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# Cross or wait? Pedestrian decision making during clearance phase at signalized intersections

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ABSTRACT

Pedestrians arriving at clearance phase (Flashing *Don't Walk*) face different levels of risk depending on behavioral choice afterwards. However, few studies have focused on the choices pedestrians make *during* this phase. This field study analyzed pedestrian choices after arrival, evaluated safety of the choices, and built a model to identify the predictors of pedestrian choices. It was found that pedestrians arriving during clearance phase made dynamic decisions based on the changing contexts. Specifically, the majority made the decision to "cross" as opposed to "wait" (85.2% vs. 14.8% respectively), although only the latter choice is legal. Seventy-nine percent of the pedestrians did not finish crossing the intersection before the traffic light turned red, and they walked 41% of the road width during a red light. For those waited, roughly half of them waited until green or crossed at an intersecting crosswalk, while others finally started on red light. Nevertheless, the waited pedestrians still faced lower risk than those crossed prematurely in terms of running behaviors, and conflicts with vehicles. Pedestrians are more likely to cross immediately after arrival when they are younger, are not engaged in secondary tasks, arrived at a position farther from approaching vehicles at the near side of the road, or arrived at a time when there are more pedestrians crossing the road. Although fewer pedestrians choose to cross when the required speed is higher (due to a wider road or less remaining time), the required speed they choose to cross at is far higher than their actual speed. These findings are essential for realistic pedestrian simulations and targeted safety countermeasures. They also imply the need for changes to certain traffic regulations and signal design to facilitate safe decision making at clearance phase.

## 1. Introduction

Pedestrian green light is usually followed by a *clearance phase*, occurring before the light ultimately turns red (see Fig. 1). This phase was implemented to help pedestrians who are already in crosswalks to finish crossing before onset of a red light (Wanty and Wilkie, 2010). The message displayed during clearance phase differs from country to country; it may be signaled by flashing Don't Walk (e.g. USA), flashing Red Man (e.g. Australia, New Zealand) or flashing Green Man (e.g. Japan, China), and is sometimes coupled with countdown timers displaying the remaining time before the light turns red. Although the regulations for clearance phase vary slightly across countries (e.g. USA, Canada, Singapore), a general rule is that pedestrians already in crosswalk at the onset of the clearance phase can continue crossing, but new arrivers cannot enter the crosswalk. The question is, pedestrian even start crossing when they face a red light (e.g. King et al., 2009; Rosenbloom, 2009), will they wait at the flashing green light? If they do wait, will they wait until green light or wait until there is a large gap in traffic that would allow them to cross? What factors will influence their decision? How does their choice affect their safety? This study seeks to answer these questions.

### 1.1. Pedestrian choices at clearance phase

Pedestrians arriving at clearance phase theoretically can start crossing at either flashing green phase, red phase or green phase (see Fig. 1). Although only the last choice is legal, pedestrians are often reported weighing other crossing choices. While building a pedestrian simulation model, Lee and Lam (2008) recorded that over 50% of the pedestrians they studied arriving during the last six seconds of the flashing green light made the choice to wait, but the majority of pedestrians crossed the road immediately if they arrived at the first seven

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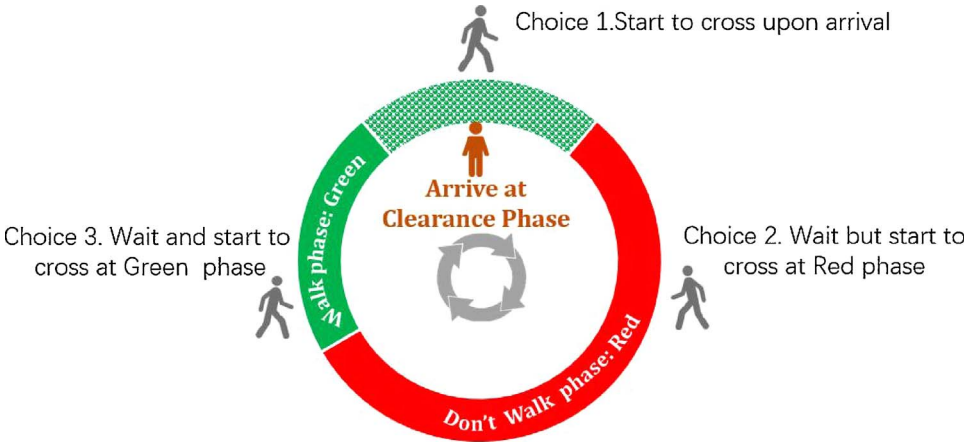


**Fig. 1.** Cycle of pedestrian signal lights in China and pedestrians' choices after arrival at clearance phase.

seconds of flashing green phase (with total clearance time being 13 s). Similarly, Koh et al. (2014) observed pedestrians and cyclists arriving during flashing green phase in Singapore, and found 34% would wait if they arrived within the last five seconds of the flashing green phase, otherwise, 100% of them chose to cross immediately. In an study in Shanghai, China, Ma et al. (2015) found that 12.4% of the pedestrians older than 50 entered the crosswalk at the flashing green phase. For pedestrians who were younger than 50, the percentage is as high as 92.7%.

Studies on other topics have also reported indirect evidence of pedestrians tending to cross at the flashing green phase. An early study on pedestrian delay found that pedestrian reduced their delay by 22%, mostly through crossing at the flashing green phase. Similar observations came from studies evaluating safety of countdown timers, where researchers typically reported percentage of pedestrians distributed over different signal phases as safety indicators.[1] For instance, Wanty and Wilkie (2010) found 23% of *all* the pedestrians entered the crosswalk at the flashing Don't Walk phase. Similarly, Kim et al. (2013) observed 19% of the pedestrians started crossing at the flashing walking person signal in Korea, and Xiong et al. (2015) reported a higher percentage (25.7%) in China. Besides these findings for adults, an observation of children in Shandong, China found that 6.9% crossed during clearance phase (Fu and Zou, 2016). These studies did not report the arrival time of the pedestrians, but it is likely that these pedestrians arrived during the clearance phase, as pedestrians who arrived earlier would have crossed immediately at green phase.

Despite the high percentage of pedestrians starting to cross immediately at the clearance phase, some pedestrians choose to wait. Will the waited pedestrians uniformly wait until green light? A possible answer is "No" based on two indirect evidences. One is that in a model built by Schmitz (2011), arrival at a flashing Don't Walk signal is a predictor of violation, with "enter on red" being one type of the violation. Therefore, it is possible that pedestrians arriving at the clearance phase may wait but finally start to cross at red phase. The other indirect evidence is that pedestrians arriving during red phase are more likely to cross against red light if the waiting time is longer (Brosseau et al., 2013; Gårder, 1989; Houten et al., 2007; Yang et al., 2006). Compared with pedestrians arriving at red phase who typically wait part of a full red phase, pedestrians arriving at clearance phase need to wait a much longer duration, which equals the remaining time in clearance phase plus a full red phase (see Fig. 1). This, again, suggest that the pedestrians originally choosing to wait may end up starting crossing during red phase. In addition to entering crosswalk at red phase, pedestrian may have other choices after they initially decided to wait. To fully understand the dynamic decision-making process in clearance phase, both decisions made upon arrival and afterwards should be tracked.

### 1.2. Risks for different choices after arrival

The choice to cross immediately upon arrival is risky unless pedestrians can finish crossing before the traffic lights turns red. However, as observed by Koh et al. (2014), 45% of the observed pedestrians and cyclists began crossing at flashing green phase couldn't finish crossing timely. More seriously, for those who began to cross during the last five seconds of the flashing green phase, none finished before red-light onset. In other studies, pedestrians were also observed being trapped in the crosswalk after the clearance phase. Huang and Zegeer (2000) found that 10.5% of *all* pedestrians remaining in the roadway at the end of pedestrian phase. Wanty and Wilkie (2010) found a higher rate of 17%. A similar percent (14%) is observed for child pedestrians in Shandong, China (Fu and Zou, 2016). We can only infer that these late finishers may include pedestrians arriving at clearance phase, as these studies did not provide data as to the arrival time of these pedestrians.

For pedestrians choosing to wait, they are expected to be safer as they cross the street; otherwise the need to comply with crosswalk regulations would be questioned. However, the safety associated with waiting may be compromised by illegal choices made afterwards. In fact, if pedestrians who initially wait at the crosswalk end up crossing at red light, they faced a risk 8 times as high as that of legal crossings (King et al., 2009). Given this statistic, it is uncertain whether the risk for pedestrians who wait but cross illegally is still lower than those crossed upon arrival. To justify the need to wait, the risk levels associated with different choices should be evaluated.

### 1.3. Predictors of pedestrian decision making at clearance phase

Once the risk levels of different choices were evaluated, specific predictors of risky choice should be identified to avoid unsafe decisions. Pedestrians' decision may be influenced by personal characteristics and contextual factors after arrival. Although no attempt has been made to identify the predictors of pedestrians' decision making at the clearance phase, studies on other violation behaviors have offered some clues on potential factors.

#### 1.3.1. Pedestrian characteristics

Pedestrian characteristics include demographical and behavioral aspects of pedestrians. Previous studies have generally found more males crossing on red than females (Lipovac et al., 2013; Rosenbloom, 2009, 2011; Tom and Granie, 2011), and males usually wait less time before crossing (Hamed, 2001). Besides gender, young pedestrians were also found to be riskier (Rosenbloom, 2009), while old pedestrians

[1] In evaluating the safety of countdown timers, researchers would compare safety indicators with and without countdown timers. The data referred were only observations for sites with countdown timers, because the signal lights in this study all have countdown timers, a module prevalent in Chinese cities.