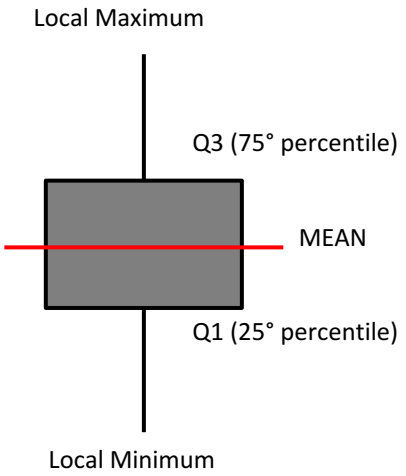
- decide to cross
- speed up

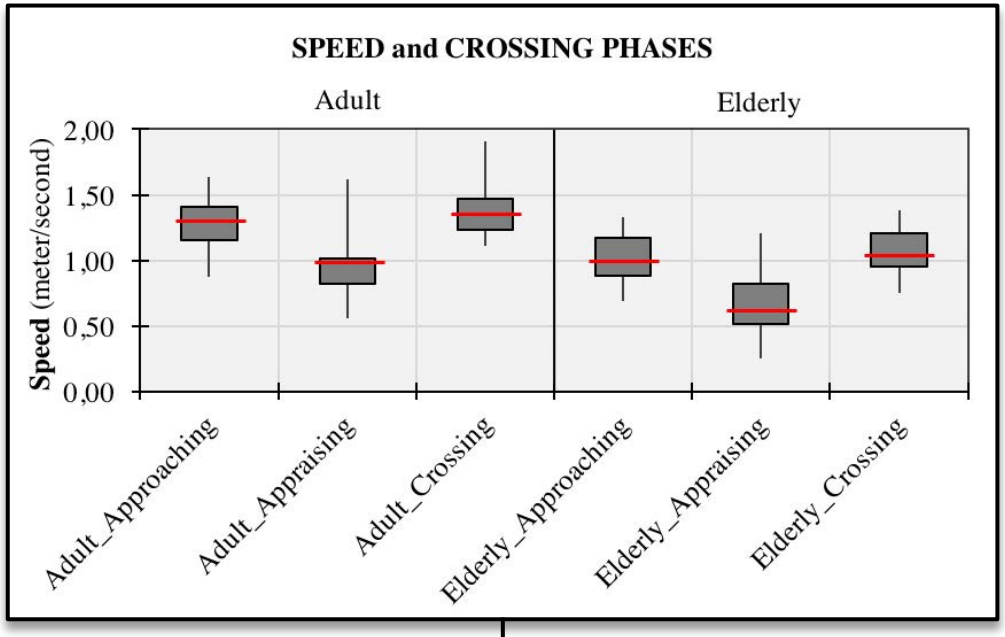


SPEED ANALYSIS AND CROSSING PHASES

	Total Sample	Adult Pedestrians	Elderly Pedestrians
Approaching Speed	1.16 m/s ± 0.22 SD	1.28 m/s ± 0.18 SD	1.03 m/s ± 0.18 SD
Appraising Speed	0.83 m/s ± 0.25 SD	0.94 m/s ± 0.21 SD	0.69 m/s ± 0.23 SD
Crossing Speed	1.23 m/s ± 0.22 SD	1.35 m/s ± 0.18 SD	1.09 m/s ± 0.17 SD

BOX AND WISKER CHART





The sequential phases: (1) walking (2) evaluation (3) crossing

Significant difference in the speed of adult and elderlies

Elderly appraising deceleration more significant than adults

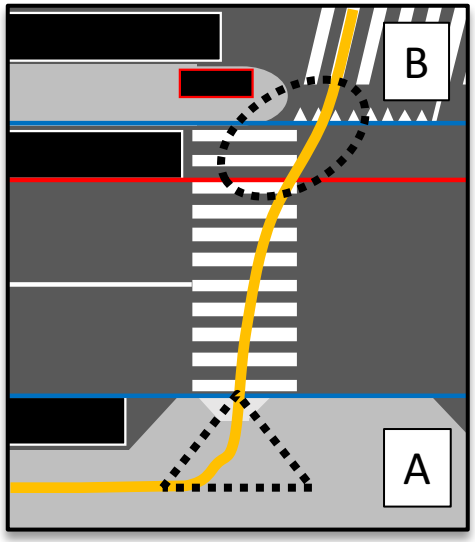
WHAT-IF SCENARIOS

Sustainable mobility for the elderly:

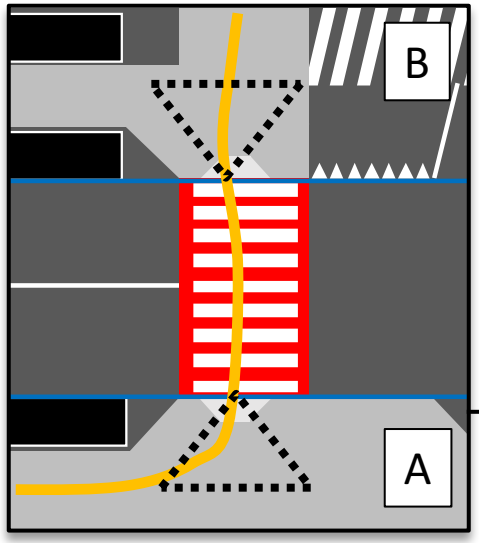
- Architectonic barriers are the most critical spatial elements for elderly pedestrians

- **Pedestrian ramps** support people with restricted mobility to access sidewalks, but they represent also a key factor in gathering all crossing pedestrians towards the zebra crosswalk (crossing point A), making them crossing in a more safe manner (compared to point B)

Observed scenario



What-if scenario



Simulation application:

Simulations used to test the efficiency and safety of a different spatial layout for the crossing point B

REMARKS

Pedestrian-vehicle interactions is a matter of **NEGOTIATION** (cooperation, competition, communication):

- **Assertiveness**: efficacy in communicating to drivers the intention to cross (e.g., waving the car down, eye contact).
- The 61% of the tracked elderly pedestrians **gave way** to at least one vehicle, waiting to cross.

THANK YOU

Acknowledgement
The Italian policy was consulted and complied in order to exceed the ethical issues about the privacy of the people recorded without their consent. Thanks to: Nunzia Borrelli, Kenichiro Shimura, Claudia Prosperi, Nami Avento, Daniele Loliva, Riccardo Perego, Ivan Tricella, Fatima Anouar, Mizar Luca Federici and Luca Crociani for their fruitful contributions in data collection and analysis. The recorded video tape the annotated data set will soon accessible for research porpoises only.

Gorrini, A., Vizzari, G., Bandini, S.: Towards Modeling Pedestrian-Vehicle Interactions: Empirical Study on Urban Unsignalized Intersection, In: Proceedings of the 8th International Conference on Pedestrian and Evacuation Dynamics - PED 2016, 17-21 October 2016, Hefei, China, pp.25-33 (2016)