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# Illegal road crossing behavior of pedestrians at overpass locations: Factors affecting gap acceptance, crossing times and overpass use

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ABSTRACT

The aim of designing overpasses is to provide safe road crossings for pedestrians by helping them to avoid conflicts with motor vehicles. However, the number of pedestrians who do not use overpasses to cross the road is very high. An observational survey of illegal road crossings was conducted at four overpass locations in Izmir, Turkey to determine the crossing time, crossing speed of the pedestrians and their distance and time gap perception for safe road-crossing within 25 m of the overpasses in both directions. Crossing time is the time needed for a pedestrian to cross a particular road. Time gap is strongly related with safety margin. If a pedestrian chooses a larger time gap, then the arrival time of the oncoming vehicle to the crossing point of the pedestrian increases thus, the possibility of a collision decreases. Each overpass was observed on weekdays during peak afternoon (12.30–13.30) and evening hours (17.00–18.00). At all overpass locations 454 illegal crossings were observed. ANOVA results revealed that age had a significant effect both on safety margin and crossing time. During the observations a survey was conducted among pedestrians who completed their crossings either using the overpass or at street level within 25 m of the overpass ($n = 231$). Factors affecting the crossing choice of pedestrians were specified in the surveys. The major part of the respondents (71.7%) indicated that time saving was the main reason for crossing at street level. Pedestrians' crossing speeds were extracted from the video recordings to observe the effect of speed limit on pedestrian behavior. As a result, at locations where the speed limit was 70 km/h, pedestrians' average crossing speed was found to be 1.60 m/s and 1.73 m/s while at locations where the speed limit was 50 km/h, pedestrians' average crossing speed was found to be 1.04 m/s and 0.97 m/s. This shows that pedestrians feel safer while crossing when the vehicle speed is low.



## 1. Introduction

Pedestrians constitute the most vulnerable part of road users worldwide. About 1.24 million road traffic deaths occur each year around the world which makes road traffic injuries the eighth leading cause of death globally. More than 270,000 pedestrians die annually in road traffic accidents, equaling 22% of all road deaths (World Health Organization, 2014).

Pedestrians might experience severe consequences due to vehicle–pedestrian interactions even at low vehicle speeds. Because of this at-grade and grade separated facilities, such as underpasses and overpasses, are built to ensure safe crossings. This paper's focus is pedestrian crossing behavior at overpass locations. Four overpass locations were observed in Izmir city, Turkey where the vehicle speed limit is 50 km/h and 70 km/h.

Pedestrian crossing behavior is often governed by gap acceptance theory (Palamarthy et al., 1994). This theory suggests that each pedestrian has his/her own critical gap acceptance. Critical gap consists of two components: crossing time and safety margin. The crossing time is defined as the time needed for a pedestrian to cross a particular street (from the time a pedestrian steps into the lane until reaches the sidewalk on the other side of the road). Safety margin is given as the difference between the time a pedestrian crosses the traffic and the time the next vehicle arrives at the crossing point (Chu and Baltes, 2001). The safety margin, crossing time and crossing speed of each pedestrian who made illegal crossings were determined in this study.

A questionnaire survey was conducted to reveal the factors lying behind illegal crossings. Pedestrians who completed their crossings either using the overpass or at street level within 25 m of the overpass were requested to participate in the survey.

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## 2. Literature review

Pedestrians choose the most appropriate gap which is greater than their critical gap before they start crossing. This gap is perceived safe by pedestrians. The Highway Capacity Manual (HCM, 2010) defined the critical gap as "*the time in seconds below which a pedestrian will not attempt to begin crossing the street. If the available gap is greater than the critical gap, it is assumed that the pedestrian will cross, but if the available gap is less than the critical gap, it is assumed that the pedestrian will not cross*." In this study, only the accepted gaps, in other words only the gaps which were greater than the pedestrian's critical gap, were investigated.

Safety margin studies have commonly been conducted in virtual environments via simulators for midblock (Dommes et al., 2012; Lobjois and Cavallo, 2009; Oxley et al., 2005) and for intersections (Liu and Tung, 2014). Some studies have been conducted on site for midblock (Brewer et al., 2006; Kadali and Vedagiri, 2013; Oxley et al., 1997; Zhuang and Wu, 2012) and for intersections (Koh and Wong, 2014).

The study conducted by Brewer et al. (2006) aimed to find the time gap that each pedestrian accepted to cross. The authors asked the pedestrians to indicate their decision by simply saying "yes" or "no" for each gap that occurred. The average time gap was found to be 8.4 s. Koh and Wong (2014) found the same time gap for non-complying pedestrians who crossed during a red light.

The age of pedestrians has been the major concern for most of the studies in the gap acceptance field. Role of age was investigated by Oxley et al. (1997) by observing 80 young and 80 senior pedestrians. On one-way roads the average gap acceptance of senior pedestrians (134.1 m) was found to be higher than that of young pedestrians (119.2 m). On two-way undivided roads the average gap acceptance of young pedestrians (51.3 m) was found to be lower than the gap acceptance of elderly pedestrians (69.1 m), similar to one-way roads. Another study conducted by Oxley et al. (2005) investigated the effect of age on safe time gap selection in a simulated road-crossing task. The safety margin was calculated as the sum of the mean walking time plus decision time, being subtracted from the time gap of the approaching vehicle. Classification of age was made as young (30–45 years), young–old (60–69 years), and old–old (75 years and over). It was found that the crossing decision is mainly dependent on the distance gap rather than the time gap. This study showed that elderly pedestrians failed at choosing the safe time gap. The young–old group had a safety margin between 0 and 2 s while the old–old group had a negative safety margin of up to −10 s. A positive sign indicates a safe road-crossing; while a negative sign indicates underestimated time required for crossing the road. Lobjois and Cavallo (2007) conducted a study similar to the study of Oxley et al. (2005). They observed that as the vehicle speed increased the time gap decreased. Lower time gaps were observed for senior pedestrians at higher vehicle speeds.

Lobjois et al. (2013) investigated pedestrian behavior using an interactive street-crossing task. Their aim was to determine the effect of the position of the gap pedestrians selected into the traffic stream on the mean time gap and their crossing decisions. Participants were required to cross a road when they perceived it as safe. The mean time gap was 3.12 s for the 20–30 year-old, 3.64 s for the 60–70 group, and 3.52 s for the 70–80 year-old group. The safety margin was 1.81 s at 60 km/h but 2.29 s at 40 km/h vehicle speed. As the waiting time increased for pedestrians the accepted time gap decreased. The decrease in the gap size did not result in an increase in risky situations; rather, the participants chose better crossable gaps. The results showed that the traffic flow allowed participants to make a comparison between gaps and choose a crossable gap. The effect of group size was found significant in the study of Zhuang and Wu (2012). Bigger groups had a positive effect on safety. The minimum safety margin was 2.5 s.

The effects of age, time gap, time of day, and speed of approaching vehicle on the decision of pedestrians to cross a road was investigated by a simulation based study (Liu and Tung, 2014). Pre-recorded videos were shown to 32 participants (16 young at age 24–29 and 16 elderly at age 61–79). In these videos vehicles were approaching from the left and the participants were asked to indicate the last moment at which they thought they would cross safely. The determinant for the participants to make a crossing decision was the distance gap. The safety margin was measured as defined by Oxley et al. (2005). The safety margin of young people was found to be greater than the safety margin of senior pedestrians, 0.40 s and −0.49 s, respectively. It was also found that higher vehicle speed leads to smaller safety margins.

Räsänen et al. (2007) observed five different kinds of pedestrian overpasses on the two one-way main streets in Ankara, Turkey. Not only the overpass users but also the pedestrian crossings at street level within 25 m of the overpass were considered. A survey was conducted to reveal the factors affecting the pedestrians' choice whether to use the overpass or not. Pedestrians who visited the overpass area more frequently were more likely to cross at street level. Time saving was another factor that affected overpass use. Finally the authors suggested that overpass use was rather a habit than coincidental behavior.

Pedestrians' walking speeds were generally measured only at signalized intersections. Tarawneh (2001) found the average walking speed of pedestrians as 1.34 m/s in Jordan. Bennett et al. (2001) obtained an average walking speed of 1.24 m/s in Melbourne. The walking speed of pedestrians at overpass locations without traffic lights may lead to an increase in crossing speeds especially if the speed limit is high. This study will ascertain the crossing speeds of pedestrians who crossed illegally at overpass locations.

In the light of the previous studies age, gender, distance and speed limit have been chosen as factors to search whether they have an effect on safety margin, crossing time and crossing speed or not.

The aim of this study is to determine the distance and time gap perception of pedestrians around overpass locations, to find their crossing speeds to understand if the speed limit has an effect on crossing speed or not, and to present the factors (gender, age, speed limit, etc.) underlying the pedestrians' illegal crossings. Illegal road crossings within 25 m of both sides of the overpass were examined. Factors affecting the safety margin and crossing time were analyzed by ANOVA.

Studies about the safety margin often focus on midblock road sections and intersections, whereas studies about overpasses mainly focus on convenience and usage ratio and do not consider the safety margin. This paper for the first time presents a study about illegal road crossings at overpass locations and safety margins at such locations, something that has never previously been published. Due to the different characteristics of the overpass locations compared to others, this study of safety margins at overpass locations has unique contributions to the literature.

## 3. Method

### 3.1. Study area

Four overpasses in different parts of Izmir were observed using a video recording technique. Izmir is the third biggest city of Turkey. There are 4,113,072 inhabitants in Izmir. The number of vehicles is 1,135,325 by September 2014 of which 604,671 are private vehicles. The locations of the intersections are shown in Fig. 1. The overpasses are located on divided roadways. The