# Modeling Pedestrian's Subjective Danger Perception toward Personal Mobility Vehicles

***パーソナルモビリティビークルへの歩行者の主観的危険度の認知モデリング***

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## Background and Objective

**Personal Mobility Vehicles (PMVs)** are motorized compact vehicles for one passenger for short distance trips which is emerging as a highly advance transportation that can provide numerous economic, environmental and social benefits.

Fig. 1 Segway Personal Transporter

*Image source: http://www.segway.com/ (Accessed on 2018/05/28)*

**Two features of pedestrian's subjective danger**

**1) Sensitivity to distance**
Sensitivity of pedestrians in relation with the distance between them and PMVs

**2) Perception of danger**
Preferable safe or dangerous situation perceived by pedestrians

***Objective:***
**Analyze the characteristics of pedestrian perception against PMVs and estimate their acceptability**

- Examine pedestrians' subjective danger or perception against PMVs
- Develop an approach to estimate perception from observable factors

## Experiment Design, Data and Results

- A series of controlled experiments were conducted to gain insights in to the trend of pedestrians' perception and subjective feelings towards PMVs.

**Table 1 Experiment Scenario List**

| Scenario Name | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PMV Speed (km/h) | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 10 | 10 | 10 | 10 | 10 | 10 |
| Lateral Distance *l* (m) | 0.6 | 0.6 | 0.6 | 0.8 | 0.8 | 0.8 | 1 | 1 | 1 | 0.8 | 0.8 | 0.8 | 1 | 1 | 1 |
| Pedestrian Orientations | Front | Side | Back | Front | Side | Back | Front | Side | Back | Front | Side | Back | Front | Side | Back |

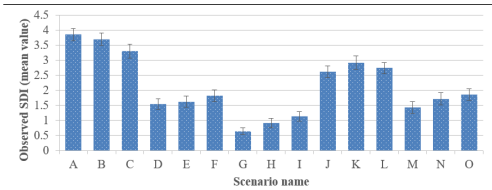
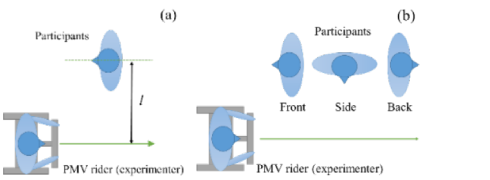



Fig. 2. Mean value of observed SDI of each scenario

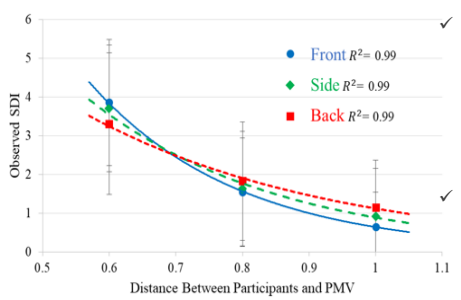
*Fig. 2 shows that longer distance between pedestrian and PMV yield smaller SDI for each speed level and head orientation*





*(a) Lateral distance between pedestrians and PMVs (l = 0.6 m, 0.8 m or 1.0 m); (b)Pedestrians' orientations (back, front or side); (c) A snapshot during a "front" scenario; (d) A snapshot during a "back" scenario.*

Fig. 3. Explanation of scenario components and snapshots during experiments




- ✓ *The slope of the regression line implies the sensitivity of the pedestrians to the object approaching them.*
- ✓ *The steepness of the slope describes the level of sensitivity pedestrians feel towards an object.*

Fig. 4. Relationship between observed SDI and distance between pedestrian and PMV (for Segway speed = 6 km/h).

Note 1: The sample number for each direction is n = 192. Note 2: The dots represent the mean values of scenarios A to I. Note 3: The error bars represent Standard Deviation

## Subjective Danger Index (SDI) Model

- Model inspired by the social force concept to estimate the safety index called **subjective danger index (SDI).**
- Modified Social Force Model (SFM) to consider the natural movement of pedestrians.
- Eliminated the anisotropy term and modified $A_i$ and $B_i$ as function of $\varphi_{ij}$ to explain that anisotropy effect is dependent on distance and relative velocity.

$$SDI(t) = A_i(\varphi_{ij}(t))exp\left(-\frac{b_{ij}}{B_i(\varphi_{ij}(t))}\right)$$

$$A_i(\varphi_{ij}) = C_A + \lambda_A cos(\varphi_{ij})\ (\lambda_A > 0),$$

$$B_i(\varphi_{ij}) = C_B - \lambda_B cos(\varphi_{ij})\ (\lambda_B > 0),$$

Variables:
$SDI$ : subjective danger index
$A_i$ : strength of interaction parameter
$B_i$ : interaction range parameter
$\varphi_{ij}$ : interaction angle
$b_{ij}$ : semi minor axis of the ellipse-shaped potential individual j to i
$\lambda$ : anistropy effect
$C$ : constant

- **Estimated SDI** is defined as the maximum value of the instantaneous SDI(t)

$$SDI = \max_t \|SDI(t)\|$$

- **Model Calibration**
  - Estimated 960 samples using least square method.

**Table 2 Estimated Parameters for SDI Model**

| Parameter | $C_A$ (1/m) | $\lambda_A$ (1/m) | $C_B$ | $\lambda_B$ | $\Delta t$ (s) |
|---|---|---|---|---|---|
| Estimated value | 16.49 | 4.73 | 0.41 | 0.07 | 2.27 |

Note: The coefficient of determination ($R^2$) = 0.20.

- ✓ *Positive value of estimated $\lambda_A$ and $\lambda_B$ in Table 2 indicates assumptions for $A_i$ and $B_i$ are appropriate.*
- ✓ *Scatter diagram in Fig. 5 shows that the 15 scenarios in Table 1 can be classified into low-speed clusters (A to I) and high-speed clusters (J to O)*

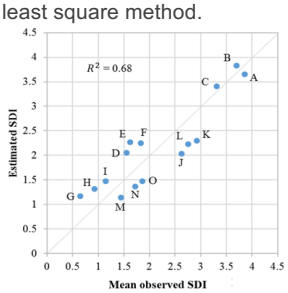



Fig. 5. Model Fitness

## Conclusions

- **Sensitivity difference**
  - Pedestrians exhibit high sensitivity when a PMV is approaching from the front an low sensitivity when a PMV is approaching from behind.
  - Pedestrian danger perception toward PMVs depends on the direction when they and PMVs interact.
- **Reversal Perception**
  - Pedestrians perceive a PMV in front of them as more dangerous compared to PMV behind them when they are near the PMV.
  - Pedestrians perceive higher danger when a PMV is behind them than when it is in front of them when they are relatively far from the PMV.