PEDESTRIAN SAFETY AROUND ELEMENTARY SCHOOLS

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I hereby declare that, all information in this document has been obtained and presented in accordance with the academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

PEDESTRIAN SAFETY AROUND ELEMENTARY SCHOOLS

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This study establishes pedestrian safety focused environment around elementary schools. In order to reach this objective 3 consecutive goals are fulfilled; firstly; proposing, a newly designed black spot analysis, "Behavioral Black Spot Analysis", secondly; documenting pedestrian behavior around black spots, and finally stimulating effective interventions around elementary schools. This study proposes a newly designed methodology; "Behavioral Black Spot Analysis" which is namely based upon pedestrians' route choice and risk perception statements. Additionally it is observed that students choose the shortest route on their way. "Behavioral Black Spot Analysis" reveals that traffic flows, pedestrian visibility, vehicle visibility, waiting time, road width are most important parameters of pedestrians' perception of traffic safety. Results of unobtrusive observations indicate that interventions have significant effect on vehicle speed, number of conflicts, yielding behavior of drivers, total number of cars forming a queue, number of pedestrians stopping on the curb, head movements, crossing angles, crossing tempos, and crossing distances of pedestrians. Behind this interventions affects pedestrians' waiting time in negative manner. Recommendations for pedestrian safety interventions are suggested.

Keywords: Black Spot Analysis, Pedestrian Safety, Route choice behavior, Crossing behavior, Intervention

ÖZ

İLKÖĞRETİM OKULLARI ÇEVRESİNDE YAYAGÜVENLİĞİ

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Bu çalışma ilköğretim okulları çevresinde yaya odaklı güvenlik çevre düzenlemesini tesis etmektedir. Bu hedef doğrultusunda sıralı olarak 3 amaç yerine getirilmiştir. Bunlardan birincisi; yeni geliştirilen "Davranışsal Kara Nokta Analizi" önermesidir. İkincil olarak, kara nokta çevrelerinde yaya davranışlarını analiz edilmiş ve son olarak etkin yapılandırmalar denenmiş, yapılandırmaların geçerliliği gözlem yöntemiyle analiz edilmiştir. Araştırmanın önerdiği "Davranışsal Kara Nokta Analizi" öğrencilerin güzergâh seçim davranışlarına ve karşıdan karşıya geçme davranışına dayandırılmıştır. Öğrencilerin güzergâh seçiminde en kısa yolu seçtikleri, trafik risk algılarının ise trafik yoğunluğundan, yaya görünürlülüğünden, bekleme süresinden ve yol genişliğinden etkilendiği "Davranışsal Kara Nokta Analizine" dayanarak gösterilmiştir. Yeniden yapılandırmalar öncesinde ve sonrasında yapılan gözlemler sonucu, yeniden yapılandırmaların araç hızı, çatışma sayısı, yol verme davranışı, kuyruk oluşturan araç sayısı, kaldırım kenar taşında duran yaya sayısı, baş hareketleri, karşıdan karşıya geçiş hızı, mesafesi ve açısı gibi faktörleri olumlu bir yönde etkilerken, yayaların bekleme süresini olumsuz yönde etkilediği kaydedilmiştir. Son olarak yaya güvenliği odaklı yapılandırmalar ile ilgili öneriler sunulmuştur.

Anahtar Kelimeler: Kara nokta, Trafik Kazaları, Yaya Güvenliği, Karşıdan karşıya geçme davranışı, Güzergâh seçim davranışı

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CHAPTER 1

INTRODUCTION

This study aims to establish pedestrian safety focused environment around elementary schools. In order to reach this objective 3 consecutive goals are aimed.

As a first step to reach the goal, it is aimed to develop a new behavior based black spot analysis which is based both up on interviews and geocided crash data.

Secondly it is aimed to document pedestrian and driver behavior at black spots. This required coding detailed behaviors of pedestrians and drivers; whether or not driver give way, how much time pedestrians waited on the curb, whether a conflict happened or not when pedestrians were crossing, where pedestrians waited before crossing, crossing angles, crossing tempos, crossing distance and head movements of pedestrian.

Finally it is planned to develop effect interventions and measure their effectiveness by counter measures.

Pedestrian crashes are still one of the most serious health risks which children face with. (Connelly et al., 199; UNICEF, 2001)

Beside the large proportion of pedestrian injuries in developed countries, pedestrian injuries account for a much greater proportion (41–75%) of traffic fatalities in developing countries. (daSilva et al., 2003)

Pedestrian crashes are more serious type of crashes compared to other type of crashes. 5% of pedestrian crashes result with fatal injuries and 10% to 39% incapacitating injuries (Garder, 2004; Kim et al. 2008). One reason why pedestrian crashes result with large proportion of injuries and death is because, if a pedestrian is hit by a vehicle when crossing the road the force exerted is greater due to higher speed (Tanduker et al., 2006)

Before effective interventions can be developed, children's road crossing behavior and the nature of road crossing errors need to be fully understood. Only then can interventions target to the aim.

1.1 Why Young Pedestrians?

1.1.1. Road Rules in Turkey

According to the Turkey Road and Traffic Codes drivers are not required to give way to pedestrians even on crossings, except for crossings with traffic lights. Pedestrians are required to look both sides before crossing. They have to predict the speed of vehicle and its arrival time to the crossing. Pedestrians can only cross if there is a pedestrian cross. A pedestrian must not cause a traffic hazard by moving into the way of a driver (KTK, 1983; KTY, 1997)

Turkey as a developing country embodies more danger for pedestrians compared to other Europian countries (Economic Commission for Europe, 2005). For instance pedestrian fatality death with in all fatalities is 24.8 in Turkey, whereas the same rate in Austria is 16.5, in Belgium 10.3, in France 12.2 and in USA 13.4. According to Hamed (2000), both drivers and pedestrians in developing countries do not comply with the traffic rules, and therefore pedestrians in developing countries take greater risks.

1.1.2. Some Pedestrians are More Vulnerable than Others

"All pedestrians are vulnerable but some are more vulnerable"

Because of the reasons counted above pedestrians can be referred as vulnerable road users. But it should be remembered that some road users are more vulnerable than others. These are young, old, handicapped pedestrians.

Pedestrian injuries in Turkey show that children aged 1-15 accounted for highest percentage of pedestrian fatalities (32%), followed by 16-30 year group (23%).

Similarly in New Zealand pedestrian injury records indicate that children aged 5–9 years accounted for the highest percentage of injuries (16%), followed by ages 10–14 (13%) and 15–19 years (12%), with no other age group accounting for more than 7% (20–24 years). Very similar findings are reported from UK, US (Malek et al., 1990) and from Canada (Jonah and Engel, 1983)

High percentages of injuries are simply and mainly result of unsafe road crossings. Unsafe road crossing rates of different age groups and injury percentages goes hand by hand. In a virtual reality system experiment it is found that young children made the greatest number of unsafe crossings and oldest the fewest (Simpson et al., 2003).

There are several factors why young pedestrians make unsafe road crossings, and which factors make young pedestrians more vulnerable than others. Factors which handicap young pedestrians can be gathered under two titles; perceived risk and compliance with rules.

1.1.3. Perceived Risk

Studies assessing children’s road crossing judgments found that children tend to rely on partial information. And therefore they do not take critical road factors into account.

Being aware of risk, allows avoiding it (Slovic,1987) Adults typically learn from their mistakes . Children seem to not understand the connection between speed, time and distance. Since children do not have a clear understanding of risk they clearly become prone to crashes.

There are numerous studies which examined risk perception of different age groups at traffic environment. It’s found that younger pedestrians had such characteristics and attitudes which lead them to take greater risks on road. These characteristics also prevent them from perceiving hazards (Parker et al., 1992)

Younger Pedestrians have more positive attitude towards crossing in risky situations (Diaz, 2002) and therefore they are more likely to say that they would cross in risky situations (Evans and Norman, 1998)

Some of the factors which cause young pedestrians to develop positive attitude towards crossing are underestimation of risk and optimism bias. Young Pedestrians tend to underestimate the risk of an crash (Deery, 1999) and they are prone to optimism bias that is they tend to perceive their own risks lower (Glendon et al., 1996)

Recent Studies on perceived risk argue that difference between age groups to cross road is due to perceived value rather than perceived risk of crossing (Hollan and Hill, 2007)

1.1.4. Compliance with rules

There are two different types of motives in obeying the law; instrumental motive and normative motive Tyler (1990). Instrumental motive is simply outcome of perceived gains and losses; compliance with the law is related to external forces. Normative motive is basically internalization of the law. In normative motive compliance with the law is in accordance with personal values.

Concerning traffic rules, young pedestrians may possibly be not internalizing traffic rules. Therefore they may be accounted as having instrumental motives rather normative.

Children fail to display compliant behaviors which contribute to safety. For instance in one of the studies conducted by Granie (2007) 54% of children look around as they walk, and only 32% looked in both directions before crossing. Similarly, while 56% of the children used the crosswalk, only 15% stopped at the curb before crossing.

Finally, these data show that the children did obey with several pedestrian rules, but did not comply with other important rules that would have resulted in safer crossing behavior (Granie, 2007).

1.2. Nature of Pedestrian Crashes

It is reasonable that most pedestrian crashes occur when pedestrian activity and traffic is heavier. For instance most pedestrian crashes occur at day time with 77,6% (Kim et al., 2008) and the peak time is between 4p.m. and 7 p.m. (Garder et al., 2004), the peak time for Ankara is between 2p.m. and 7p.m. In some studies Fridays (Kim et al., 2008) are over represented where as in some other studies Saturdays (Garder et al., 2004). In Ankara most crashes occur on Thursday and Sundays have the lowest percentage (Kaygısız,2008).

In terms of wheather, the majority of crashes occur during clear weather (75%-77.9%). Only 9 % of crashes occur when it is raining. (Kim et al., 2008; Garden et al. 2004).

Lastly it should be npted that most of pedestrian crashes happened at locations where there is no traffic control device or signage.

Concerning recent the study considered times of the day and wheather in order to reach better results. Pre and post measures are conducted on busy hours and clear weather.

1.2.1. Unsafe behaviors

Rosenbloom et al. (2008) used video recordings to examine the crossing behavior of children. It is concluded that not looking was the most frequent unsafe behavior, followed by the combination of not looking and not stopping, and not stopping before crossing. In other studies not stopping before crossing and not looking before crossing, running a red light, crossing the street at an improper location and jay walking were found to be most frequent unsafe behaviors committed by pedestrians (Kim et al. 2008; Lam, 2000; Rosenbloom et al., 2004; Zeedyk and Kelly, 2003).

In a similar research which researchers dealt with risky crossing behavior, explanatory variables were founded to be gender, age, crossing frequency, number of people in a group, access to private vehicle, destination, home location and previous accident involvement; surprisingly, traffic parameters were not found to be statistically significant. As a result pedestrians waiting times were strongly related with crossing attempts. And pedestrians behaved differently in the second part of the road where they were found to be taking more risk (Hamed, 2001; Tiwari et al. 2007).

Unobtrusive observations revealed that accompanying adults did not have an impact in diminishing these critical unsafe behaviors. Children with accompanying adult rarely pressed the crossing button, and never checked for traffic themselves by turning their heads to the right or to the left (Lam, 2000; Rosenbloom et al., 2008; Zeedyk and Kelly, 2003).

1.3. Route Choice Behavior

Researches which study route choice behavior usually observe pedestrians' decision making process from a point to several destinations or vice versa. Route choice behavior is usually studied by use of simulation techniques. Route Choice analyses can be classified in two; route choice models and crowd models. Modeling techniques may range from macroscopic to microscopic simulations, from continuous to discrete time, from time to event-based examinations (Xiaoping et al., 2009).

1.3.1. Directness

Hill (1982) has studied on pedestrians' decision giving strategies in urban environment. He concludes that, like most walking processes, route selection strategies are largely subconscious, and directness is the most common reason for selecting route. Directness is not only the length of the route, but also its simplicity (cited in Hoogendoorn and Bovy, 2004).

Although pedestrians choose the shortest route they are hardly aware of why they choose the specific route (Senevarante and Morall, 1986). Some factors that are examined to play important role in route choose behavior are habit, number of crossings, pollution and noise levels, sheltering poor weather conditions, and stimulation of the environment. To which extent these route attributes play a role in route choice behavior depends largely on trip purpose (Bovy and Stern, 1990; cited in Hoogendorn and Stern, 2002)

1.3.2. Barrier effect (Severance)

Barrier effect refers to the tendency of roads and traffic to create a barrier to nonmotorized elements of road users. Barrier effect can stand for either physical (actual barriers to movement) or psychological (perceived impediments to movement) ones.

Hine and Russel (1993) used video recordings to model barrier effects on pedestrian behavior. Video recordings of pedestrian movements, vehicles speed and traffic flow along a road with no pedestrian facilities and interviews with pedestrians reporting their perception of the environment were used to reach to the aim. The results showed that traffic conditions often led pedestrians to take different routes or switching to other transport modes, instead of walking.

1.3.3. Opportunistic and Law Obeying Route Choice

One of the best studies in Route Choice Behavior is conducted by Liu et al. (2000) in which they extended the DRACULA micro-simulation model in order to extensively study the interaction between vehicle and pedestrian movement. In the mentioned study researchers studied network of highways, walkways and vehicle responsive signal control strategies. According to Liu et al. pedestrians are sorted in to opportunistics and law-obeying ones. As a result it was found that drivers and pedestrians' decisions are based on default probabilities. Their study later on inspired some other studies on pedestrians' route choice behavior. Proportion of opportunistic pedestrians to law obeying pedestrians were later on studied in China by Yang et al. (2006) In the mentioned study opportunistic ones were the ones which were violating red light on the absence of policeman, vehicle flow or other pedestrians.

In recent studies more advanced techniques are integrated in to studies, especially multi-agent simulation techniques.   These newly used instruments are mainly based up on artificial intelligence.

One of the recently developed techniques in this manner is PEDFLOW, a simulation tool for pedestrian flow (Kukla et al., 2001). The PEDFLOW includes following steps; direction determination, observation, parameterization of observation, rule evaluation and movement.

1.3.4. Utility Theory

Utility theory refers to human as adaptive organism. This theory is adapted to route choosing behavior. (Van Berkum and Van Der Mede, 1993; cited in Hoogendoon and Bovy, 2002). A pedestrian, which decides to choose a route, optimizes his/her utility by calculating the uncertainty.

The utility theory is adapted by Hoogendoorn and Bovy (2002) in order to analyze route choice behavior. In their theory pedestrian behavior is splitted in to 3 different levels; Strategic level (Departure time choice, and activity pattern choice), Tactical level (Activity scheduling, activity area choice, and route-choice to reach activity areas), Operational level (Walking Behavior). In this hierarchy it is assumed that utilities at lower level influence operational behavior. The article mainly focuses on tactical level and it is concluded that tactical level is influenced by both external factor and internal factors. External factors can be counted as presence of obstacles, stimulation of the environment and internal factors are time–pressure, attitudes of the pedestrian.

In another research Hoogendoorn (2004) try to find out how pedestrian minimize the cost of walking. The multiagent system in this study has two bases physical model and a control model. Physical model as it can be understood from its name it is based on physical principles such as friction and force principles. The control model is used to model the acceleration principles.

Subconscious activities of route choice behavior are thought to be affected by;

1. Distance or travel time between origin and destination.
2. Proximity of obstacles or other physical obstructions; closeness to walls.
3. Number of sharp turns and rapid directional changes (route directness).
4. Expected number of interactions with other pedestrians (level-of-service).

5. Stimulation of environment, and attractiveness (e.g. ambience conditions, shopping windows, shelter in case of poor weather conditions).

Considering studies conducted, pedestrian route choice behavior is a detailed issue and needs deep analysis. In this study pedestrian route choice behavior is only analyzed in order to find out black spots in appointed areas. It is hypothesized that pedestrians will choose shortest routes on their ways to home.

1.4. Pedestrian Crossing Behavior

Crashes involving pedestrians are most likely to occur when the pedestrian is crossing the road. For example, between 1995 and 1998 in the US 63% of pedestrian crashes occurred while the pedestrian was attempting to cross. Same proportion was 79% in Australia in at 2004. (daSilva et al., 2003; Roads and Traffic Authority, 2005)

There is variety forms of studies conducted about Pedestrians' crossing behavior. These studies usually used unobtrusive observation or simulation. An important portion of these studies concerns safety issues, roadway designs, and traffic control features. And many other studies have concerned gap acceptance models, discrete choice models.

The traffic safety of a pedestrian who is crossing a street is influenced by many factors. Therefore research on pedestrian behavior is usually detailed, deterministic, traffic and environment oriented. Usually only one potential determinant is observed in articles. Although contemporary researches examine pedestrian behavior in detail they lack modeling. Only few articles are in effort of sketching a pedestrian behavior model. (Papadimitriou et al., 2009)

There are three scenarios when a pedestrian attempts to cross. If a pedestrian crosses when there are no vehicles around, then he/she will be definitely safe.

If the pedestrian wishes to cross a street when there are vehicles passing by, he/she can either wait for a ‘safe’ gap to occur, for a vehicle to slow down or stop for him/her, or just walk out into traffic and make the traffic flow stop. In the case of the pedestrian jumps in road, the driver has two choices; he/she will stop or he/she will not brake. Sometimes driver will even accelerate to show that he will not give way to the pedestrian. (Björklund and Aberg, 2005) In this case probably both driver and pedestrian give themselves a safety gap in case of emergency.

The third option is jumping in to the road without considering any safe gap. This third option is primarily chosen by intoxicated people and possibly by people in great stress or with mental handicaps—or definitely by mistake. Sometimes children may even do this because they do not realize dangers. Measures to provide safety for people walking straight out into traffic may be different than measures aiming at providing safety for people choosing either of the other two strategies. But there is no chance of separating these groups from each other.

Studies concerning pedestrian crossing behavior can be grouped under two titles; Psychology oriented approaches and Traffic oriented approaches. Although both approaches goes hand in hand, they focus on different aspects of the pedestrian crossing safety.

There are very important articles concerning psychological background of pedestrian behavior.

Such studies on psychological factors give sophisticated understanding of the pedestrian behavior but compared to traffic oriented approaches they lack developing counter measures and precautions, in the light of findings. Direct studies of safety; such as intervention studies have direct contribution to safety culture. And it is more likely that traffic conditions and safety precautions have more direct affect on crossing behavior.

Many Studies in pedestrian crossing behavior investigates safety margin/gap acceptance and waiting time.

1.4.1 Waiting time

Waiting time is one of the most important factors that need to be studied if pedestrian crossing behavior is examined. Waiting time is an influencing factor on unsafe pedestrian crossing.

Hamed (2001) and Tiwari et al. (2007) studied the factors that influence a pedestrian's waiting time and frequency of attempts to cross streets. In both studies it is founded that pedestrians' expected waiting time has profound influence on the number of attempts to cross the street. As waiting time increases pedestrians get impatient and violate the traffic signal and take risk. This risk or violation places them at increased risk of being struck by a motor vehicle (Carsten et al., 1998).

So reducing waiting time of pedestrians would probably decrease the chance of pedestrian being crashed by vehicle (Tiwari et al. 2007). One of the best solutions to waiting time is introduced by Keegan & O'Mahony (2003). They did not reduce waiting time but placed flashing timers to pedestrian crosses. This solution reduced crossings on red light from 35% to 24%. Telling pedestrians how much they will wait is actually a very similar approach with telling customers how much they will wait. It is well known that informing customers on waiting time reduces overestimation of it (Antonides et al., 2000) In the light of this finding it should be bearded in mind that relative value of 10 seconds waiting time is not always same with relative value of 10 seconds walking.

Finally and very importantly Hamed (2001) reports that pedestrians who frequently use a certain pedestrian crossing and who live nearby the crossing are likely to accept higher risk and reduce their waiting time at pedestrian crossings. This indicates that pedestrian crossings which are planned to be built near school gates may not have sufficient effect on pedestrian behavior.

Referring to the findings listed above; in this study one of the ways to enhance safeness in this study is to reduce waiting time in interventions. It is hypothesized that reduced waiting time will cause safe crossing attempts.

1.4.2. Gap Acceptance / Safety margin

Gap acceptance or in other words safety margin is simply; idea of "the further the car, the safer to cross". The size of the gap to cross in traffic will differ from pedestrian to pedestrian as a function of their individual factors (walking speed, fatigue, carrying heavy luggage) and environmental factors (e.g. strong winds, rough road surface, width of the road).

Himanen and Kulmala (1988) investigated probability of a driver breaking or weaving, and probability of a pedestrians' crossing behavior. They used discrete choice techniques on the basis of video recordings to model the probabilities. The results also allowed for the calculation of safety margins in driver/pedestrian interactions. In the study it was found that, number of vehicles, vehicle speed, pedestrian distance from kerb, number of pedestrians simultaneously crossing and city size were explanatory variables, whereas road width, median refuge, yield rules and most of the pedestrian variables were not found to be significant.

Oxley et al. (1997) examined the crossing behavior of pedestrians at mid-block locations by the means of kerb delay, gap acceptance, crossing time, time-of-arrival, minimum safety margin and crossing style (non-interactive vs. interactive). Measurements for elderly pedestrians were compared to those of younger ones. Results showed that elderly pedestrians present increased kerb delay, and accept larger gaps; however they also frequently adopt unsafe interactive crossing styles.

Simpson et al. (2003) investigated crossing decisions of young adults and children at mid-block locations. Participants were tested at a virtual environment. Many indicators were analyzed; such as, collisions, crossing times, accepted and rejected gaps and total number of gaps. Very interestingly safety margin is found to be based on inter-vehicle distance rather than speed.

In previous studies (Connelly et al., 1996; Simpson et al., 2003; Johnston and Peace, 2007; Te Velde et al., 2005), it is found that pedestrians engage in more unsafe crossings in uniform distance trials rather than in uniform speed trials.

There are also some studies investigating effect of age on pedestrian crossing behavior, mainly, safe time gap selection. Oxley et al. (2005) used simulated road crossing tasks in order to reach this aim. Participants' decision times were compared via ANOVA. A logistic regression model was then developed for gap selection, in relation to walking time, age group, time (or distance) gap and vehicle speed. It was found that elderly pedestrians took more risk in terms of traffic gaps. Same finding were also verified in other studies (Te Velde et al., 2005).

Beyond that, the proportion of yes responses to crossing in different situations increased rapidly for the young participants who reached close to 100% asymptote (crash level) when the vehicle was more than 100 m or 7 s away from them (Oxley et al., 2005).

In a similar study it is found that older pedestrian prefer sidewalks and their crossing facilities are much better, and older pedestrians express more doubts about their own abilities. (Bernhoft and Carstensen, 2008; Simpson et al., 2003). These findings present the highly risky conditions of young pedestrians among other road users.

Why young pedestrians' crossing decisions rely on distance rather than arrival time of vehicle is a simple developmental matter. Studies indicate that children's daily judgments heavily rely on distance rather than speed (Matsuda, 1996). This simple judgment of distance and speed is extended equally to traffic behavior which is named as gap acceptance (Connelly et al., 1996).

Why children and young pedestrian rely on distance rather speed in traffic is also attributed to poor physical and motor skills (Briem and Bengtsson, 2000) and to perceptual development (Hoffrage et al.,2003)

On the other hand Rosenbloom et al. (2008b) argue that for a preschooler speed of vehicle is a bigger source of fear rather than distance. They take distance into account only when speed is low. For adults situation was found to be different. Adults conceptualize both speed and distance as source of danger. Above mentioned studies points out that development plays a crucial role in the integration of the concepts of speed and distance into a coherent understanding of these elements' involvement in a road-crossing task.

Considering gap acceptance process of young children it is hypothesized that pedestrians will engage crossing when the bump is further away from pedestrian cross.

1.5. Driver Behavior

In some countries, such as United States most drivers stop when a pedestrian steps into the street, but in Turkey, even though pedestrians have the right-of-way, drivers seldom stop. Informal observations of drivers indicate that many drivers ignored pedestrians in crosswalks, and sometimes accelerated or swerved to pass them.

In traffic, the possibilities to communicate are restricted but a driver can, more or less deliberately, show his or her intentions to other road users by selection of speed and position on the road. Drivers can, for example, slow down or stop to show that they will give way, or maintain the speed or accelerate to show that they do not intend to give way to other road user.

Janssen et al. (1988) studied driver interaction with pedestrian. It was found that speed and position of the vehicles were important for drivers' decisions to give right of way. Formal observations of drivers at a campus revealed that most of drivers never came to a complete stop when a pedestrian was in the crosswalk and 43% of the drivers did not stop. (Cited in Björklund and Aberg, 2005)

Varhelyi (1998) studied how drivers' gave way and their speed adaptation at mid-block crosswalks, hypothesizing that the speed of drivers approaching a crosswalk depends on pedestrian's arrivals. Drivers' speed behaviour was videotaped and measured using speed guns. Pedestrians' presence was compared with opposite situation by the usage of t-test. Results indicated that very low proportions of drivers were giving-way to pedestrians; a consistent pattern was observed, drivers maintained high speed or even accelerated in order to warn pedestrians of their intention not to give-way. Moreover, the drivers' decision zone was found to be identified at around 50 m before the crosswalk. This finding brings us to the importance of speed.

1.5.1. Free Speed

Generally, the free speed is defined by the speed of driver when the driver is not influenced by other road users. The free speed is influenced by vehicle, the driver, the road, and (road) conditions such as weather and traffic rules (speed limits) (Hoogendoorn, 2004).

Estimation of the free speeds and the free speed distribution is not a straightforward task. Drivers can be in two states; car-following or driving at their free speed. Thus only drivers driving freely will provide an unbiased estimation of the free speed distribution (Botma, 1999).

In addition to free speed measures new modeling are tried to be established in order to present how drivers choose their free speed. However, these models have not been successful in their practical application (Jepsen, 1998; Botma, 1999)

1.5.1.1. Free Speed and Yielding

Garder (2004) studied the interaction between free speed and yielding behavior. It is concluded that the higher the driving speed, the lower the percentage of drivers who stop or yield pedestrian in crosswalks. This relationship is illustrated from observation from various states in USA. Results show that when the average speed is <11 mph (18 km/h), almost 100% of drivers yield to pedestrians who have taken one step out into the crosswalk. Where the average speed is 11–15 mph (18–24 km/h), 28% do; if 16–20 mph (26–32 km/h), 23% do; and 21–30 mph (34–48 km/h), 17% yield.

The study conducted by Garder points to an important subject about free speed; where as in order to reach a efficient result in an intervention, free speed of vehicles should be reduced up to 18km/h. Thus drivers will yield almost 100%.

1.6. Improving Safety

There are some gaps in knowledge about how to best improve safety for pedestrians. In addition to the behavioral and human factors, both pedestrian and driver behavior is influenced by design of intersections, vehicular, roadway, environmental, and other contextual factors. Since this study aims to improve safety around elementary schools other studies examining interventions lighten methods followed in this study.

1.6.1 Black Spot Analysis

First step to efficient intervention measures passes through black spot analysis, because reasonably identifying and ranking high pedestrian crash zones plays a key role in developing efficient and effective strategies to enhance pedestrian safety.

The GIS based methodology is most widely used technique to identify high pedestrian crash zones. The GIS based methodology simply includes geocoding crash data, creating crash concentration maps, and then identifying high pedestrian crash zones. LaScala et al. (2000)

Methods such as crash frequency, crash density or in other words crash rates are extensively used techniques in GIS based in methodology. One such example is conducted by Roche(2000) where black spots are determined by crash rates. However a method which considers crash frequency based on severity, vehicle flow density, and pedestrian explore would be more meaningful and guiding.

An effective Black spot analysis by usage of GIS should follow 3 steps. (1) Geocoding crash data, (2) Creating a crash concentration map, and (3) Identifying zone shape and size (Plugurtha et al., 2007).

Step 1: *Geocoding pedestrian crash data*

This step is the first and most important step where "dirty" data is cleaned. This systematic geocoding of crashes is done by the use of "address match" feature. (Braddock et al., 1994; Andaluz et al.,1997).

Step 2*: Creating a crash concentration map*

This step is also easily conducted by density map feature which is available on GIS software programs. For example number of crashes per kilometer square can be displayed on virtual maps. There are several methods which can be followed while creating a concentration map.

The common method is named; Simple Method. In simple method the entire region is divided into equal cells. A circular search area is drawn around each cell. Then each cell is represented by number of crashes in the area of the cell.

Step 3*: Identifying zones, their shapes and sizes*

A high pedestrian crash zone could be linear or circular in shape. For instance if dense clusters of crashes are observed to be closely spaced along a road, then these clusters are considered to be a linear zone.

There are several methods in determining crash zone-black spots (Plugurtha et al. 2007).

Crash frequency method is the simplest method. In crash frequency method all types of fatal and injury crashes are given equal weights. An extension of the crash frequency method is the *crash frequency based on severity method* in which different crashes are weighted differently. This model referred to crash frequency model due to its functionality. For instance by *crash frequency based on severity method* one can determine zones with more severity.

Crash density method is used if areas are not devided equally. In this method crash weight is devided to zone area or length.

Crash rate (CR) method is most sophisticated one where vehicular volumes, pedestrian volumes, or population in the proximal area is taken into account. In this method crash weights are divided to typical measures of exposures (pedestrian volume, vehicle volume, population).(LaScala et al., 2000) But the crash rate method can be biased when vehicle volume is very low. (Layton and Robert, 1996; McMillen and Robert, 1999).

1.6.2. Intervention

There are broadly three possible approaches to sort out problems that road users face with in environments which are shared by both vehicles and pedestrians (Leaf and Preusser, 1999).

The first approach is to give pedestrians absolute priority. This approach was practiced about 100 years ago in many communities.

The second approach is to give true priority to pedestrians. This was applied in all roads especially in main arterials and between streets. A pedestrian crossing a street has to take full responsibility. To be safe, pedestrians must stay away from roads when cars are approaching. Turkey's today reality is very similar to this second approach, except for signalized crosswalks. A pedestrian who attempts to cross from a pedestrian cross, need to wait for a safe gap, or all nearby vehicles to fully stop or pass.

The third approach is accounting pedestrians and vehicles as equal partners, road users. Neither pedestrian nor vehicles are seen as adversary to traffic. Studies indicate that in order to make this interaction possible vehicle speed should be very low (Leaf and Preusser, 1999; Garder, 2004).

There are various number of interventions which are conducted to enhance the third approach. These interventions had positive outcomes and enhanced interventions have enhanced safety.

For instance implementations for prompting motorists to stop for pedestrians (social assistance to increase the proportion of drivers stopping for pedestrians in crosswalks) (Nasar, 2003), or reconstructions interventions as building a safe island (Nee & Hallenberg, 2003), construction of speed humps advance stop lines and pedestrian-activated amber flashing lights (Van Houten & Malenfant, 1992), construction of speed humps (Cottrell et al. 2006; Garder et al. 2002) also had positive outcomes. Other implementations as countdown timers (Keegan & O’Mahony, 2003), fluorescent strong yellow–green pedestrian warning signs at mid-block locations (Clark, Hummer, & Dutt, 1996), detections which realize pedestrian and warn drivers (Hakkert et al., 2002) also had positive outcomes and enhanced driving.

Although these studies have implemented efficient engineering systems they have lacked deep view of pedestrian behavior. According to Hakkert et al.(2002) although implementations concerning traffic safety are improving safety, they have not got much affect on unsafe pedestrians behaviors.

1.6.2.1. Building Hump

The purpose of the hump is to force drivers to reduce their speeds to mitigate an ‘‘unpleasant’’ bounce when passing the hump. (Cottrell et al. 2006)

Older speed bumps were narrow and high profile that could have damage the vehicle. Then speed bump evolved to speed hump, because of its more forgiving shape. The most popular type of speed hump is the Watts design, a maximum height of 7.5 to 10 cm, and a width of 3.7 m with a parabolic profile (Cottrell et al. 2006).

Speed hump can be counted as a traffic calming device. Chadda and Cross (1985) concludes that introduction of speed humps in 14 streets of Australia, U.K. and the United States decreased speed between 1% and 64%. But decreasing traffic speed is not enough unless 90 percentile driving speed calms 30 km/h (Johnsson and Leden, 2007).

Johansson and Leden (2007) concluded that the height of a speed cushion was important in lowering the traffic speed. For 70 mm height they received 34 km/h and for 55 mm 41 km/h for 90 percentile speed.

The effect of a longer distance between the speed cushion and the crosswalk

According to the findings of Johansson and Leden (2007) a higher share of children and elderly were given priority where the speed cushion was located at a further distance from the marked crosswalk. But on the other hand when the distance between crosswalk and speed hump is further then the 90-percentile speed at the marked crosswalk was about 5 km/h higher than the older.

In the light of findings it is hypothesized that higher share of children will be given priority when the distance between speed hump and crossing distance is higher.   In addition speed humps should be lower than 70mm in order to decrease 90th percentile speed to 30 km/hr.

1.6.2.2. Marking Crosswalks

Marking crosswalks increases yield rates (expected improvement 6%) towards pedestrians (Leden, 2002). Additionally if marked crosswalks at non-signalized locations are compared to unmarked crosswalks, Marked crosswalks are two times riskier or in other words marked crosswalks seem to be almost 50% safer than unmarked ones.(Garder et al., 2004)

But on the other hand there are opposes of this idea. Ekman (1997) argues that marked crosswalks are more risky due to a false sense of safety for pedestrians (cited in Garder et al. 2004). For instance about 10% of all marked crosswalks on 50 km/h-streets in Sweden were eliminated in 2000 and 4% more in 2001. Especially crosswalks which are located at streets with low pedestrian flow were chosen to be eliminated (Garder et al., 2004).

1.6.2.3. Traffic Calming

It is argued that speed is one of the most important factors that causes serious injuries (Leaf and Preusser, 1999) and prevent safe road crossings (Leden, 2002).

Leaf and Preusser (1999) showed that higher vehicle speeds are strongly associated with both a greater likelihood of pedestrians being involved in a crash and with more serious pedestrian injury. Their study indicates that 5% of pedestrians will die when struck by a vehicle travelling at 20 miles an hour or less. This compares with fatality rates of 40%, 80% and nearly 100% for striking speeds of 30, 40 and 50 mph respectively. In a similar study Pasanen (1991) argued that a speed of 50 km/h causes a risk of death almost eight times higher than a speed of 30 km/h. Strong relation of crash severity and speed was also marked in other studies (Garder, 2004)

Leden (2002) found that risk for pedestrians increased with increasing vehicle flow and decreased with increasing pedestrian flow.

Summarizing interventions conducted about speed it is obvious that decreasing speed would have positive outcomes.

For instance traffic calming has clear effect on yielding behavior. Reconstruction also increases yielding behavior. Yielding behavior rises from 21% to 45% (Garder et al. 2004) in some other interventions from 14% to 51%(Johnsson and Leden, 2007)

On the other hand reconstructions may have negative effect on safe behaviors. After reconstructions, pedestrians stopping at the curb decreased for all age groups, even when a car was approaching. (Johnsson and Leden, 2007).

Therefore constructing pedestrian cross may give a false sense of safety, which in turn may reduce some safe behaviors; such as not looking to both sides and etc.

1.7. Hypotheses of Study

1- Considering directness principle it is hypothesized that pedestrians will choose shortest route on their way to home.

2- Interventions planned to build in this study may decrease some behaviors; if they rise waiting time or give a false sense of safety.

3- Considering gap acceptance theory it is hypothesized that pedestrians will engage in safe crossing attempts more when the bump is further away from pedestrian cross.

4- Reduced speed will cause fewer conflicts and safer crossings.

5- After interventions are completed it is hypothesized that drivers will yield more, pedestrians will wait less on the curb, fewer conflicts will occur, crossing tempos will reduce as a result decreased speed and increased gaps between vehicles.

6-Finally head movements of pedestrians may reduce as a result of sense of safety.

CHAPTER 2

METHOD

2.1. Participants

Totally 630 participants are involved in this study. 278 are morning and 352 of participants are evening students, where all students fall in to age range of 12-15 years old. This age range corresponds to 6th, 7th, and 8th grade students in Turkey.

2.2. Procedure

2.2.1. Determining Black Spots –Behavioral Black Spot Analysis-

2.2.1.1. Determining Risky Regions

In the first step of the study we aimed to determine most risky points in city traffic of, capital of Turkey, Ankara. In order to reach our aim Traffic Information system is widely and deeply used in the first step of the study.

TIS (Traffic Information System) is a system which is fundamentally based upon screening crashes on virtual maps by the use Geographic Information System (GIS). Basically all Traffic Police Officers own a GPS (Global Positioning System) device, and by use of these devices they record down coordinates of crashes. And while reporting the crash they also report coordinates. By this way all crashes in Turkey are screened on maps in respect to their categories.

Step 1: *Geocoding pedestrian crash data*

By the use of TIS, accident reports of 2003 and 2004 in the data are analyzed. All steps are conducted via MapInfo Professional 7.0 SCP. The data was changed into .tab extension before the study. This transformation was conducted in order to determine black spots. Before starting to the study “dirty” data is cleaned. This systematic work was done by the use of address match technique (Andaluz et al., 1997; Braddock et al., 1994). Finally the data included pedestrian fatalities and injuries with exact matches.

Step 2*: Creating a crash concentration map*

The common method; Simple method is used in order to create concentration maps. After determining all primary schools in capital city of Turkey, Ankara, these schools were virtually surrounded with circles with a diameter of 600m. By this way Ankara was divided in to sections of approximately 1 km^2 where all sections were named with the name of the school in it. These sections were ranked depending on the pedestrian crash rates. By the use of this data most risky 20 school zones in the city were chosen. These 20 Primary school regions were those with highest rate of pedestrian crashes. Each School is represented by number of crashes in the area of the cell

Step 3*: Identifying zones*

After exploring school regions, 6 schools were determined for the study. These 6 schools out of 20 schools were decided to be chosen on the basis of easiness and applicableness of investigation. (Names of schools will not be reported in respect to ethical concerns)

2.2.1.2. Determining Black Spots within Risky Regions

In order to identify black spots in these 6 school regions, maps of school zones were handed out to students. Since normal maps are hard to understand for a 12 year old student, these maps were simplified in to sketches. In pictures below a non simplified and simplified version of a school map can be seen. Street names and School names are deleted from maps due to ethical concerns.

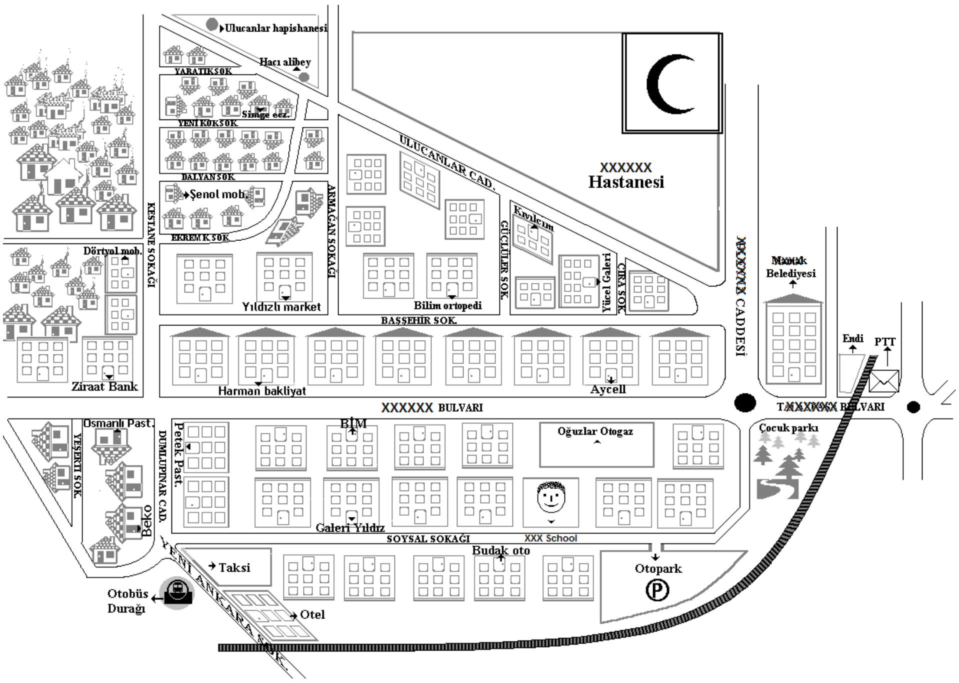


Figure 2.1. A simplified map of a primary school

Image 2.1. A satellite image of the same school

Next, simple maps of school environments (as shown in Figure 2.1.) were handed out to 630 students (age range 11-14). Students were asked to draw the routes which they were using when coming and going to school, and to plot the points where they felt in danger-risky.

School children's opinions of the traffic risk, road reconstructions and change were gathered either by simplified maps or observation techniques. Earlier research by Leden (1988) had indicated that 11–13 years old school children could be the most appropriate age group for assessing effects of countermeasures; this age group was therefore chosen. (cited in Johansson and Leden, 2007)

These maps were only conducted to students which were going home on foot. Before students filled maps, some trials were done to be sure that students understood which steps they should follow. These trials were conducted by a company of a teacher. After students filled maps they were asked some demographic questions, whether they had an accident or not, and if an adult accompanied him/her.

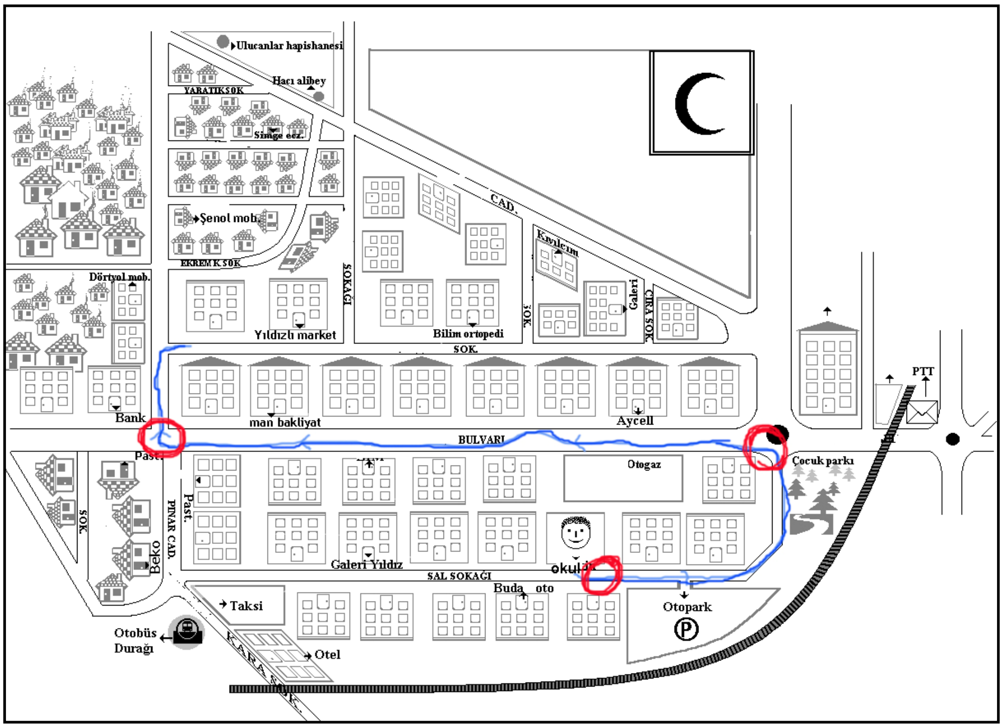


Figure 2.2. A map which is filled by a 6th grade student

Behavioral black spot analysis was based on risk evaluations of pupils. In order to analyze these maps which are filled by students, simply, for each intersection number of students passing from that intersection, and number of students felt in danger were calculated. And from these intersections a risk ratio was calculated. The risk ratio was calculated by dividing number of students felt in danger at the intersection to number students passed from that intersection.

Finally, by comparing behavioral black spot analysis results with real accident data, black spots were determined.

2.2.2. Observation

In the next step of the study number of schools being analyzed dropped from 6 to 5 due to the reconstruction at one of the sites decided to be studied. In this step of the study it is aimed to observe driver and pedestrian behavior. In order to reach this aim blackspots were recorded by cameras unobtrusively. At each scene two cameras were placed; a head camera for recording head movements of pedestrians, and a top camera for recording vehicles passing through the point.

At the observation step, firstly, the best camera view for the top and head cameras were determined. In order to have the best angle usually balconies of high buildings were chosen. For Head camera usually an unnoticeable corner of the black spot was chosen. If a suitable place could not be found, the head camera was placed inside a car, and the car was parked to an appropriate place.

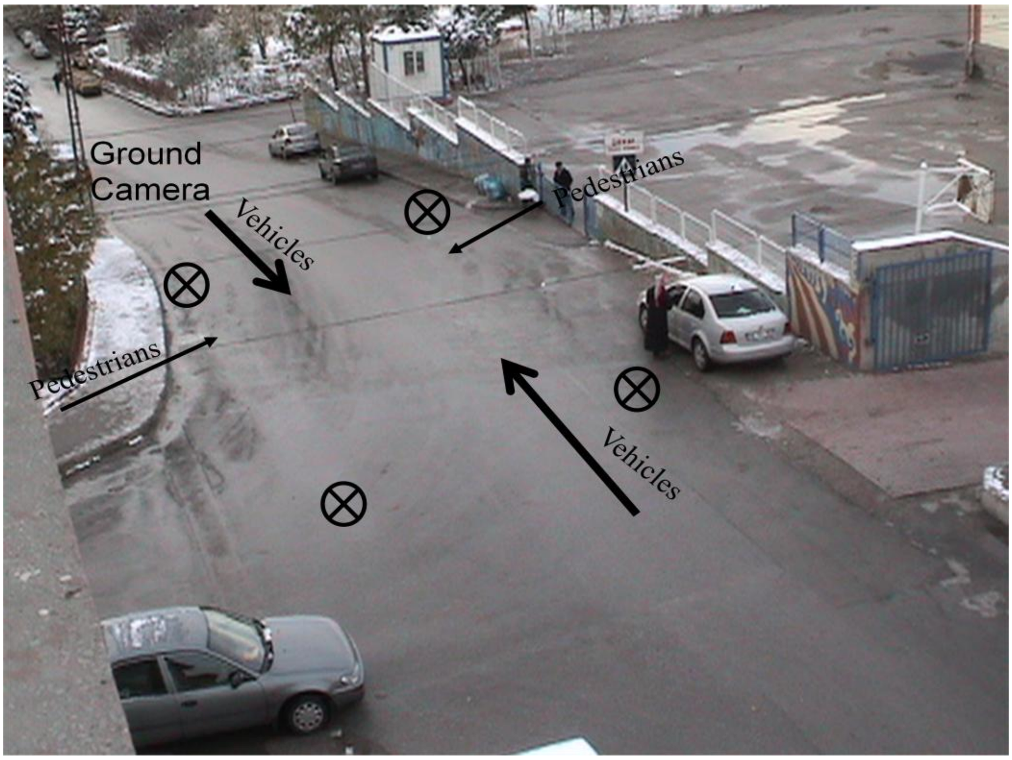


Image 2.2. An example of a view of top camera and place of ground camera (Photo taken by Bünyamin Erkan Çiçek)

Finally formal permission to make recordings was get, and house owners were persuaded to place cameras to their balconies. House owners were paid some money in reply to their permission; those who did not accept money got a present; which was usually a bunch of flower. In order to win house owners' confidence a police officer accompanied to the person who will install the top camera to the balcony.

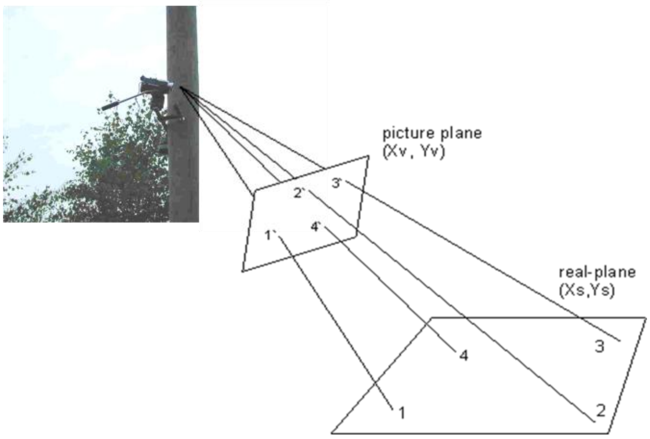


Figure 2. 3. Basic principle of how the top camera works.

For each school scene, assistants recorded any kind of thing that may be affecting traffic flow and is not in the camera view. Communication in between assistants was maintained by walkie-talkies.

In addition to these procedures one day before the recording the school scene was prepared. Since recordings are analyzed by semi-automatic computer program called Viva-Safe, an imagery rectangle should be drown in to the scene and corners, and have to be shown to the top camera. Corners of the rectangle are painted lightly in white and these corners are indicated to the camera before recordings. These rectangles are usually about 9m to 18m. (Image 2.2., Figure2.3.)

Recordings were done at the hours of day which traffic is most dense. By this way it is aimed to screen pedestrian behavior and the difficulties pedestrian face more frequently. As a result every school was recorded 2 times between 12:30 and 13:30 on a shiny day.

These times were selected because they are the periods during which most child pedestrian crashes occur (Kaygısız,2008; Road Crashes Great Britain, 2000).

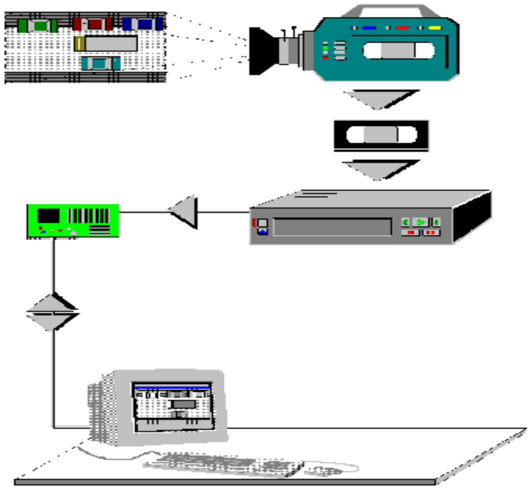


Figure 2.4. Analysis by Viva-Safe

Finally 120 minutes recording data for each camera was obtained for each school separately, which makes 1200 minutes total recording data for the whole study.

On the second step of Observation stage a semi-automatic program named Viva-Safe was used in order to analyze recordings. Viva-safe mainly takes the Top Camera in to account. In situations where Top-Camera is not sufficient the Head-Camera is used to get the reliable data[1]. (See Figure 2.4)

2.2.2.1. Behaviors Coded

Variables were based on behavioral categories used in previous studies (Hoogendoorn, 2004; Rivara et al., 1991; Rosenbloom et al. 2008; Routledge et al., 1974; Simpson et al., 2003; Zeedyk & Kelly, 2003).

These categories were designed for observing; crossing distance to the marked crosswalk, stopping at the curb, checking for approaching traffic by looking right and left before crossing (head movements before crossing),

[1] VIVA Traffic is a special video analyzing software. This Professional tool is built by traffic engineers, computer engineers, and city planners in Kaiserslautern University, Transportation Department. Viva Traffic is a widely used tool in Europe for city, traffic planning, and proactive policing. By this tool various variables can be measured automatically; such as distance, speed and acceleration of vehicles. (Per G. et al., 1999).

pedestrians' crossing tempo (usuall, rapid, running), waiting time before crossing, pedestrians' waiting point before crossing (sidewalk, curb, street), crossing angle (direct, glancing). In addition variables such as; speeds of vehicles, number of conflicts between pedestrians and vehicles, yielding behavior of drivers, and number of cars forming queue were also reported.

These variables were selected because they are thought to be the safest behaviors for child pedestrians.

2.2.3. Intervention & Post-Measurement

The third stage of this study is intervention and post-measurement. After analysis, blackspots are aimed to be constructed to control and change pedestrian and driver behaviors in those environments. At this stage one more school was dropped from the intervention, because the municipality refused constructing intervention to the site because of heavy road traffic. One school out of remaining 4 schools was chosen as a control school, and at this school scene a reconstruction was not conducted. The control school is named as School A, and other schools are named; School B, C, and D.

Although for each school a different reconstruction design was aimed, these designs had general characteristics. Firstly designs were aimed to be constructed to places where conflicts and pedestrian flow are most dense. Secondly by these designs it is aimed to reduce vehicle speeds mainly by bumps, and subsequently by narrowing down road, building traffic signs and pedestrian cross. Thirdly while building constructions it is intended to develop a "Pedestrian focused" Traffic Environment, by enhancing pedestrian visibility, and scope of pedestrians. Finally for each school a different type of construction design was proposed to the municipality to be built. From the images below, these construction designs can be seen (Names of Schools and Streets are delete due to ethical concerns). As it can also be seen from construction designs the distance between the speed cushion and pedestrian cross was not held constant (5m vs. 9m). So this variable (distance between speed cushion and pedestrian cross) was implemented as an IV to the study.

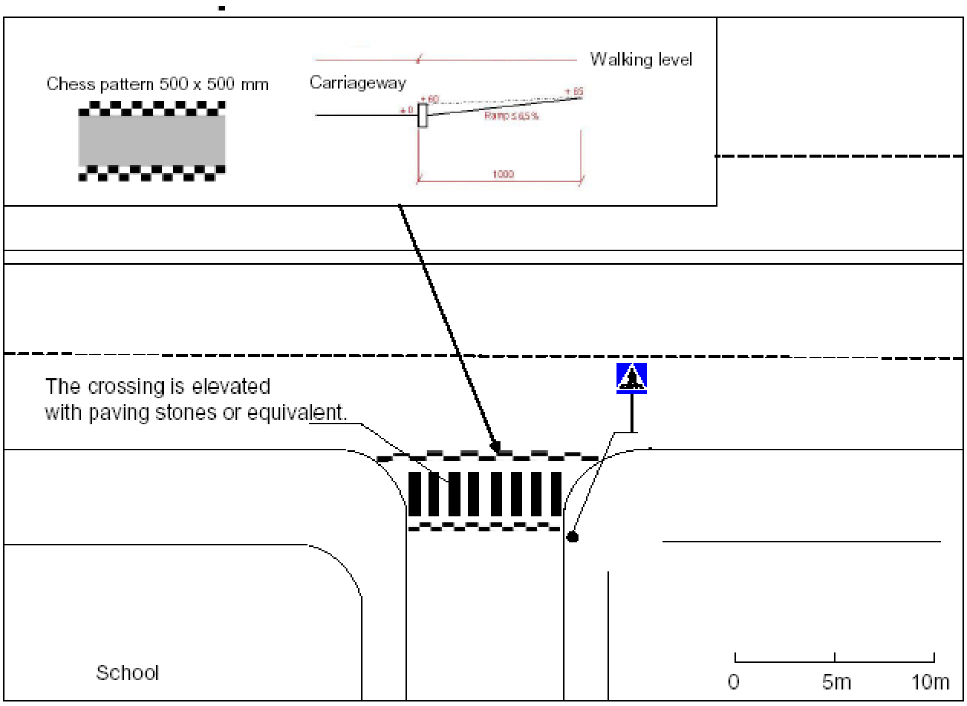


Figure 2.5. A construction design for a school

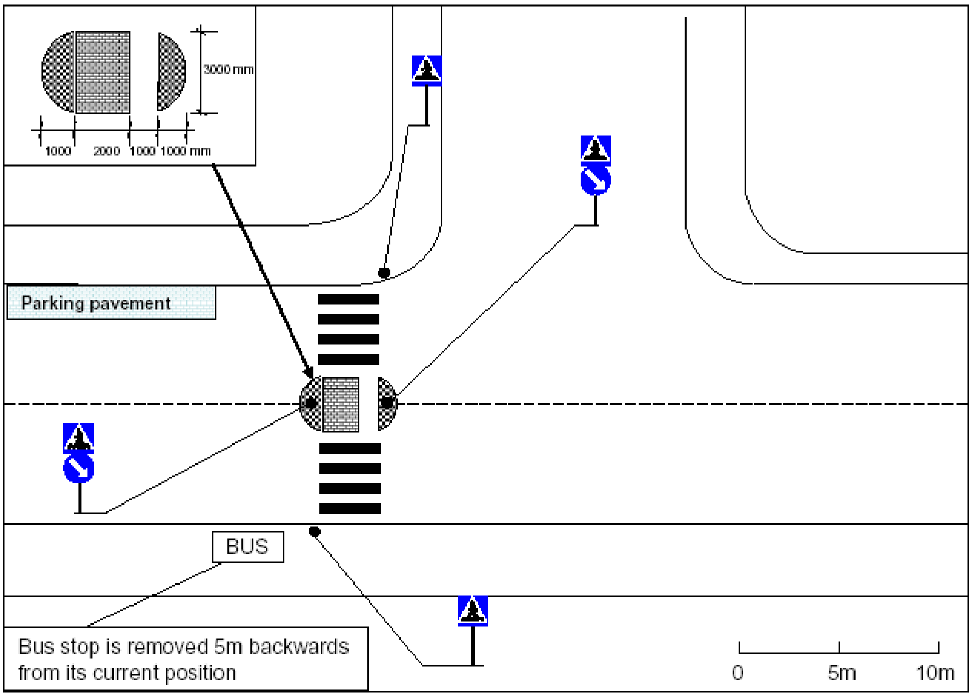


Figure 2.6. A construction design for a school

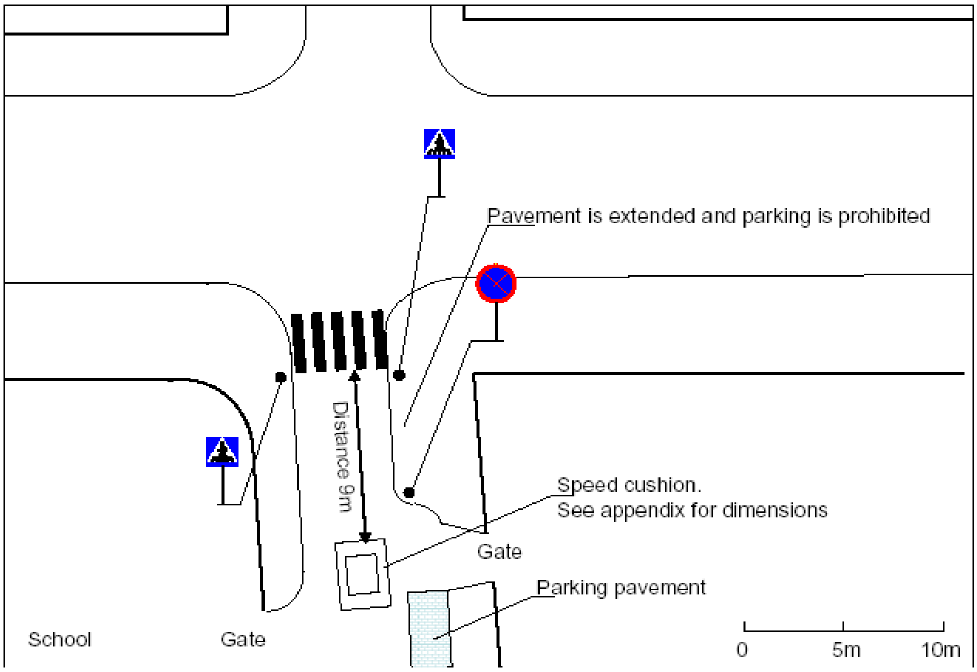


Figure 2. 7. A construction design for a school

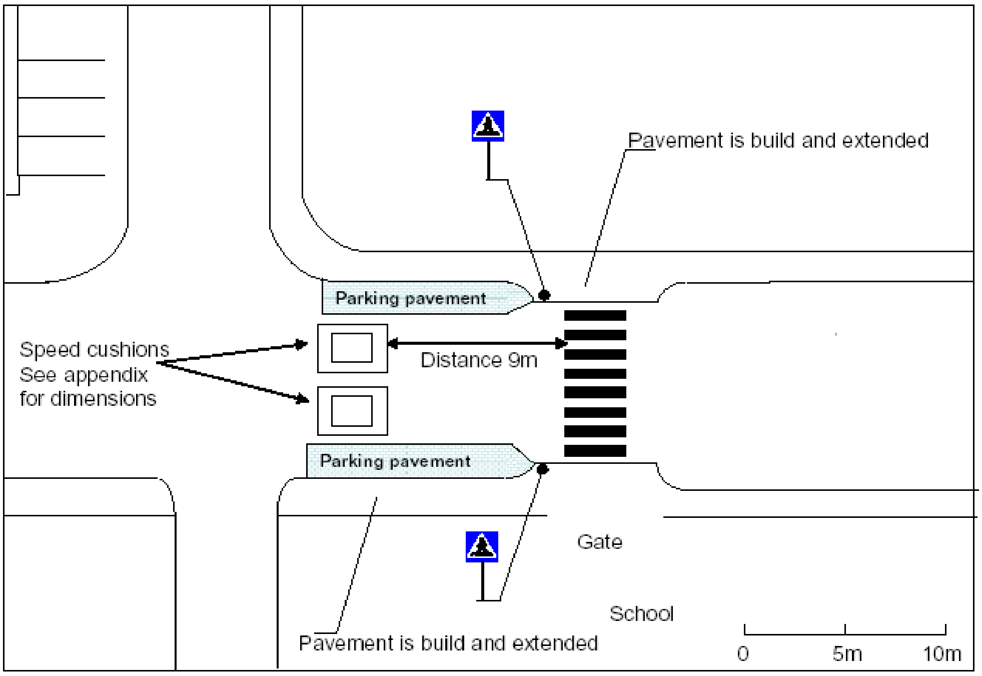


Figure 2.8. A construction design for a school

As a next step these construction designs were proposed to the municipality, in order to get permission to build them. Unfortunately because

Image 2.3. A 605mm to 45mm standard speed bump.

of the restrictions, building a safety island in to the street and narrowing the street were not suitable to municipality codes. Therefore these designs were restricted to simple humps and pedestrian cross. In addition building a hump to one of the proposed streets was also rejected by municipality authorities due to the dense traffic flow on the mentioned street. Finally interventions were limited to municipality standards and standard speed bumps were used to reduce vehicle speed which had dimensions of 605mm to 45mm (See Image 9).

Image 2.4. School B’s image before and after the Intervention

Image 2.5. School D's image Before and after the Intervention

Finally in order to measure effectiveness of interventions observations in second step were repeated. In order to make post measurements, researchers waited gave 3 months habituation time after black spots were reconstructed. Observation step was repeated for 4 schools, where 3 of these schools were reconstructed (School B, C, and D) and one of these schools was left as a control school.

CHAPTER 3

RESULTS

Parallel with the method applied findings of the observation will be given in 2 chapters. The first section includes analysis of "behavioral" black spot analysis. The second section includes findings of observation and pre-post measures.

3.1. Black Spot Analyses

The behavioral black spot analysis is mostly depending on descriptive statistics.

At this stage of analysis students were asked to draw the route which they were following when going home and coming back to school. Since students in Ankara where going to school in two shift, students route choice behavior was also analyzed in accordance with two shifts in all 6 schools.

As mentioned in method, since names of schools are confidential, letters from A to F will be used for each school.

3.1.1. "School A"

The first School is defined as "School A". In 2003 and 2004, 73 pedestrian crashes (injuries and fatalities) occurred within 1 km^2 around the school. "School A" is a school which is very close to a metro station. School's gate is opening to a street with a slight slope and a smooth traffic. 25metres close to school there is a 2 way divided street with heavy traffic. Along the street there are 2 universities next to each other. This region of the city can be determined as having high SES.

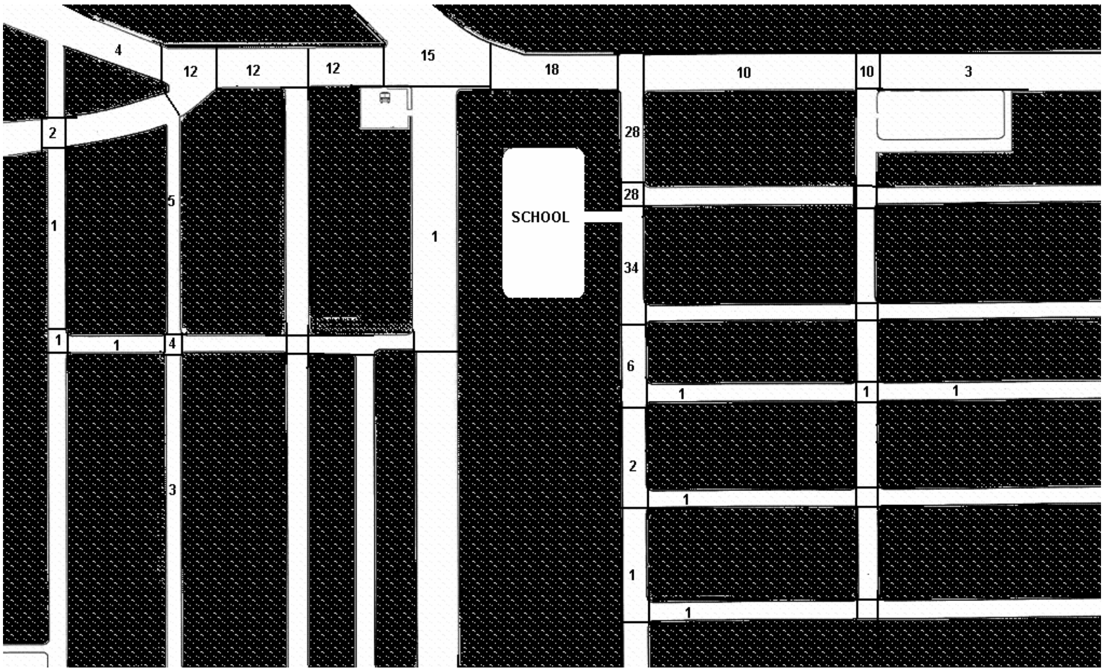


Figure 2.1. Routes used by morning student at 7:30 while going School A

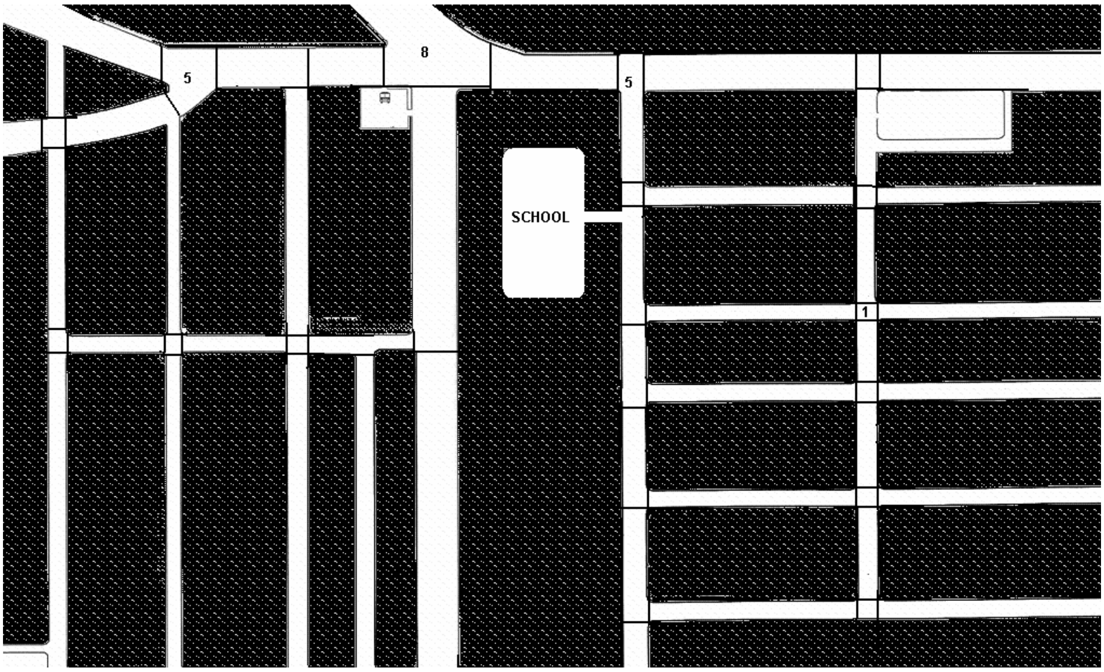


Figure 2.2. Points received as risky by morning students at 7:30 while going School A

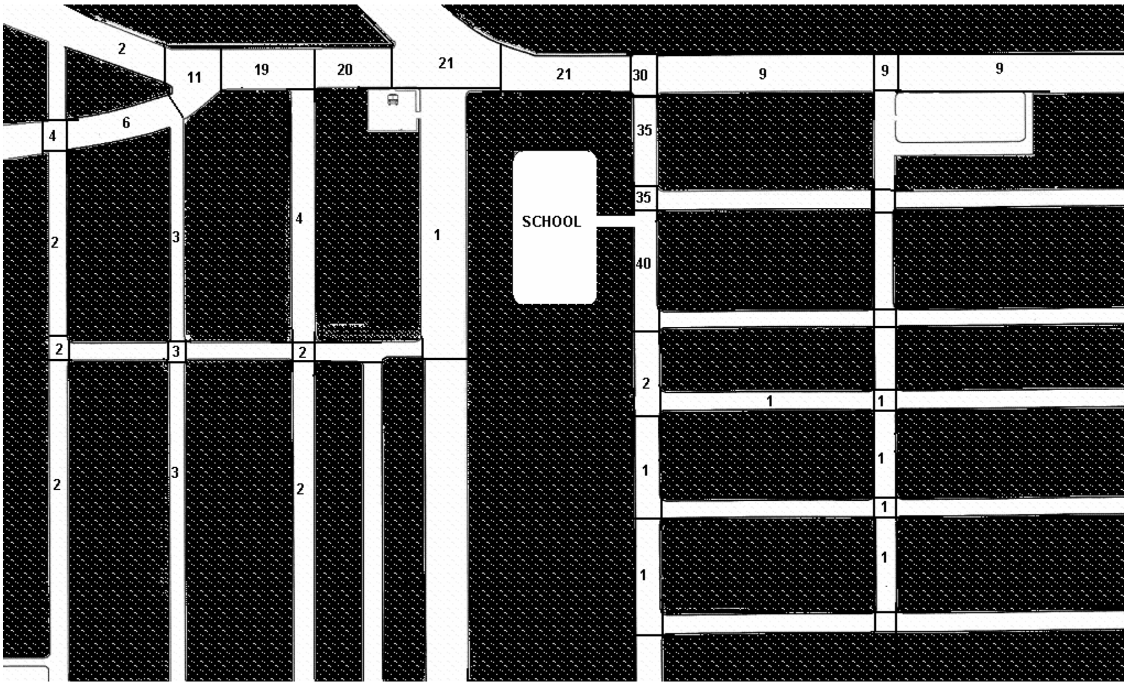


Figure 2.3. Routes used by morning student at 13:20 while going back to home

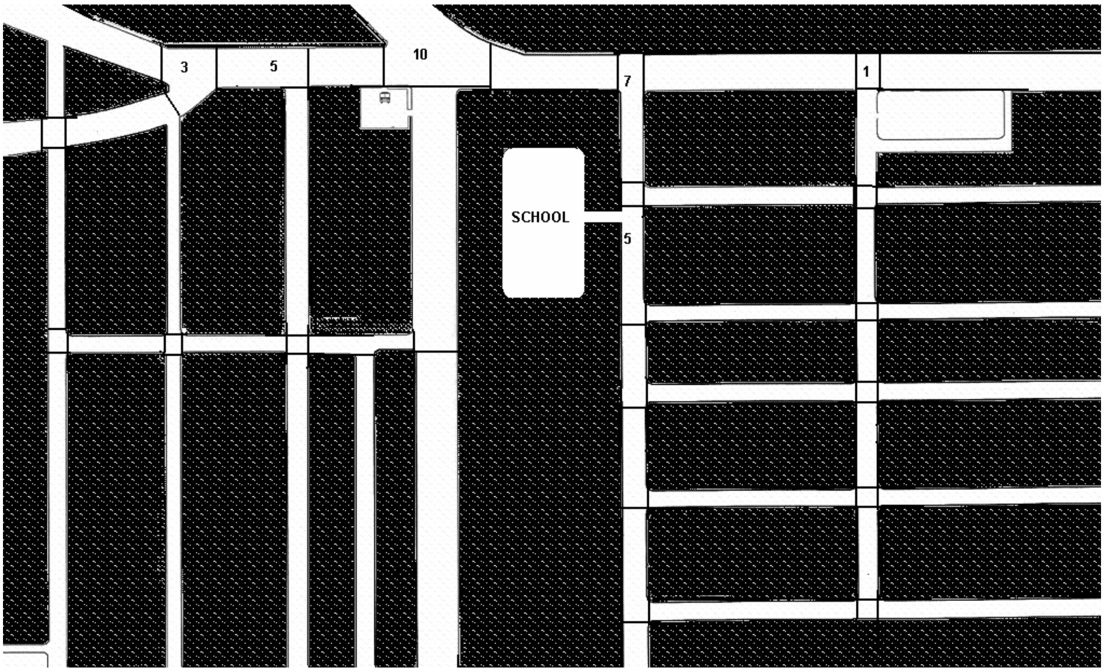


Figure 2.4. Points received as risky by morning students at 13:20 while going back to home

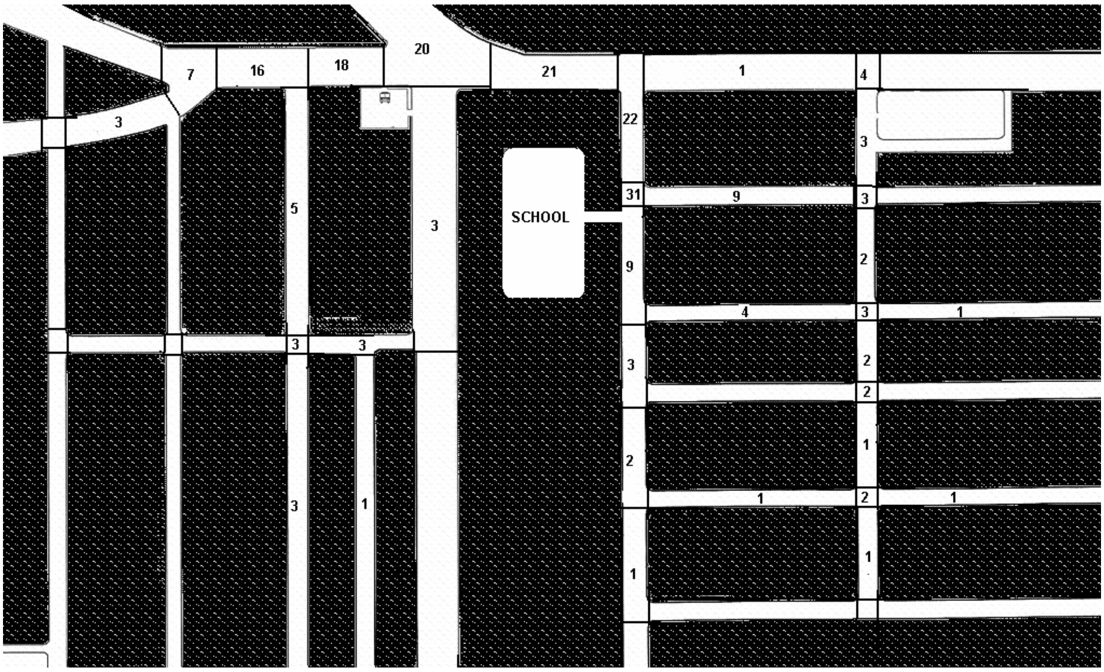


Figure 2.5. Routes used by afternoon student at 14:00 while going School A

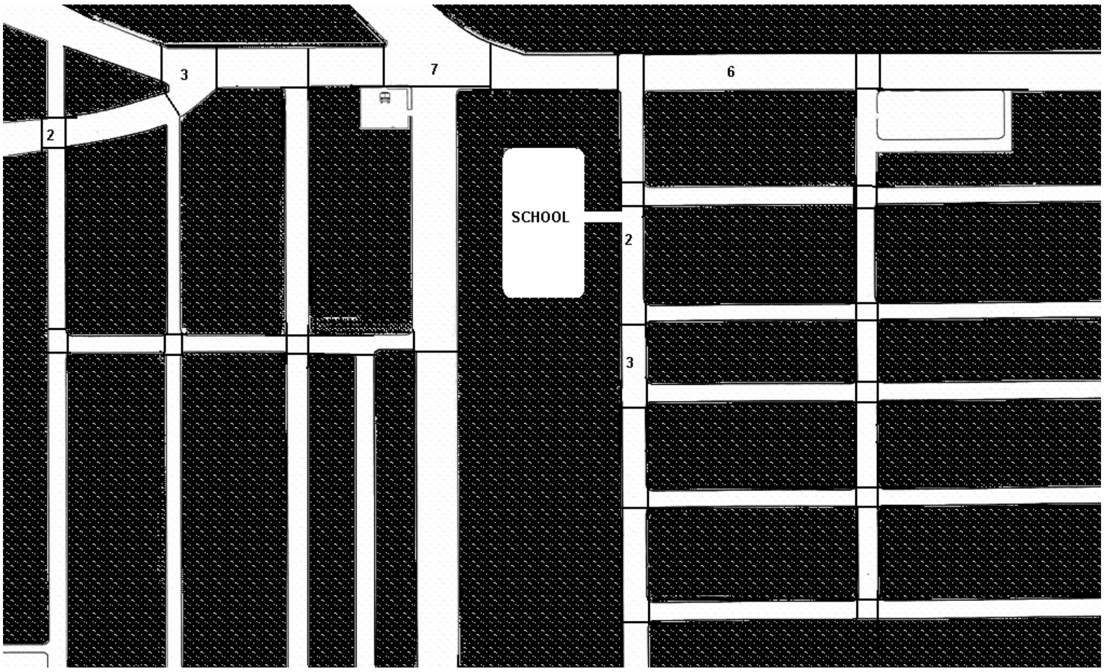


Figure 2.6. Points received as risky by afternoon students at 14:00 while going to school

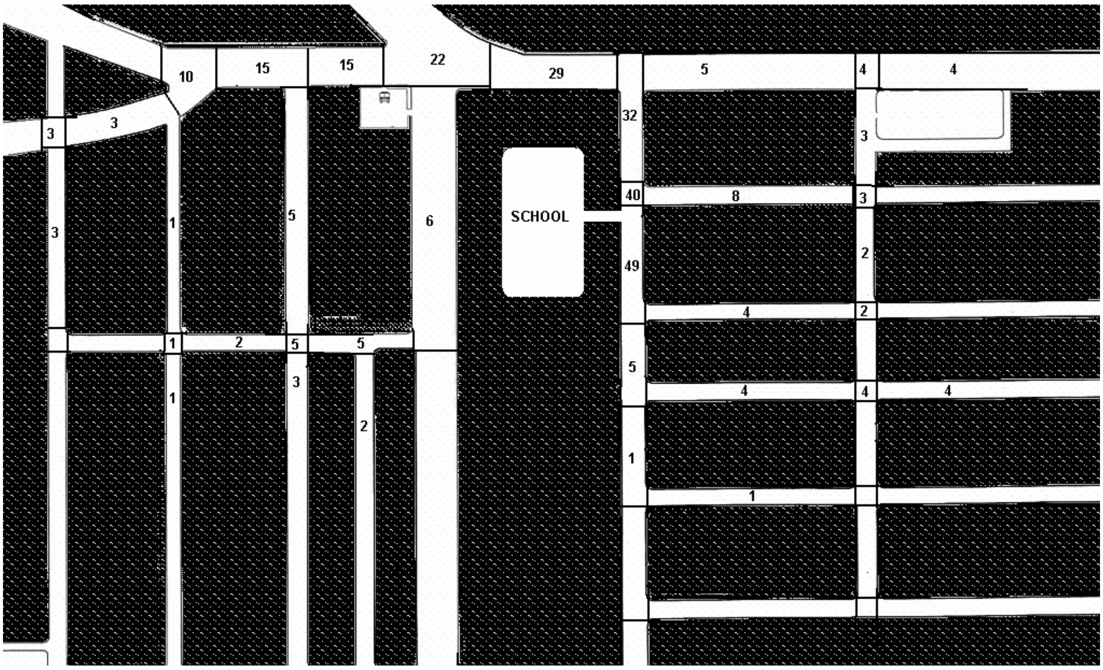


Figure 2.7. Routes used by afternoon student at 18:50 while going back to home

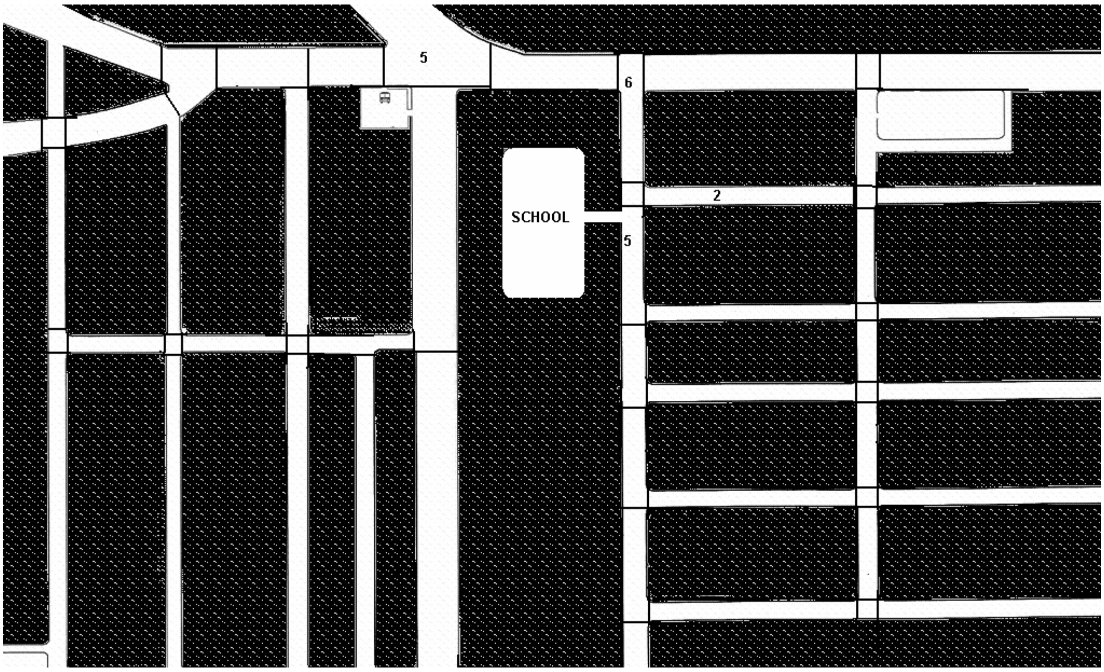


Figure 2.8. Points received as risky by afternoon students at 18:50 while going back to home

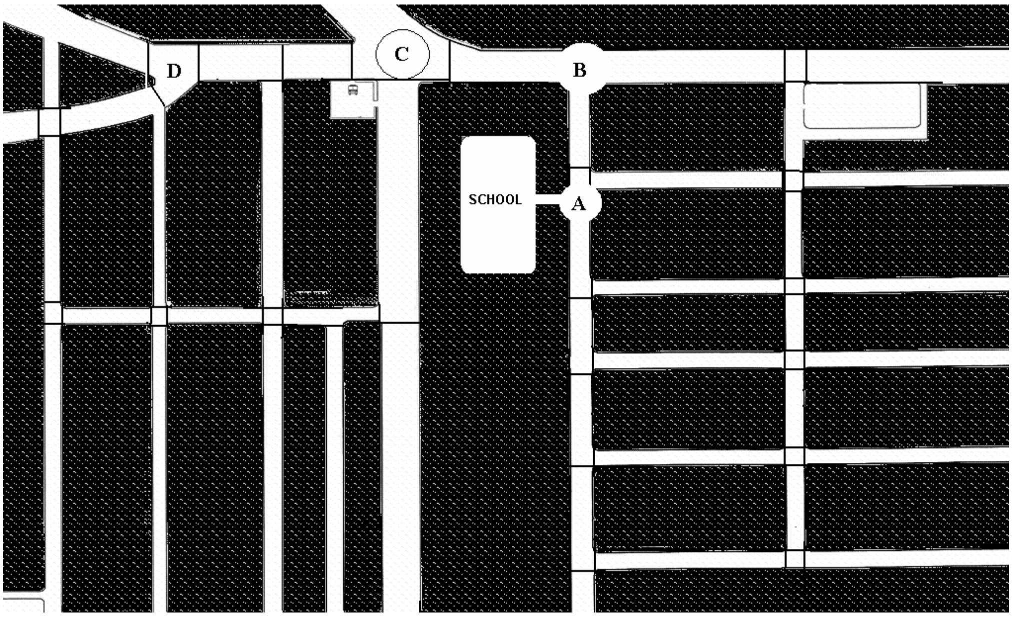


Figure 2.9. Points where students feel risky

When routes followed by students of School A are discovered it can be seen that children use shortest route on their way. In addition to this because bus stops and metro stations are placed on main roads, most of the students have to use the main road. And these students which are walking on the main road where there is a heavy traffic face with more risky situation. Students coming from main roads marked more risky places compared to students coming from branch roads and cross streets.

163 times students pass from in front of the school where school gate is placed. This point is lettered; A. (See Figure 2.9.) On the other hand front of school is only marked as risky 11 times. This makes a risk percentage of 11/163 which is 0.07

112 times students passed from the point B where street in front of school joins with main road. (See Figure 2.9.) This point of the map is marked as risky 17 times. The risk percentage of this point 17/112 which makes 0.15

The place where the main road forks is found to be most risky place. The traffic flow is fast on this point (C) and there is no light. And most of the students need to cross from this point. These circumstances makes this point the most risky place. With percentage of 30/78 which is 0.38

The forth risky place is the point D where main road forks again (See Figure 2.9.) There is a metro station here and a traffic light. But still it is marked as risky by11 students out of 40 students; and this makes a risk percentage of, 11/40 which is 0.27

When these four places which are marked to be highly risky by students are compared with real pedestrian crashes, it is seen that real pedestrian crashes are placed on the main road rather than front of the school. So black spots depending on real data are overlapping with the answers given by children.

From these 4 points, the point where the school street joins with main road is chosen as the observation and intervention point. Other 3 places are eliminated. School gate is not much risky (7%) compared to other points. Other two points, one of them already has traffic arrangement (lights, pedestrian cross), and the second place is a place where municipality would reject doing an intervention because of high traffic flow.

Table 1. Risk percentages of "School A" region at different times of the day

Time of the day	Direction	Total number of risk marks	Number of Pedestrians	Risk Percentage
07:30	Going to School	19	34	55,90
13:20	Going to Home	31	40	77,5
14:00	Gong to School	23	40	57,5
18:50	Going to Home	18	49	36.70

3.1.3. School C

The third School is defined as "School C". In 2003 and 2004, 91pedestrian crashes (fatalities and deaths) occurred within 1 km^2 around the school. "School C" is located on a street which is parallel to one of the main roads of Ankara. This area of the city is plain and slopless. The street which passes in front of the street is a two way street without a safety island. There are many car galleries around the street. This region of the city can be counted as having low SES.

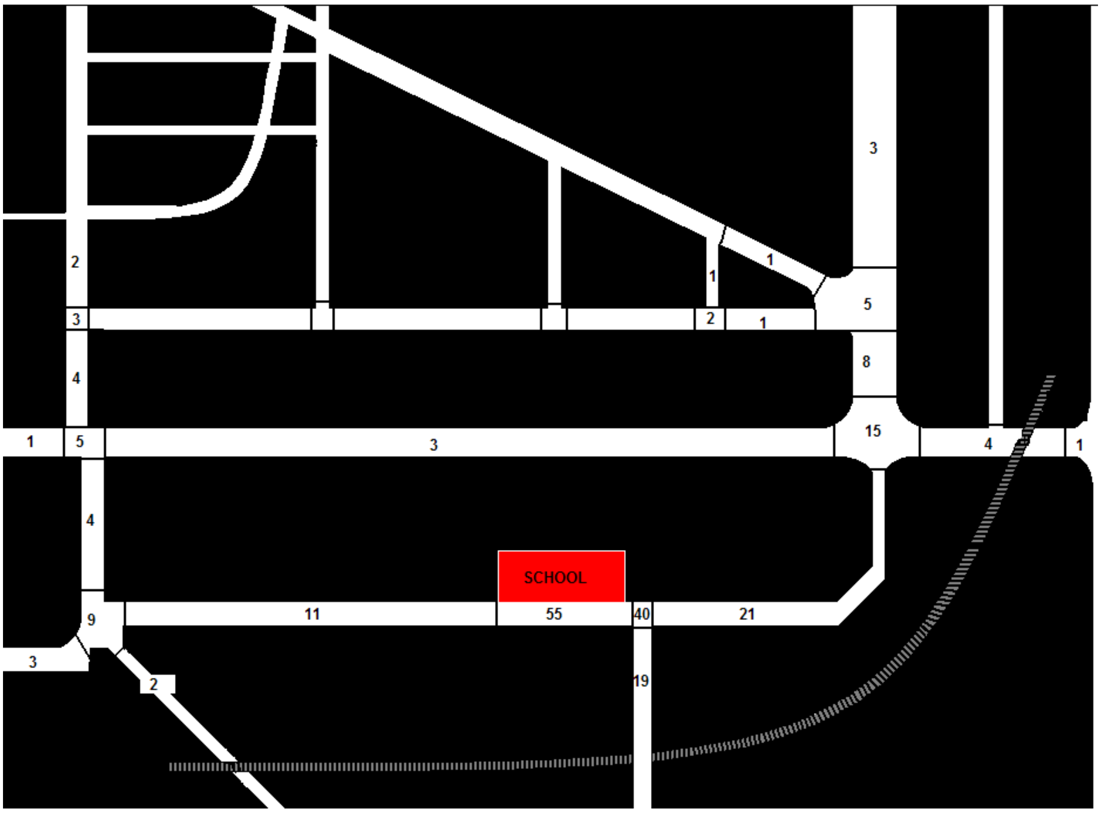


Figure 2.10. Routes used by morning student at 7:30 while going "School C"

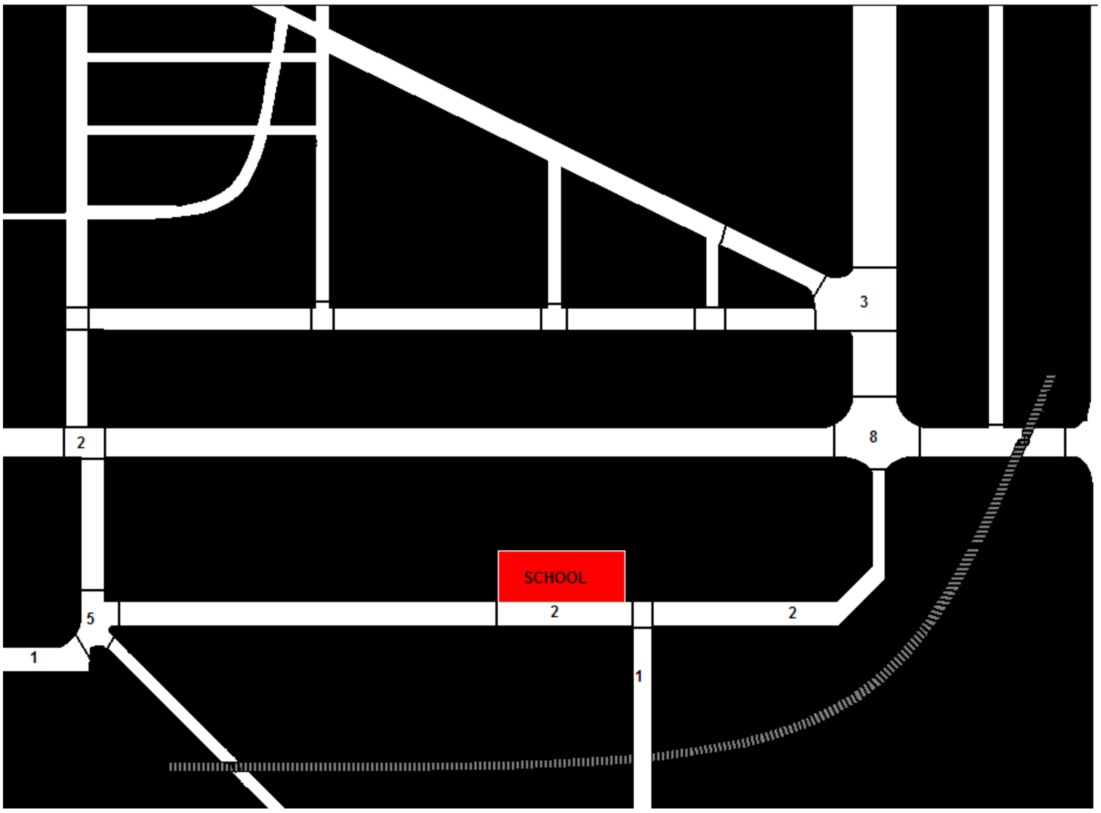


Figure 2.11. Points received as risky by morning students at 7:30 while going "School C"

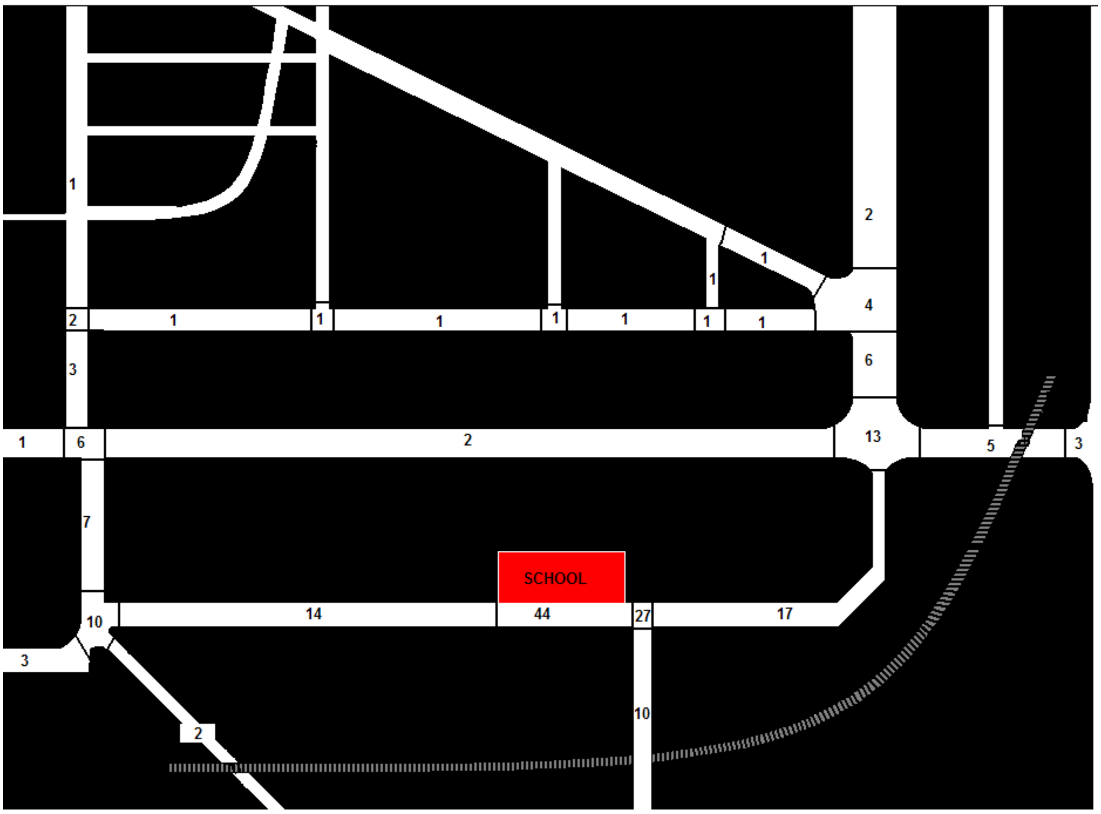


Figure 2.12. Routes used by morning student at 13:20 while going back to home

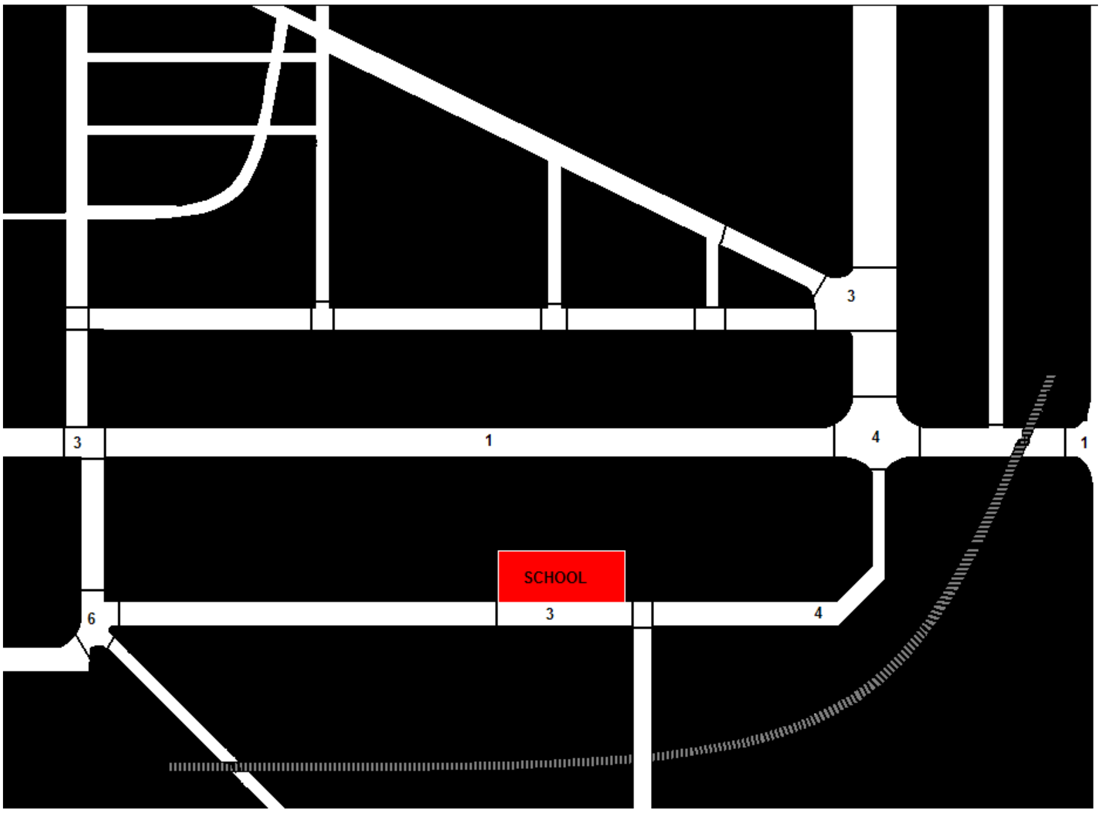


Figure.2.13. Points received as risky by morning students at 13:20 while going back to home

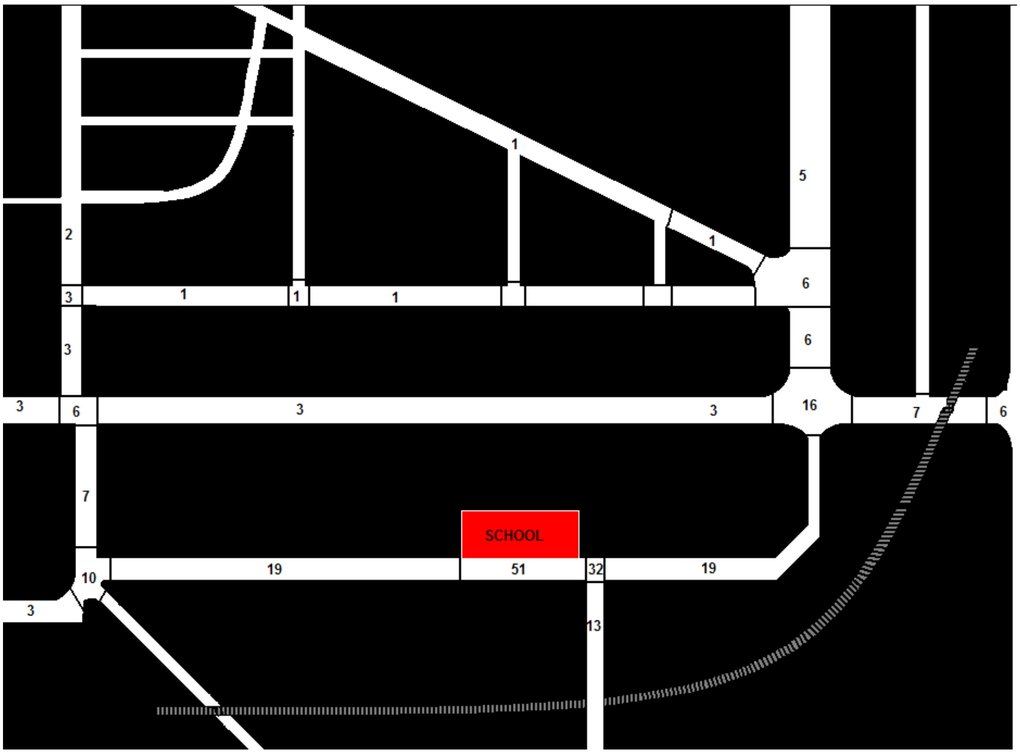


Figure.2.14. Routes used by afternoon student at 14:00 while going “School C”

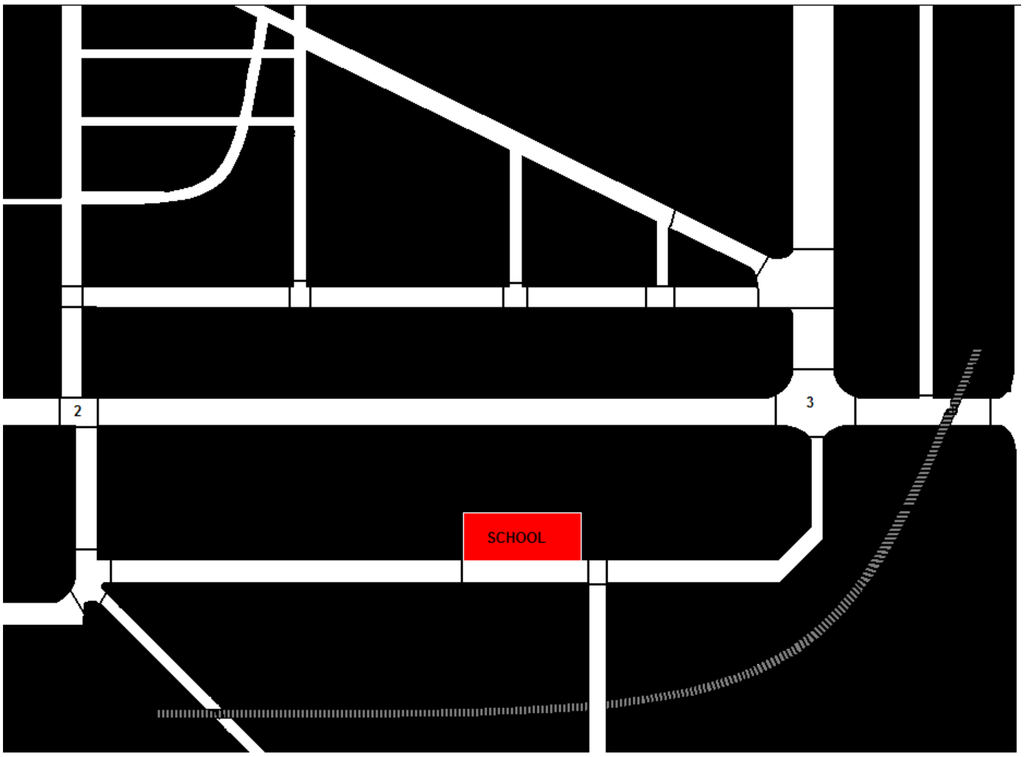


Figure 2.15 Points received as risky by afternoon students at 14:00 while going to “School C”

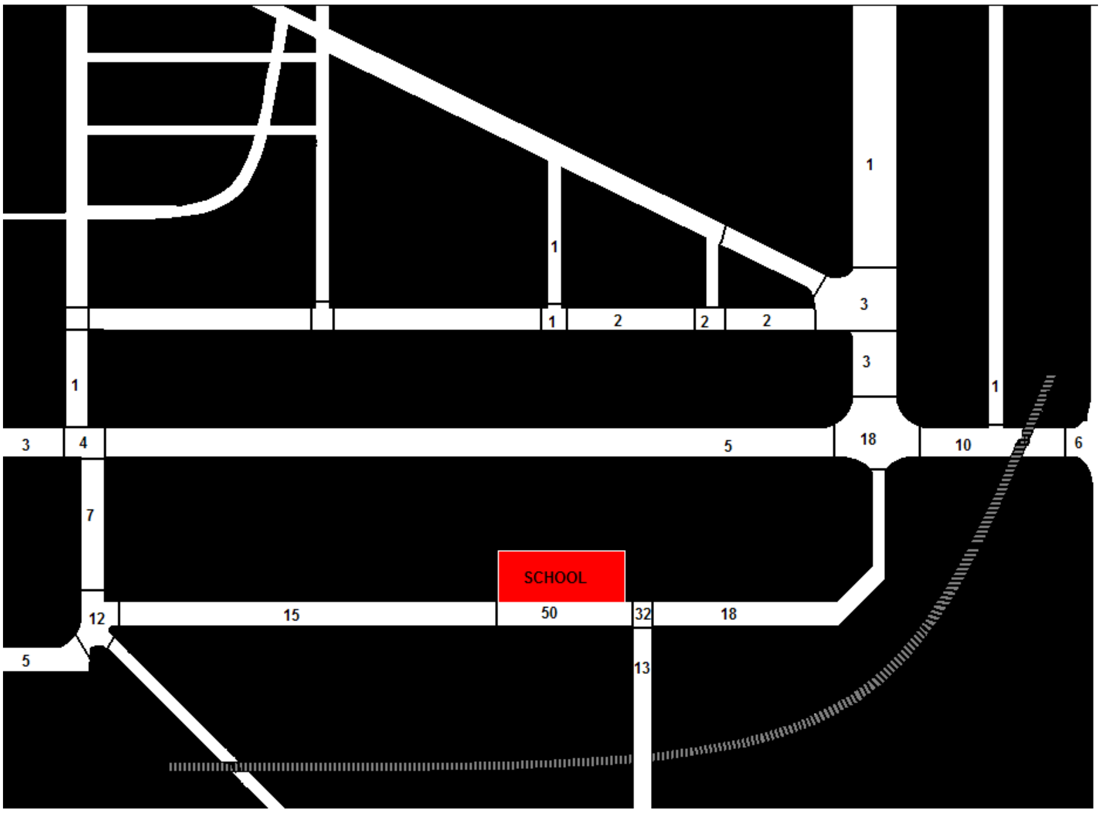


Figure 2.16. Routes used by afternoon student at 18:50 while going back to home

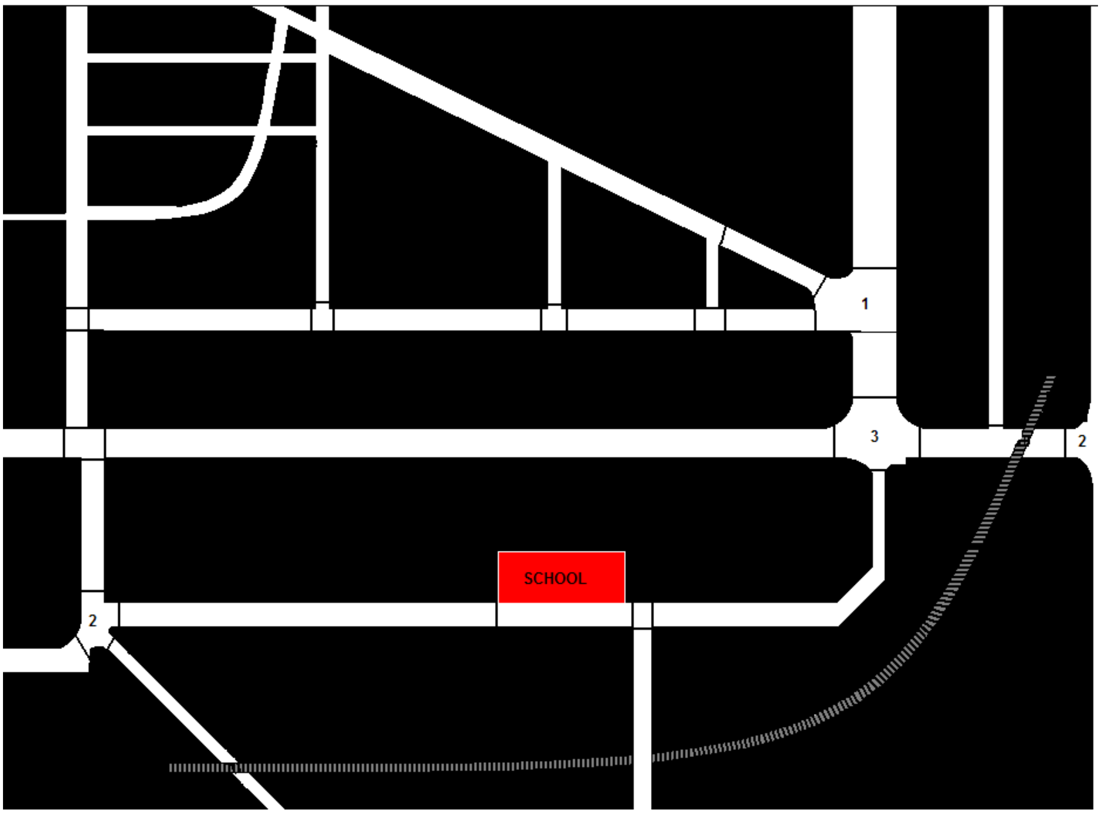


Figure 2.17. Points received as risky by afternoon students at 18:50 while going back to home

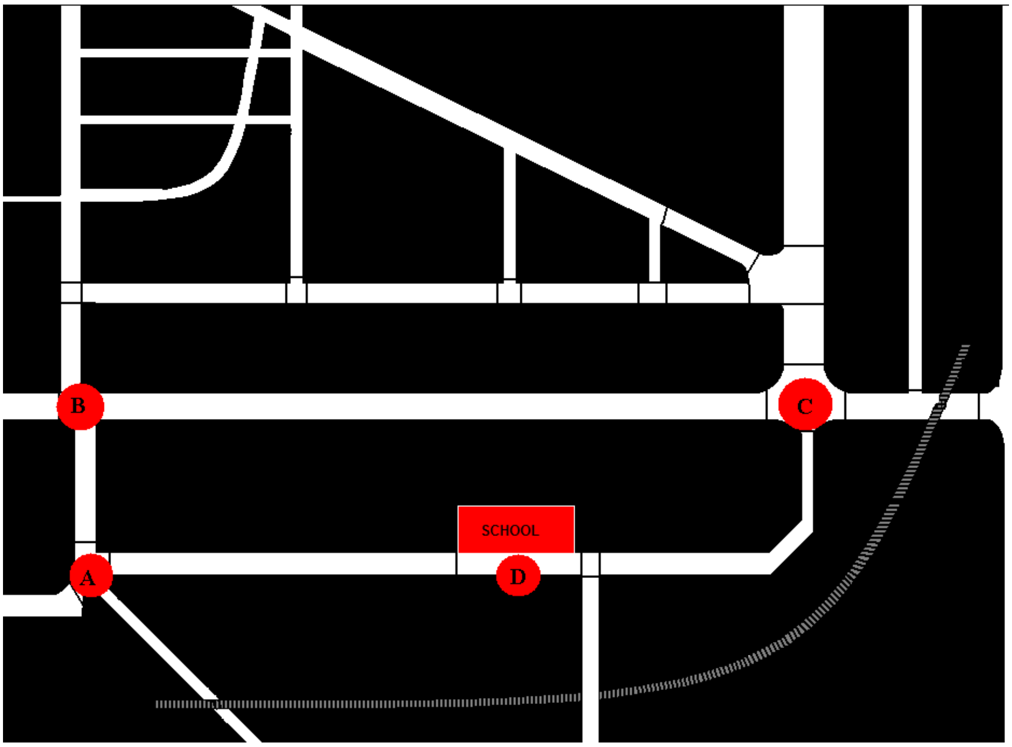


Figure 2.18. Points perceived as risky

When routes followed by students of School C are discovered it can be seen that children use shortest route on their way. Different from some other school areas this school's region has a low SES and is mostly surrounded by houses. At the School C from the routes drawed by students it can be understood that; at different times of the day different risk percentages occurred. And interestingly Students marked risky points more while they were coming to school rather than going home.

Table 2. Risk percentages of "School C" region at different times of the day

Time of the day	Direction	Number of times which student felt risky	Number of students that filled form	Risk Ratio
07:30	Going School	24	55	0.43 (24/55)
13:20	Going Home	5	51	0.10 (5/51)
14:00	Going School	25	44	0.56 (25/44)
18:50	Going Home	9	50	0.18 (9/50)

It is also found that pedestrian feel the most risk when they cross the main road which is parallel to the street located in front of the street. At 2 points were school's street meet the main road pedestrian feel riskiest.

At point "A" 21 students pass and 13 of them feel risky. This makes a ratio of 62%.

At point "D" 62 students pass and 18 of them feel risky. This makes a ratio of 18%.

Both of them are the riskiest points around the school. But point "A" is the most risky point because it is located both on Main Street and at this point of the street there is no traffic light.

But analyzing point "D" although it is located on main road there is a traffic light. Therefore pedestrians which feel in danger reduces from 62% to 18%

Pedestrians also feel in danger at point "B". 41 students reported that they pass from point "B", and 13 of them crossed point "B" indicating that they felt in danger at point "B". And this makes a risk ratio of 13/41 which is 31%. Students probably felt in danger because 4 roads coming from different angels were meeting here. And the crossing distance is much higher compared to other streets.

And in front of the school, at point "C" 11students felt in danger out of 200 students. This makes a risk ratio of 5.5%. This is a very low ratio, but since pedestrian flow is high at this point and main road needs so much big interventions which this study cannot afford, point "C" is chosen as intervention point.

3.1.4. "School D"

The fourth School is defined as "School D". In 2003 and 2004, 74 pedestrian crashes (injuries and deaths) occurred within 1 km^2 around the school. "School D" is located on the corner of the road. This neighborhood is located on a big hill therefore all streets have a slight slope. The road which school is located on is also hill shaped. And the school's gate is located at the peak of the hill. Additionally, this region of the city can be defined as high SES.

	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
0	2	2			5			4			12			
1	1	4	3	2	20	12	12	20	18	17	8	9	8	10
2	2	1			21			16						
3	2	2	0	2	23	2	2	20	4	7	5	5	5	10
4	1	1			27			19		5				
5	1	8	5	8	54	43	42	44	22	22	13	3	3	2
6	0	5				SCHOOL		3		2				
7	0	4						3		2				
8	0	4	2	2	2	2	2	4	3	5	4	2	2	2
9	0	2	0	0	0	0	0	1	1	1	2	0	1	0

Figure 2.19. Routes used by afternoon student at 14:00 while going "School D"

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
0					1									
1			1		8	1	1	9	1		2			3
2								0						
3					4			5		1		1		
4	1				3									
5	1	3			40			17		7	1			3
6					SCHOO L									
7														
8										1	2			
9														

Figure 2.20. Points received as risky by afternoon students at 14:00 while going to school

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	2	1			5			5			10			
2	1	3	2	2	18	11	13	17	14	13	6	5	4	11
3	2	1			18			15						
4	2	2	0	2	22	2	1	20	4	8	6	6	7	11
5	1	1			23			19		7				
6	1	9	5	9	55	45	44	46	23	22	14	13	8	12
7	0	4			SCHOO L			3		0				
8	0	3						3		0				
9	0	3	1	1	1	1	1	4	3	3	3	1	1	1
10	0	2	0	0	0	0	0	1	1	1	3	1	1	1

Figure 2.21. Routes used by afternoon student at 18:50 while going home

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1					1									
2					8	1	1	8	2		1	1		1
3														
4					2			5		3				
5														
6	1	3			42			19		7	1	1		1
7					SCHOO L									
8														
9											2			
10														

Figure 2.22. Points received as risky by afternoon students at 18:50 while going to home

Same with other schools also at school “D” pedestrians follow shortest routes possible.

At school “D” main roads surrounding the school are not perceived as risky. That is possibly because students do not cross from main roads. When the region is investigated it can be perceived that there are mainly military buildings on the other side of main roads.

Below (Figure 2.23.) the ratio of students which perceive a specific point risky to number of students which pass from that specific point is illustrated.

The most risky points are 4 points which roads “E” and “H” cross with roads “2” and “6”. This is probably due to traffic flow.

These four points 2E, 2H, 6E and 6H has risk ratio of .50, .46, .75, and .40 consequently. Therefore the most risky point is 6E with risk ratio of .75. “6E” is where school gate is located. 82 students of 109 students who pass from this point perceive it as risky. Finally this point (6E) is chosen as intervention point.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1														
2					16/38			17/37						
3														
4														
5														
6					82/109			36/90		14/44				
7					SCHOOL									
8														
9														
10														

Figure 2.23. Points where students felt risky

3.1.5. “School E”

The fifth School is defined as “School E”. In 2003 and 2004, 69 pedestrian crashes (injuries and deaths) occurred within 1 km^2 around the school. This region of the city can be defined as high SES. There are many restaurants, bars, and cafes around the school. This region is one of the most populated regions of the city. Beside that it has heavy traffic at every hour of day. There is a two way main road in front of the street, without a traffic island.

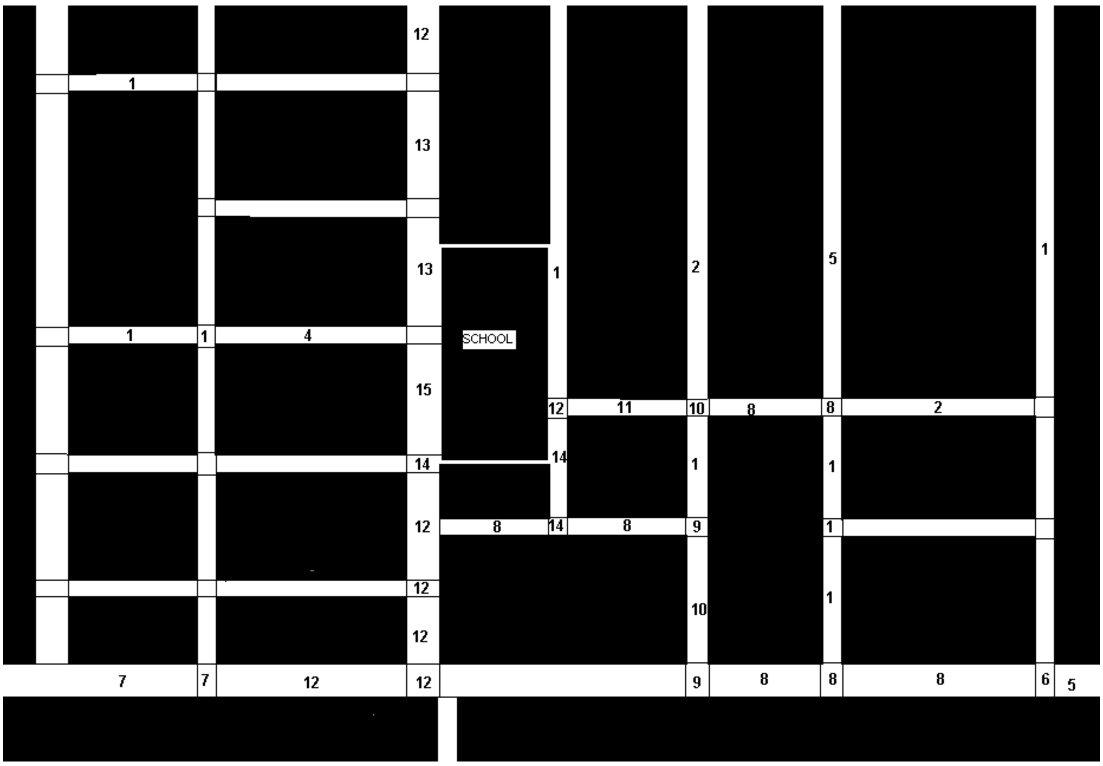


Figure 2.24. Routes used by morning student at 7:30 while going “School E”

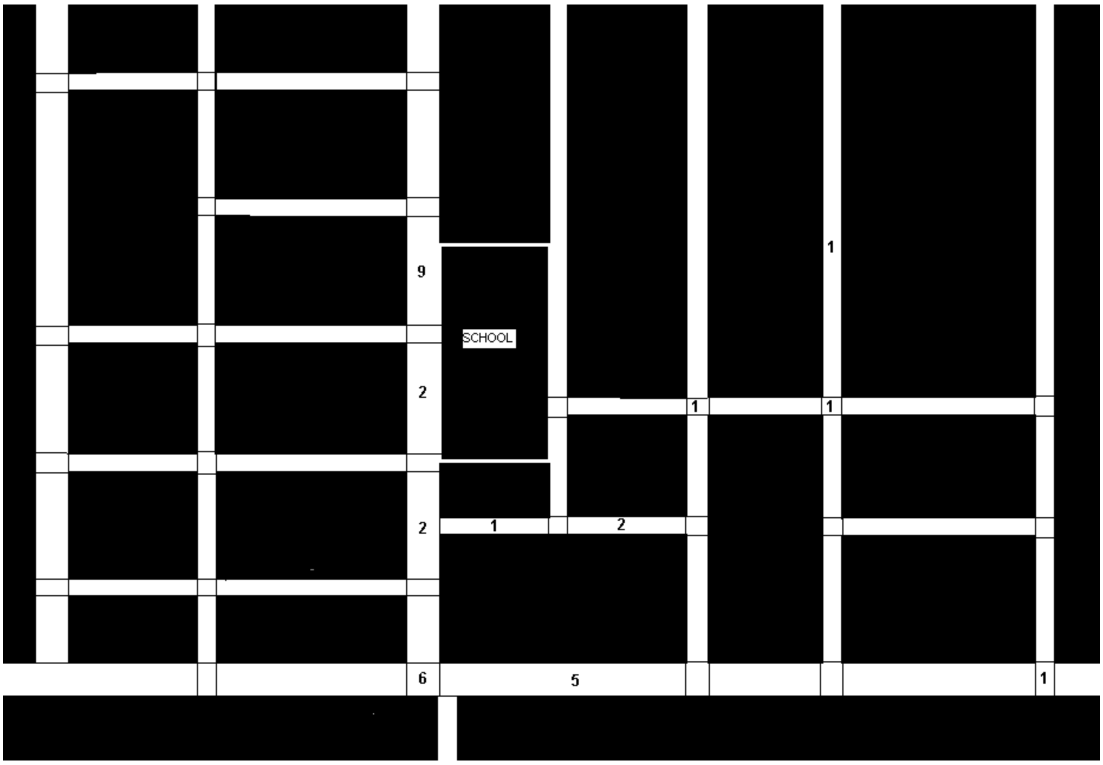


Figure 2.24. Points received as risky by morning students at 7:30 while going "School E"

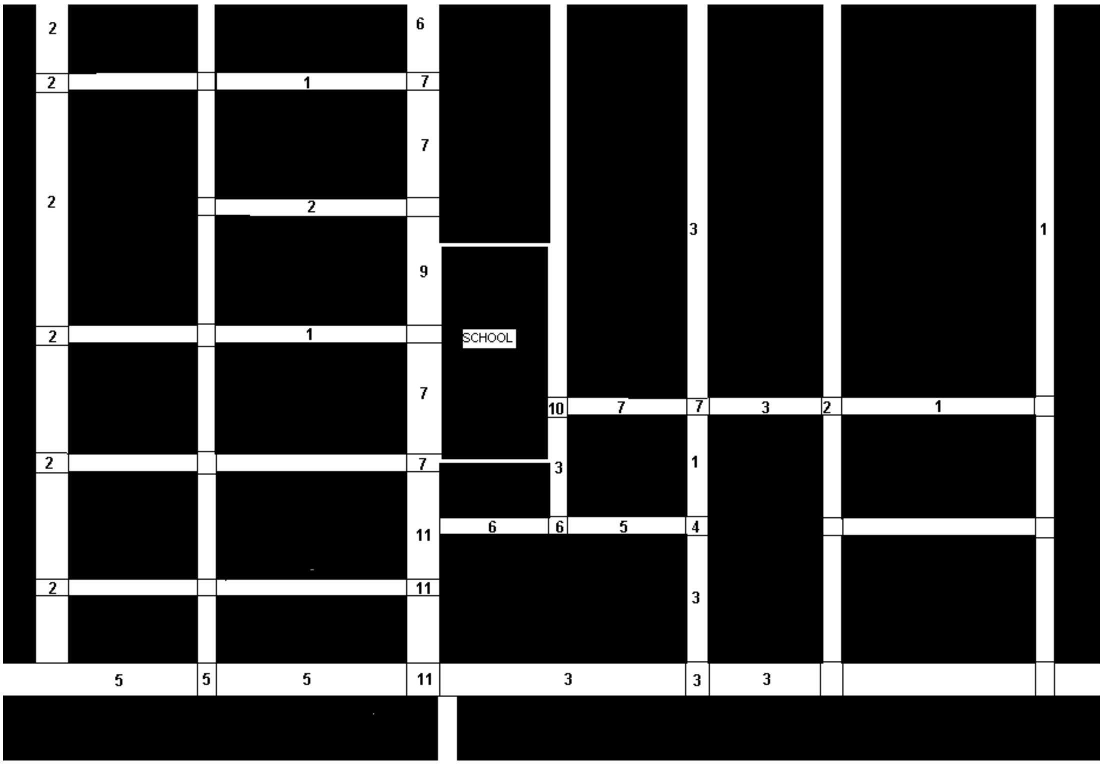


Figure 2.25. Routes used by morning student at 13:20 while going back to home

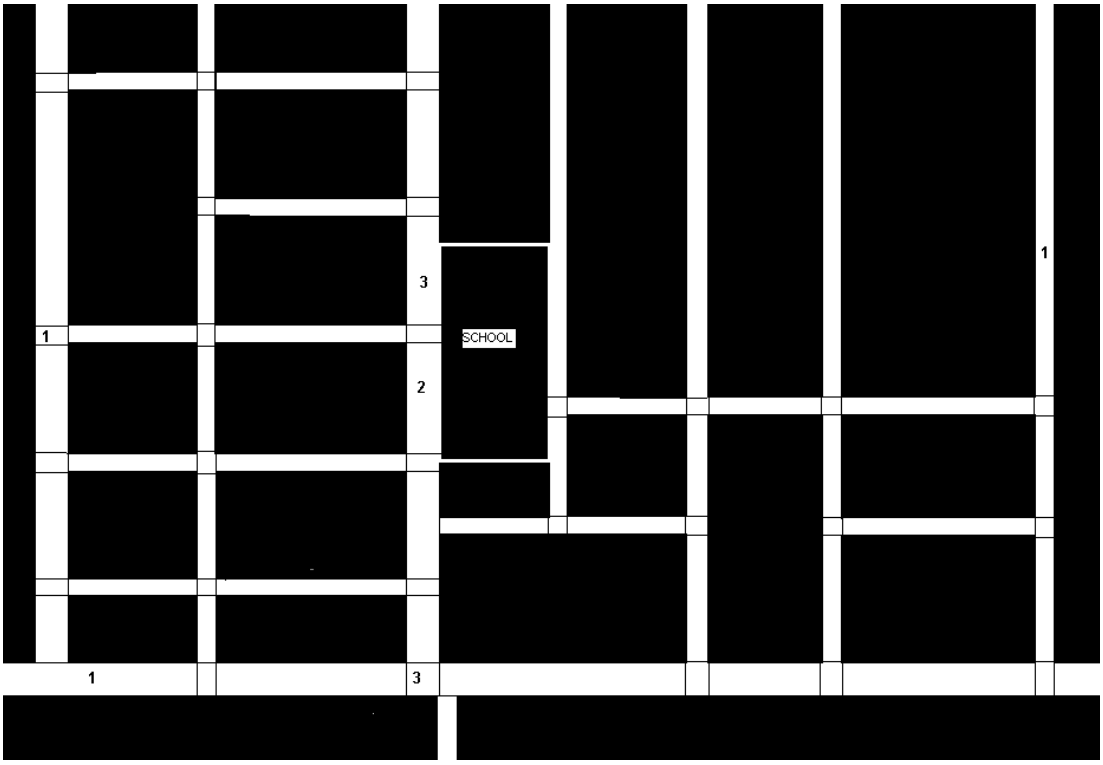


Figure 2.26. Points received as risky by morning students at 13:20 while going back to home

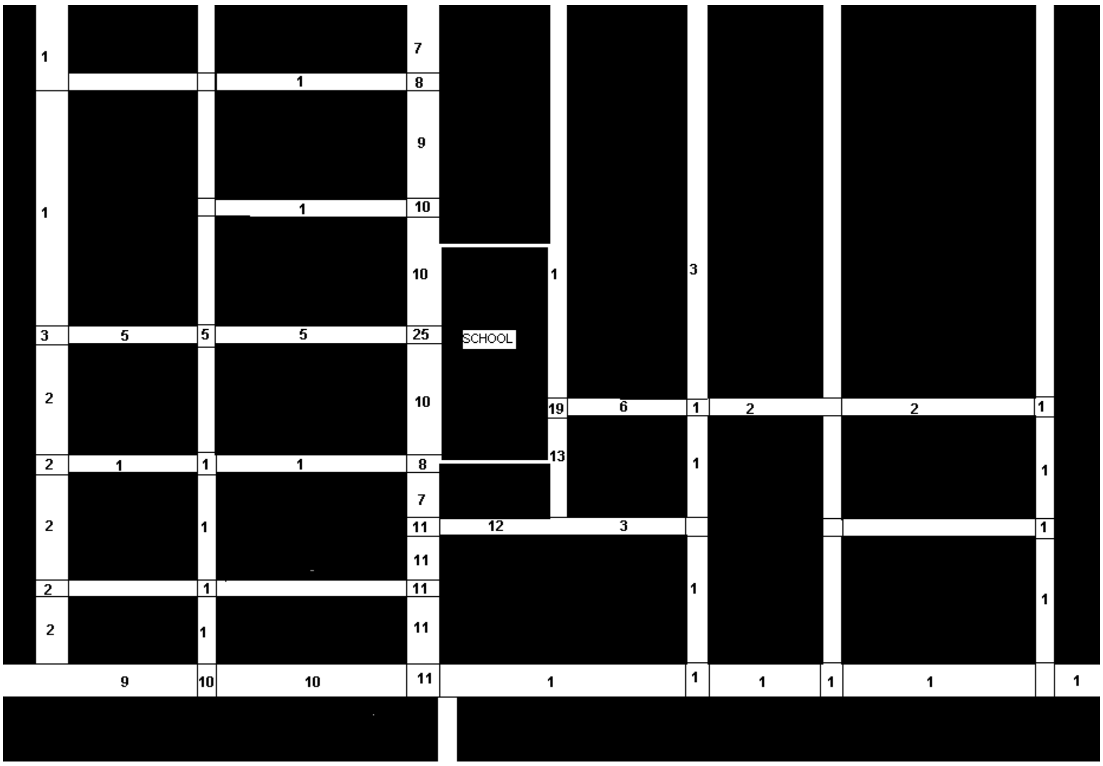


Figure 2.27. Routes used by afternoon student at 14:00 while going School E

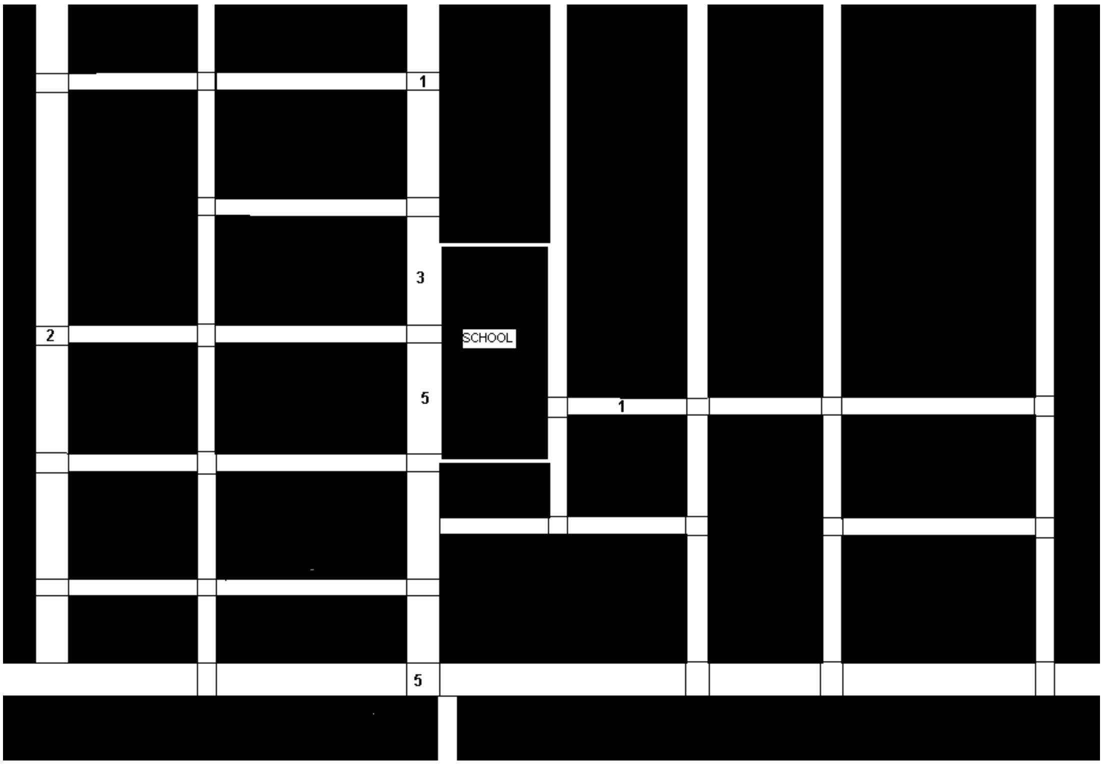


Figure 2.28. Points received as risky by afternoon students at 14:00 while going to “School E”

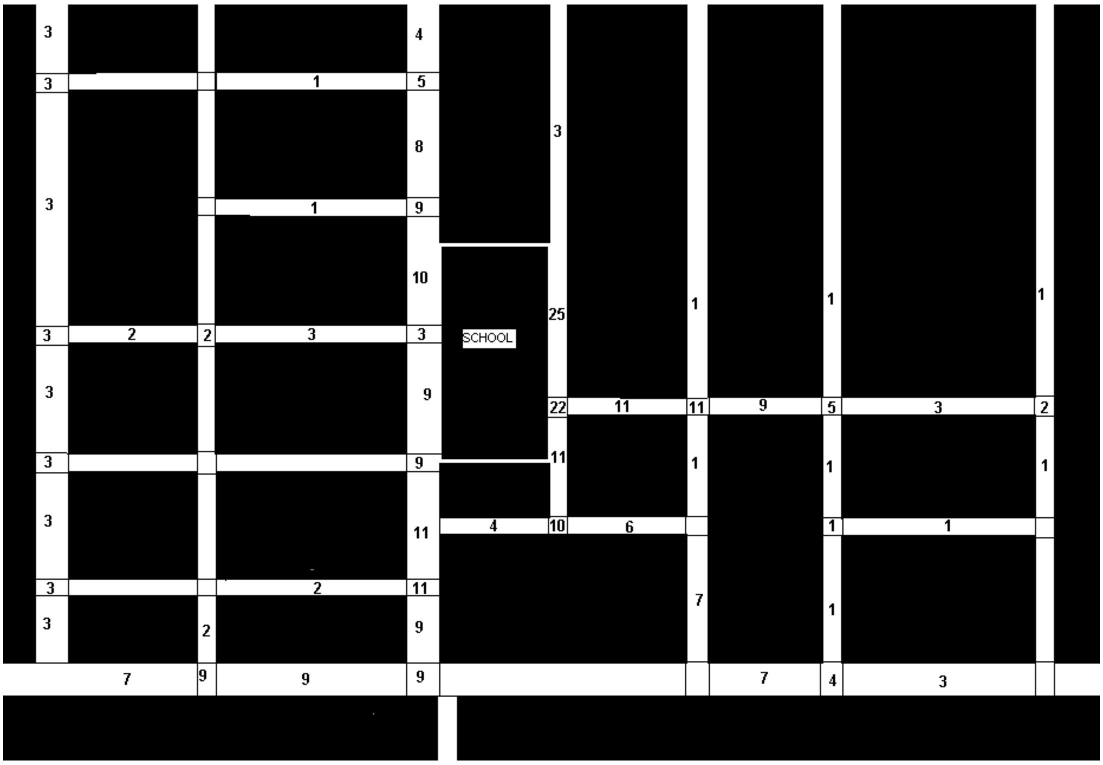


Figure 2.29. Routes used by afternoon student at 18:50 while going back to home

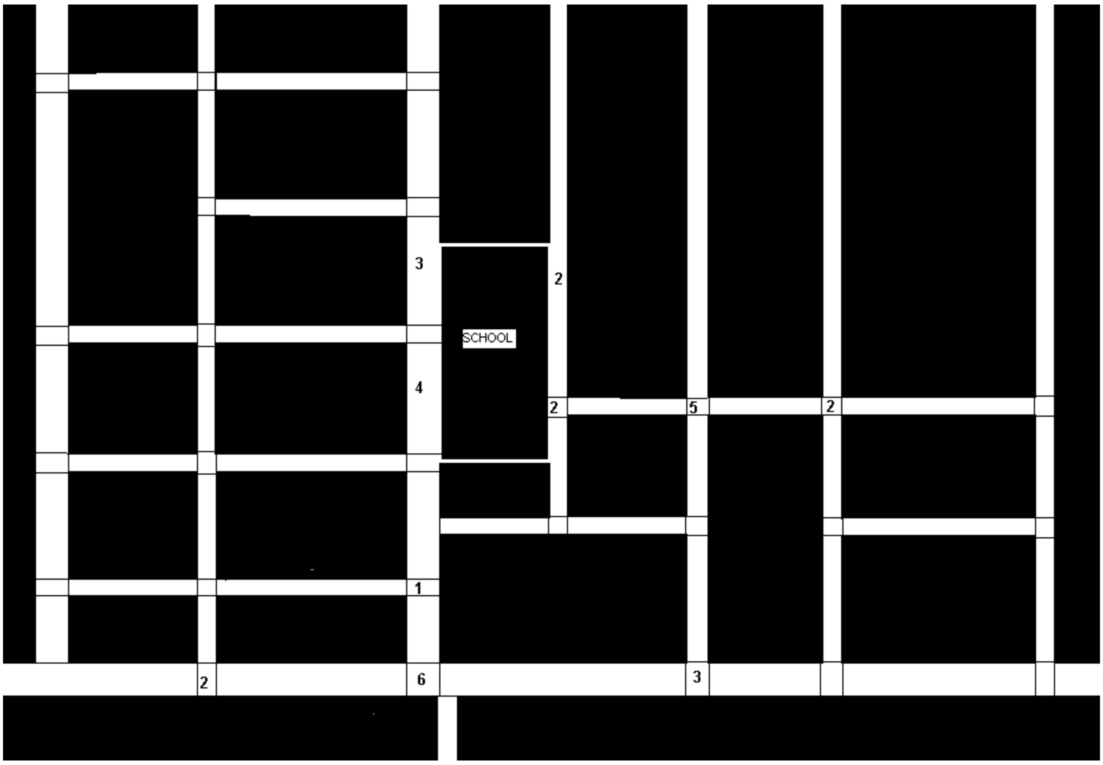


Figure 2.30. Points received as risky by afternoon students at 18:50 while going back to home

Pedestrians generally marked three places as risky. These points are those which pedestrian crashes occurred in 2003 and 2004. These points are marked as “A” “B” and “C” on the map. From the first point, the point “A” 42 students pass in a day and from those 18 of them fill in danger. That makes a risk ratio of; 18/48 which is 0.38

The second point the point “B” is also very close to school gate. 13 of 41 students who pass from point “B” feel in danger, and that makes a risk ration of 13/41 which is .32

Finally the last point is point “C”. From point “C” 43 students pass in a day. And from those 43 students, 20 of them marked point “C” as risky. And that makes a risk ratio of 20/43 which is .47

Point “C” is marked as most risky point, it is located on conjuction of two main roads, it doesn’t have a traffic light, and it is of the points which pedestrian crashes heavily occurred in 2003 and 2004 according to GPS data.

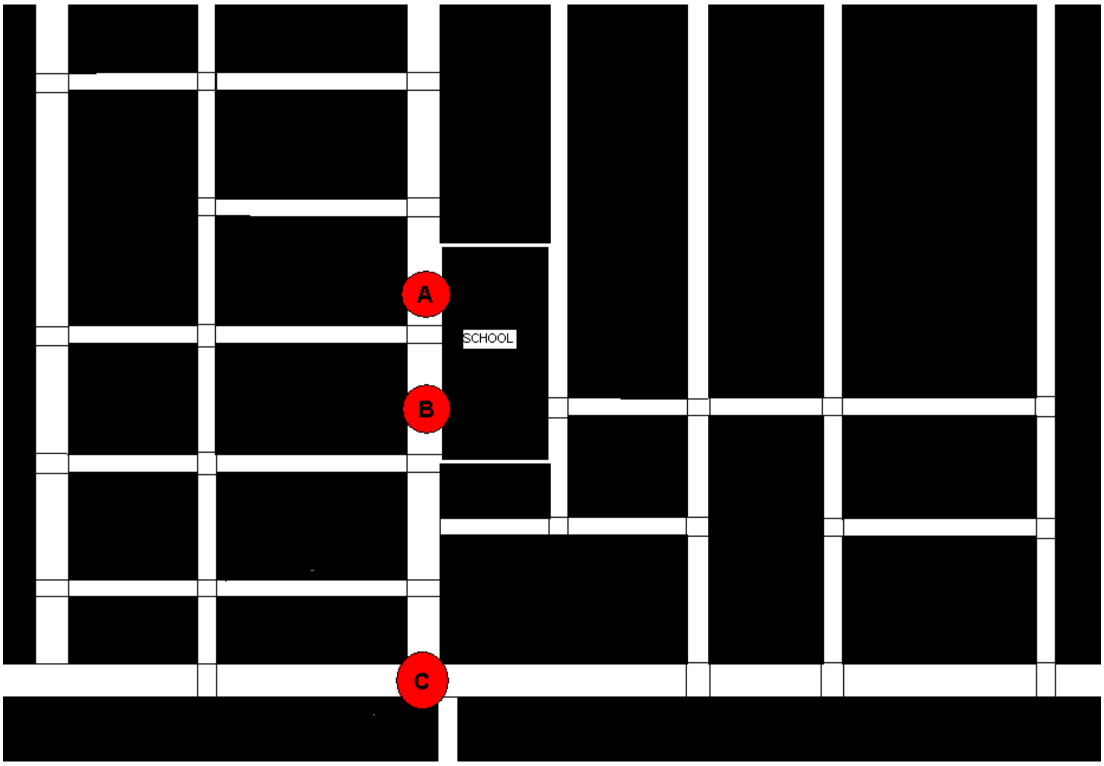


Figure 2.31. Points perceived as risky by students of School E

When the data is investigated in accordance with time of day, it can be easily seen that students feel in danger, in early morning at 7:30 when coming to school (Risk Ratio: 0.97) and at night when going back to home (Risk ratio: 1.36)

Table 3. Risk percentages of "School E" region at different times of the day

Time of the day	Direction	Number of times which student felt risky	Number of students that filled form	Risk Ratio
07:30	Going School	31	32	0.97 (31/32)
13:20	Going Home	10	17	0.59 (10/17)
14:00	Going School	17	25	0.68 (17/25)
18:50	Going Home	30	22	1.36 (30/22)

3.1.6. School "F"

The sixth School is defined as "School F". In 2003 and 2004, 57 pedestrian crashes (injuries and deaths) occurred within 1 km^2 around the school. This region of the city can be defined as having low SES. The school is surrounded by many slams. There is a intercity road with 6 lanes passing in front of the school. Although the speed limit is 50 in the city, vehicles on this road usually have a traffic flow of 100 km/hr.

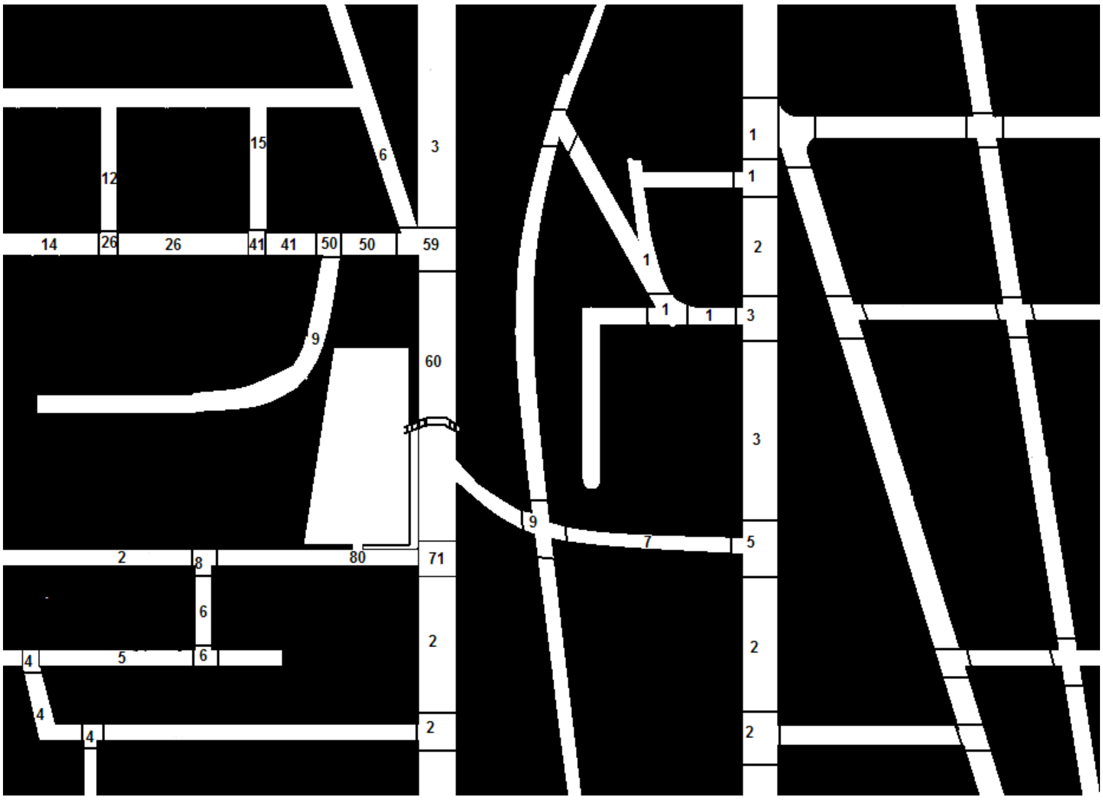


Figure 2.32. Routes used by afternoon student at 14:00 while going School E

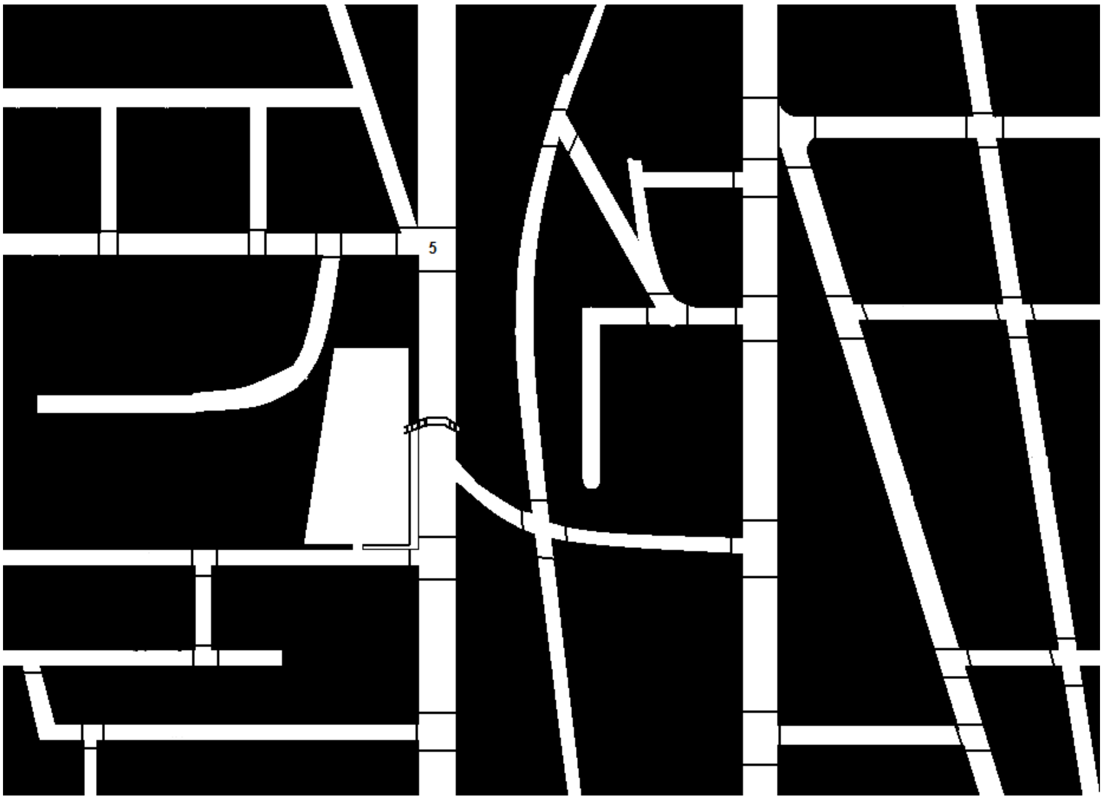


Figure 2.33. Points received as risky by afternoon students at 14:00 while going to School F

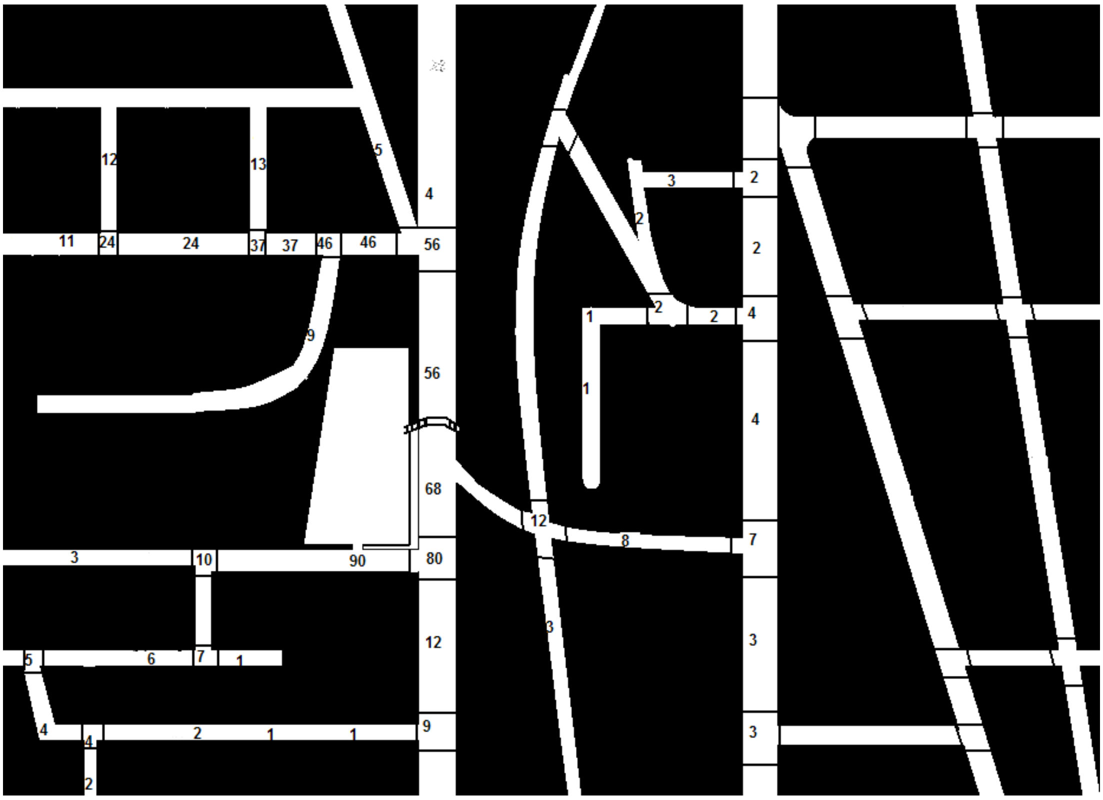


Fig. 12. Routes used by afternoon student at 18:50 while going back to home

At School F 94 students filled the form, but only 5 of them put a cross on the map, indicating that they were feeling risky in terms of traffic. Those 5 crosses were put while they were coming to school, when going back to house; students put no cross on the map. So considering that the pedestrian crashes were either sorted out (by pedestrian bridge) or pedestrian crashes on this area were not related with students, “School F” was dropped from study.

3.2. Experimental Analysis

School E was also dropped from study at this stage. Municipality refused to build an intervention at “School E” Therefore 4 schools was left. Schools “A”, “B”, “C”, and “D”. School “A” was chosen as control school as mentioned before. At school B distance between pedestrian cross and speed hump is chosen to be 9m and in school C and D distance between school pedestrian cross and speed hump is chosen to be 5 m.

The differences between pedestrian’s behavior before and after intervention were explored and tested statistically with chi-square tests. Significant results ($p < 0.05$) are reported below.

3.2.1. Speed of Free Cars

One of the most important aims of the study was to measure speed of cars. It is hypothesized that speed humps would reduce the speed of cars. In order to measure effect of speed, free speeds of cars were measured before and after implication.

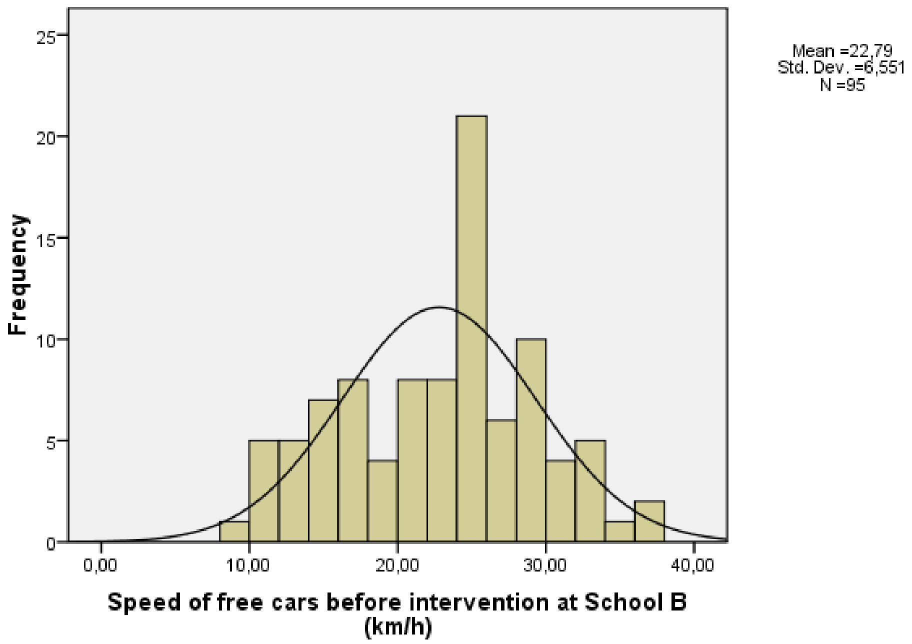
There was a significant difference in speed of free cars in each intervention area. For School B before intervention mean of speed dropped from 22.8 km/hr (SD=6.5 km/hr) to 17.8 km/hr (SD=2.6 km/hr) after intervention; $t(142,1)=5.17$, $p<0,001$.

The speed at 90th percentile in School B is reduced from 31.5 km/h to 21 km/h. In order to reach our aim, traffic calming was targeted to reach to maximum 30 km/h at 90th percentile (Johnsson and Leden, 2007). Therefore 21km/hr is considered in the safe limit.

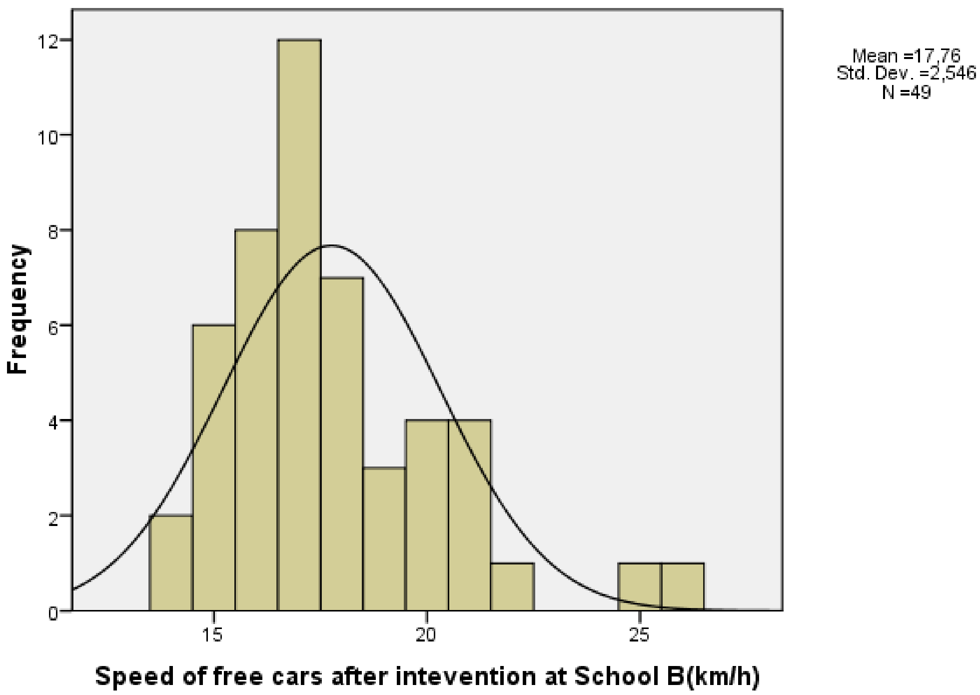
Table 4. Comparison of speed of free cars before and after intervention at School B

Comparison of speed of free cars before and after intervention (5m)		
	Speed of free cars before intervention at School B (km/h)	Speed of free cars after intervention at School B (km/h)
N	95	49
Mean	22,8	17,8
Median	24,5	17,0
Mode	25,0	17
Std. Deviation	6,5	2,6
90th Percentile	31.5	21
T test for equality of means	t(142,1)=5.17, p<0,001	

Speed of free cars before intervention at School B (km/h)



Speed of free cars after intevention at School B(km/h)



In the second school; School C there was also significant change between speed of cars before intervention (M=35.7 km/hr, SD=7.6 km/hr), and after intervention (M=19.8 km/hr, SD=5.75 km/hr); $t(179,1)=14.48$, $p<0,05$.

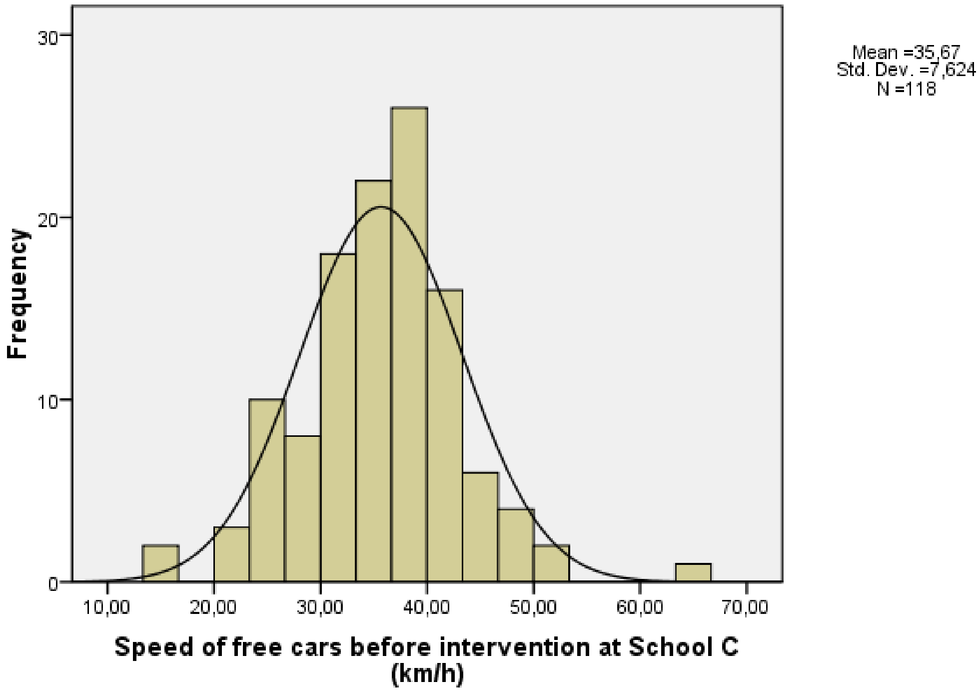
In the last school, School D; speed of cars were M=32.1 km/hr before intervention and reduced to 19.3 km/hr after intervention, indicating significant difference; $t(142,1)=12.31$, $p<0,001$.

Table 5. Comparison of speed of free cars before and after intervention at Schools C and D

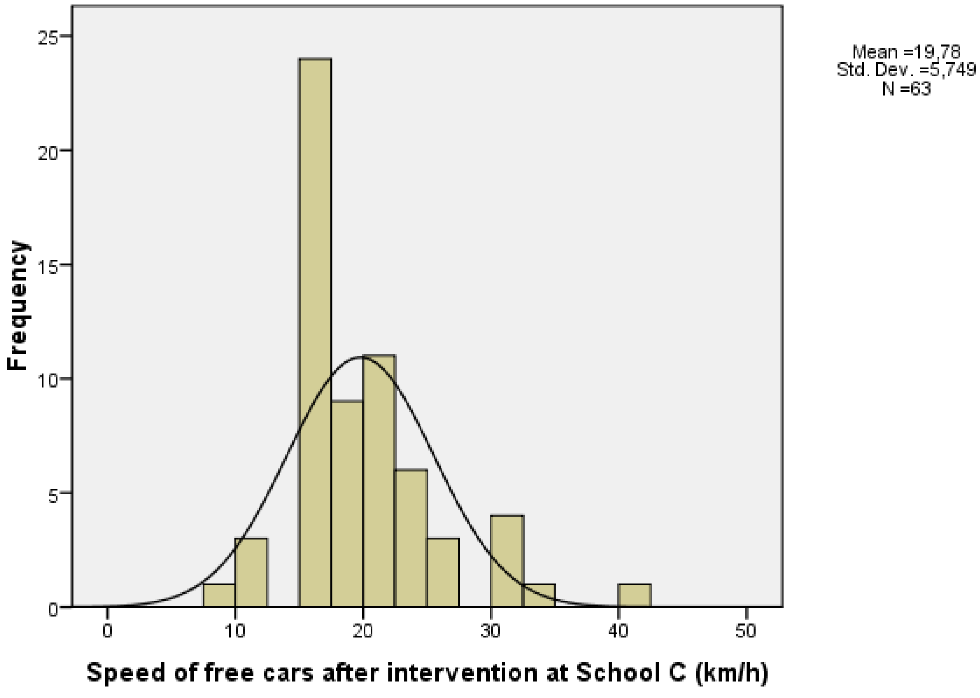
Comparison of speed of free cars before and after intervention (9m)				
	Before intervention	After intervention	Before intervention	After intervention
	School C		School D	
N	118	63	71	73
Mean	35,7	19,8	32,1	19,3
Median	35,1	19,0	32,1	19,0
Mode	35,0	17	33,0	19
Std. Deviation	7,6	5,75	7,6	4,5
Percentile 90	43.80	29.40	42.80	26
T test for equality of means	t(179,1)=14.48, p<0,05		t(142,1)=12.31, p<0,001	

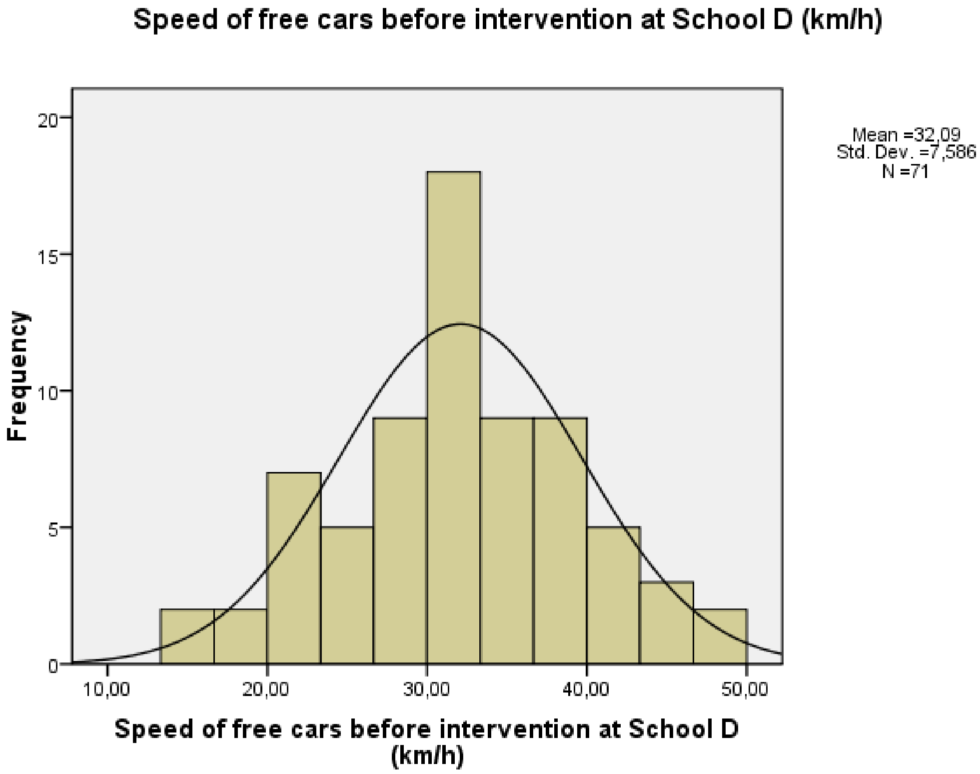
Speeds of free cars around School C and School D at 90th percentile were reduced from 43.8 km/h to 29.40 km/h, and 42.80 to 26 km/h respectively. Both of the declines are considered successful.

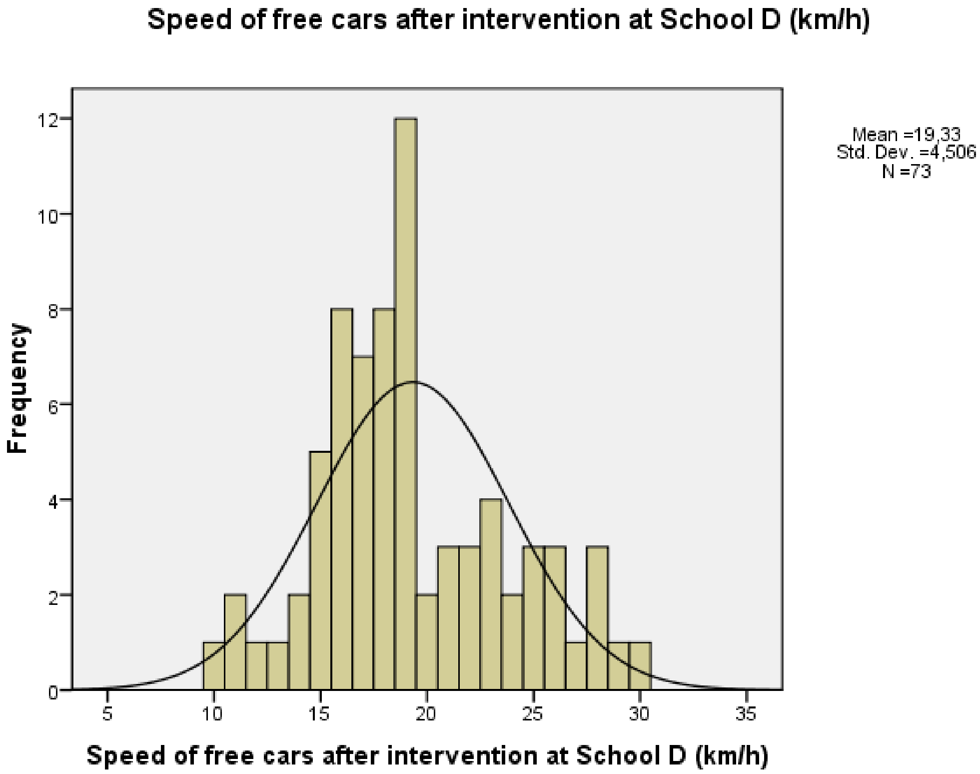
Speed of free cars before intervention at School C (km/h)



Speed of free cars after intervention at School C (km/h)




Speed of free cars before intervention at School D (km/h)
Mean =32,09
Std. Dev. =7,586
N =71
Frequency
0
5
10
15
20
10,00
20,00
30,00
40,00
50,00
Speed of free cars before intervention at School D (km/h)


Speed of free cars after intervention at School D (km/h)
Mean =19,33
Std. Dev. =4,506
N =73
Frequency
0
2
4
6
8
10
12
5
10
15
20
25
30
35
Speed of free cars after intervention at School D (km/h)

3.2.2 . YieldingBehaviour

Table 6. Comparison of Rate of cars which gave way before and after the intervention

	Rate of cars which gave way at School B (9m)	
	Before	After
Did not give way	80 (86%)	93 (71,5%)
Give way	13 **(14%)**	37 **(28,5%)***

*p<.05

	Rate of cars which gave way at School C (5m)		Rate of cars which gave way at School D (5m)	
	Before	After	Before	After
Did not give way	36 (70,6%)	37 (62,7%)	35 (87,5%)	39 (81,3%)
Give way	15 **(29,4%)**	22 **(37,3%)**	5 **(12,5%)**	9 **(18,7%)**

A series of $\chi 2$ were conducted in order to determine whether there were differences in yielding behavior as compared before intervention and after intervention.

At all sites, independent of the distance between pedestrian cross and speed hump, the frequency of pedestrians given way increased after changes were made.

However, the percentage of yielding behavior is still lower than drivers which did not give way. And increase was not always significant.

The highest yielding behavior is reported in School “C” (37.3 %), but increase was not significant.

In Schools “B”, “C” and “D” yielding behaviors increased from 14% to 28.5%, from 29,4% to 37,3% and from 12,5% to 18,7%, respectively. From these schools in only school B difference was significant *p<.05.

3.2.3. Pedestrians' Waiting Time

Pedestrian waiting time is one of the predictors of safe crossing. It was hypothesized that waiting time would reduce after intervention, because a safe gap would occur, and cars would slow down.

Pedestrians waiting time increased in all sites. In the first Site School B; waiting time was 2.53 seconds before intervention and increased significantly to 3.85 seconds after intervention; $t(221,1)=3.46$, $p<0,001$.

Table 7. Pedestrians' waiting time before and after the intervention at "School B"

	School B (9m)	
	Before	**After**
	2.53	3.85
t-value	t(221,1)=3.46, p<0,001	

In the second site School C; waiting time was 4.19 seconds before intervention and significantly increased to 5.53 seconds after intervention; $t(107,1)=1.43$, $p<0,01$.

In the third site School D; waiting time was 1,79 seconds before intervention and significantly increased to 2.79 seconds after intervention; $t(85,1)=2.18$, $p<0,05$.

Table 8. Pedestrians' waiting time before and after the intervention at School C and D

	School C (5m)		School D (5m)	
	Before	**After**	**Before**	**After**
	4.19	5.53	1.79	2.79
t-value	t(107,1)=1.43,	p<0,01	t(85,1)=2.18,	p<0,05

Comparing three sites, waiting time is lowest in School D; both before intervention (1.79 seconds) and after intervention (2.79 seconds).

3.2.4. Number of cars forming queue

Cars forming queues are also violating safe crossing attempts, and increases waiting time. Analyzing three sites, in all sites cars formed longer queues after interventions.

In Control School (School A) mean of number of cars forming a queue did not significantly change. On the other hand in school B mean of number of cars forming a queue increased from 1.35 to 2.19, which is significant; t(316,1)=6.54 p<0,001.

In School C cars formed significantly longer queues after intervention (M=3.85) compared to before intervention situation (1.75); t(227,1)=6.55, p<0,001.In School D mean of cars forming a queue raised from 1.12 to 1.40 after intervention. Which is a significant change; t(156,1)=2.76, p<0,01.

Table 9. Comparison of number of cars forming queue before and after the intervention

	School A (CONTROL)		School B (9m)	
	Before	**After**	**Before**	**After**
	1.75	1.90	1.35	2.19
t-value	t(228,1)=.89	p=.372	t(316,1)=6.54	p<0,001

	School C (5m)		School D (5m)	
	Before	**After**	**Before**	**After**
	1.75	3.85	1.12	1.40
t-value	t(227,1)=6.55,	p<0,001	t(156,1)=2.76,	p<0,01

3.2.5 High Severity Situations and Conflict

Numbers of conflicts which students face is analyzed before intervention and after intervention. It is hypothesized that number of conflicts decrease after intervention.

In the control group although number of conflicts increased in post measurements this increase is not significant.

In all three intervention sites numbers of conflicts in the post-measures were fewer than those measured in pre-measures. Percentage of conflicts between the pedestrian and vehicle decreased from 7,5%, 27,5%, 10,3% to 2,3%, 8,6%, 6,2% respectively in schools B,C, and D. Although there is a slight decrease in all sites, this decrease is only significant in School C, where percentage of conflicts decreased from 27,5% to 8,6%; (χ^2 (1)=6,27, p <0.05).

Table 10. Percentage of Conflicts between vehicles and pedestrians.

	School A (Control Group)		**School B (9m)**		**School C (5m)**		**School D (5m)**	
	N	Percent	N	Percent	N	Percent	N	Percent
Before Intervention	5	4,3	7	7,5	14	27,5*	4	10,3
After Intervention	14	10,7	3	2,3	5	8,6*	3	6,2

*p<.05

3.2.6 Pedestrians Stopping at the Curb

Pedestrians stopping on the curb increased in all intervention except for School D. In school D no students are reported to stop on curb, because on this site there is no side walk.

In two other sites percentage of students stopping on the curb increased from 5%, 29% to 29%, and 45% respectively in Schools B and C. The increase is only significant in School B where pedestrians stopping on the curb increased from 5.4% to 29,2%; (χ^2 (1)=19,82, p <0.001)

Table 11. Percentage of pedestrians stopping on the curb

	School B (9m)		**School C (5m)**		**School D (5m)**	
	N	Percentage	N	Percentage	N	Percentage
Before Intervention	5	5,4*	15	29,4	0	0
After Intervention	38	29,2*	26	44,8	0	0

*p<.001

3.2.7 Where Pedestrians wait Before Crossing

Pedestrians waiting positions before crossing is analyzed via chi-square test. In schools B and C it is fewer percentages of students are observed to be waiting on curb after intervention. In school B percentage of students waiting on street dropped from 89,2% to 57,7% significantly; (χ^2 (2)= 14,26, p <0.001). In school C; this percentage was 82,4% before intervention, and dropped to 57,6% after intervention; (χ^2 (2)= 6,484, p <0.05).

In addition, percentage of students waiting on curb increased from 9,7%, 15,7% to 25,9%, and 37,3% respectively for schools B and C.

And percentage of students waiting sidewalk slightly increased from 1,1%, 2% to 5,4%, and 3,4% respectively for schools B and C.

Finally no change is observed in School D since there is no sidewalk.

Table 12. Locations pedestrians wait before crossing

		School B (9m)		**School C (5m)**		**School D (5m)**	
		N	Percentage	N	Percentage	N	Percentage
Sidewalk	Before Intervention	1	1,1**	1	2*	0	0
	After Intervention	7	5,4**	2	3,4*	0	0
Curb	Before	9	9,7**	8	15,7*	0	0

	Intervention						
	After Intervention	35	25,9**	22	37,3*	0	0
Street	Before Intervention	83	89,2**	42	82,4*	29	100
	After Intervention	88	57,7**	34	57,6*	48	100

*p<.05

**p<.001

3.2.8 Crossing Angle of Pedestrians

Crossing angle of pedestrians is an important measure of safety. It is hypothesized that direct crossing rate will increase after interventions.

In school B direct crossing angle of pedestrians significantly increased from 61,3% to 90,8; ($\chi^2(1)$= 30.26, p <0.001). In school D although direct crossing angle significantly increased from 25,6% to 33.3%, this increase was not significant.

On the other hand In school C, in opposite of other schools, percentage of pedestrians crossing directly decreased significantly from 96,3% to 70.7; ($\chi^2(1)$= 7,2, p <0.01).

Table 13. Crossing angles of pedestrians

		School B (9m)		**School C (5m)**		**School D (5m)**	
		N	Percentage	N	Percentage	N	Percentage
Direct	Before Intervention	57	61,3**	26	96,3*	10	25,6
	After Intervention	118	90,8**	41	70,7*	16	33,3
Glancing	Before Intervention	36	38,7**	1	3,7*	29	74,4
	After Intervention	12	9,2**	17	29,3*	32	66,7

*p<.01

**p<.001

3.2.9 Crossing Tempo of Pedestrians

Crossing tempo of pedestrians are categorized in to three values; usual, stands for crossing in usual tempo; rapid, which stands for crossing in rapid tempo or jogging but not running; and running which stands for running. This categorization is based to findings of Wakim et al. (2004). Four discrete states are proposed in their model; standing, walking, jogging and running.

In school C percentage of students crossing in usual tempo significantly decreased from 92.2% to 51.7%. This percentage shifted to rapid tempo and running; where students crossing rapidly shifted from 5,9% to 34.5%; ($\chi^2(2)$= 11.4, *p* <0.01).

The change in school D is also parallel to the change in school C. In school D percentage of students crossing in usual tempo significantly decreased from 89.7% to 76.3%. This percentage shifted to rapid tempo and running; where students crossing rapidly shifted from 0% to 19.1%; ($\chi^2(2)$= 8.5, *p* <0.01).

Table 14. Crossing tempos of pedestrians

		School B (9m)		**School C (5m)**		**School D (5m)**	
		N	Percentage	N	Percentage	N	Percentage
Usual	Before Intervention	74	79,5	47	92,2*	35	89,7*
	After Intervention	105	80,7	30	51,7*	42	76,3*
Rapid	Before Intervention	15	17,2	3	5,9*	0	0*
	After	19	14,6	20	34,5*	9	19,1*

	Intervention						
Running	Before Intervention	3	3,2	1	2,0*	4	10,3*
	After Intervention	4	3,1	8	13,8*	4	8,5*

*p<.01

3.2.10. Pedestrians head movements

Pedestrian's head movements were studied and used as an approximate measure for describing if pedestrians were looking for approaching motor vehicles or not. The hypothesis was that percentages of head movements will decrease after construction of pedestrians cross. Head movements were thought to decrease as a result of safety feeling of constructions, and decreased speed of vehicles.

Results demonstrated different findings from excepted. In all three sites percentages of pedestrians looking both sides increased after interventions.

In school B percentages of students looking both sides significantly increased from 1.1% to 9.2% after intervention conducted; ($\chi^2(2)$= 10.6, p <0.01).

In school C percentages of students looking both sides significantly increased from 2.0% to 20.7% after intervention conducted, ($\chi^2(2)$= 6.1, p <0.05). On the other hand there is also slight increasment in percentage of students who do not look to any side before crossing.

Finally in School D percentages of students looking both sides significantly increased from 2.6% to 35.4% after intervention conducted; ($\chi^2(2)$= 18.0, p <0.001). In School D, in parallel with school C, there is also increase in percentage of students looking no way.

Table 15. Pedestrians' Head Movement

		School B (9m)		School C (5m)		School D (5m)	
		N	Percentage	N	Percentage	N	Percentage
No way	Before Intervention	3	3,3**	0	0*	0	0***
	After Intervention	1	0,8**	3	5,2*	4	8,3***
Left or Right	Before Intervention	89	95,7**	49	96*	31	79,5***
	After Intervention	117	90**	42	72,5*	24	50***
Both	Before Intervention	1	1,1**	1	2*	1	2,6***
	After Intervention	12	9,2**	12	20,7*	17	35,4***

*p<.05

**p<.01

***p<.001

3.2.11. Crossing Distance of Pedestrians

The crossing distance of pedestrians from a school gate (for pre-measures) or from a pedestrian cross (for post measures) is an important factor of safety. It was hypothesized that pedestrians will cross more closely to school gate after interventions.

Results show that in all three schools pedestrians' crossing distance decrease after interventions were conducted. In schools B and D this decreasement is significant where as in school C decreasement is not significant.

In schools B pedestrians' crossing distance decreased significantly from 3.12m to 0.16m; (t (219) = 10.0, p<.001). And in school D pedestrians' crossing distance significantly decreased from 5.15m to 2.19m after interventions were conducted; (t (85) = 6.4, p<.01)

Table 16. Crossing Distance of Pedestrians

	School B (9m)	School C (5m)	School D (5m)
Before Intervention	3.12**	2.74	5.15*
After Intervention	0.16**	2.16	2.19*

*p<.01

**p<.001

CHAPTER 4

DISCUSSION

The present study visions to contribute to pedestrian' safety needs around elementary schools; by stimulating structural and functional interventions, in predetermined crash zones.

In order to contribute this vision; 3 consecutive aims are fulfilled; proposing, a newly designed, behavior focused black spot analysis, documenting pedestrian behavior around these black spots, and stimulating effective interventions around elementary schools.

The study is mainly based upon; GIS crash concentration maps, primary school students' route choice and traffic risk reports, unobstrusive observations, in which observers observe a natural setting in an inconspicuous manner before and after the interventions.

Turkey as a developing country embodies more risks and higher rate of deaths compared to other European countries (Economic Commission for Europe, 2005).

Considering pedestrian crashes in World; child pedestrians account for highest percentage of injuries and deaths (Jonah and Engel, 1983; Malek et al., 1990; Kingma, 1994; Trafik İstatistik Bülteni,2007). In addition it is well known that most of child pedestrian crashes occur around schools, or near home (Trafik İstatistik Yıllığı, 2003; Road Crashes in Great Britain, 2000).

4.1. General Findings

4.1.1. Black Spot analysis

4.1.1.1. Proposing a new methodology: "Behavioral Black Spot Analysis"

The result of student handouts which they pointed risky situations are in line with GIS crash concentration maps. This finding is thought to make considerable contribution to black spot analysis methodology in traffic studies. The proposed method in this study is named "Behavioral Black Spot Analysis". This methodology is namely based upon pedestrians' route choice and risk perception statements. In order to validate this technique the study has to be replicated. And for reliability check, answers of students need to be compared with GIS based results by the use statistical techniques.

The "Behavioral black spot analysis" technique is more advantageous than crash frequency, crash density or in other words GIS based techniques in some terms. "Behavioral black spot analysis" can be used and applied before crashes occur in an area; but GIS based methodology can only be applied after crashes take place, or start to dense in a specific area.

On the other hand "Behavioral Black Spot analysis" can only be applied for pedestrian crashes if the method is applied to pedestrians as in this study. If vehicle crashes are needed to be analyzed than simplified maps of sites needed to be handed out to drivers; and ask them to draw the root when they follow when going home, and mark places where they feel in danger as a driver. In this case simplified maps need to cover larger areas. The same technique can also be applied to bicyclists.

Finally; considering findings of this study; this study shows the importance and earns of the usage of engineering techniques such as Traffic Information System in understanding and improving traffic environment.

4.1.1.2. Route Choice Behavior

Evaluating; route choice behavior of students; it can be summarized that in all sites students choose the shortest route on their way. These findings support the directness theory of Hill (1982). On the other hand opposite to the findings of Bovy and Stern (1990) it seems that students do not pay much attention to number of crossings, pollution, noise level, and simulation of the environment, on their ways to school and back to the home.

4.1.1.3. Black Spot Analysis

Generally discussing the findings of "Behavioral Black Spot Analysis" it can be concluded that; traffic flow, pedestrian and vehicle visibility, waiting time, road width are most important parameters of pedestrian safety.

In earlier studies traffic flow, visibility and waiting time were found to be affecting pedestrian safety. But contrary to the inference of this study road width was found to be insignificant on pedestrian safety (Himanen and Kulmala, 1988). This contradiction maybe because, road width may not have a direct effect on pedestrian safety, but as the road width increases the vehicle flow increases too. In addition as the road width increases the crossing time also increases, and by the result of these variables, road width may have an indirect effect on pedestrian safety.

Previous study that observed pedestrian safety found that; pedestrian accident risk increased with increasing vehicle flow and vehicle speed (Leaf and Preusser, 1999), and decreased with increasing pedestrian flow (Leden, 2002). Findings of present study show that; although black spots are condensed at points where vehicle flow is high, these points are also those where pedestrian flow is high. For instance school gates are points where pedestrian flow was highest. And nearly in all sites, school gates were marked as risky.

Interpreting this finding it can be concluded that although pedestrian flow have a positive effect on traffic safety, this factor may not have an effect on risk perception of pedestrians, but drivers. Secondly; referring to the traffic risk analysis, it is known that traffic crashes occur more where population density is more. This may be just because there are more people living in those sites or the finding of Leden (2002), pedestrian risk decrease with increasing pedestrian flow need to be reexamined.

Analyzing black spots around elementary schools it may be concluded that all sites and all black spots have their own characteristics. And therefore all sites need different construction in relation with its vehicle density, vehicle speed, earlier yielding rates, crash characteristics, and regional differences.

Going one by one; in the first school, School A, different from other schools school gate was not found to be risky. One reason for this may be the school's gate is placed on a one way, sloppy street; and vehicle flow on this street is uphill, Vehicles going uphill both goes slowly and stop easily. In addition the street is narrow, and because of this no cars can park on the street. And this makes pedestrian more visible.

The effect of pedestrian visibility on a specific point being black spot is also salient in school D. School D's gate is one of the most risky points in whole study. When this point is investigated, it can be easily seen that the visibility is a problem for both drivers and pedestrians. The School gate is located on a road which is hill shaped. And the gate is at the peak of the hill. So when a pedestrian exits from the school he/she cannot see if a vehicle is approaching, unless the vehicle comes to eyesight. And that's only about 20m-25m at this specific situation. Since the driver's decision zone for giving way to a pedestrian is 50m before the crosswalk, a driver which faces with a pedestrian who is 25m away; gets in a decision pressure; he/she either brakes suddenly, or maintain the speed to show that he/she will not give way.

Visibility is also a factor which we face at school C. School C's gate is placed on a point where a curve ends. Again neither pedestrians nor drivers have a chance to see each other before a specific distance.

One of other risky points in school "A" was next to a traffic light. It is interesting to find out that a lighted cross is perceived as risky by pedestrians. When the cross is investigated it is found out that; although there is a traffic light. The waiting time for pedestrian is more than a minute. And as the waiting time become longer, pedestrian attempts to cross the street more. On the other hand effect of traffic lights in pedestrian safety cannot be disregarded. In school C for instance; pedestrian which feels in danger reduces from 62% to 18%, on the same road, at two different point one with traffic light and the other without it.

4.1.2. Findings of Unobtrusive Observation

Speed of the car significantly decreased in all sites. And in all 3 intervention sites traffic calming reached to the targeted speed at 90th percentile; which is 30 km/h. Considering the effect of speed bump on traffic calming it seems that; a 605mm to 45mm standard speed bump is efficient in calming the traffic flow to 30km/h at 90th percentile. In an earlier study 55mm speed cushion reduced the 90th percentile driving speed only to 41km/h (Johnsson and Leden, 2007). This contradiction maybe as a result of the difference between speed hump and speed cushion. Speed cushions have more forgiving shape. But in this study speed humps were used.

When the speed changes before and after interventions are examined in all 3 sites; it can be concluded that the effect of speed hump on vehicle flow is always in specific range of ratio. For instance a vehicle passing at 30km/h before intervention, passes at about 20km/h after a hump is build. But a vehicle passing at 40km/h before intervention passes at about 30km/h after a hump is build. Therefore if speed calming is aimed at a street which has a fast vehicle flow, constructing a speed hump will not make any good, because traffic cannot be slowed down to 30km/hr if the speed is high.

In accordance with the decreasing vehicle speed, total number of cars forming a queue also increased in all sites significantly. When cars form queues, the distance between vehicles starts to diminish. The relation between speed and cars forming a queue is not examined in earlier studies.

It is well known that according the gap acceptance theory, pedestrian rely their crossing decision mainly to distance rather than speed, (Connely et al., 1996, 1998).. This decision mechanism is most active when the vehicle speed is slower (Rosenbloom et al., 2008b)

Considering gap acceptance theory, cars forming queues, caused increasement in waiting time. This increase in waiting time was significant in all sites. On many studies increased waiting time led to frustration and frustrated pedestrians attempted to unsafe crossings (Carsten at al., 1998).

On the other hand as the waiting time increases; pedestrians are observed to cumulate near the pedestrian cross. This accumulation may cause safer crossings compared to single crossings. Because it is an assumption that increasing pedestrian flow increases driver alertness. And therefore increased pedestrian flow decreases pedestrian risk (Leden, 2002).

Wrapping together, it is assumed that decreasing vehicle speed, or in other words calming traffic, especially at areas where vehicle flow is high, causes vehicles to form queues as illustrated in figure. Since pedestrians crossing decisions are based upon distance (Gap Acceptance Theory), vehicles forming queues increases pedestrians waiting time. This results with more pedestrians waiting near the pedestrian cross. Finally the sequence forks in to two opposite results; either frustrated pedestrians jump in to the road and takes risk when there is not enough gap, or they all together wait for a safe gap, and cross when there is a safe gap. This mass crossing causes driver alertness, which in turn increases road safety.

It should bared in mind that at crossings near the school gates, increasing the waiting time would be a lot more riskier that other places, because it is a finding that pedestrians who frequently use a certain pedestrian cross are likely to accept higher risks by reducing waiting time (Hamed, 2001).

Interventions always have a positive effect on yielding behavior. But this increase was only significant at the site where the distance between crosswalk and speed bump was 9m. This finding seems to fit to earlier studies, where higher share of pedestrian were given way when the speed cushion was located at further distance from crosswalk (Leden et al., 2006). The problem with close pedestrian cross and vehicle flow is indicated in the study where Leden et al. (2006) interviewed with 2 children where crosswalk was 5m ahead speed cushion. Children state that it was problematic to decide if drivers intended to stop or not when they slowed down for the speed cushion. The problem seems to be salient when the speed cushion is situated close to the crosswalk.

On the other hand distancing the speed hump from pedestrian cross increases free car speed (Johannson and Leden, 2007). Therefore more studies need to be conducted for finding the optimal distance between speed cushion and pedestrian cross, where speed is minimum, and yielding behavior is maximum.

In all sites; percentage of pedestrians stopping at the curb increased, in other words number of pedestrian stopping on the street before crossing decreased.

In addition pedestrians crossing in angle, and crossing distance decreased, and percentage of pedestrians crossing directly increased. Crossing angle is an important safety measure because crossing directly shortens the crossing distance and therefore crossing time.

Percentage of pedestrians looking both sides before crossing also increased in all sites.

According to Rosenbloom (2008), not looking was the most frequent unsafe behavior, followed by not stopping. In other studies in addition to this findings, crossing the street at an improper location and jay walking were found to be most frequent unsafe behaviors committed by pedestrians (Rosenbloom et al., 2004; Kim et al. 2008) Considering results of earlier findings, it can concluded that a very simple intervention (speed hump and pedestrian cross) have a significant effect on all unsafe behaviors. So interventions do not only affect the driver behavior but also pedestrian behavior. Psychological process behind this positive effect need to be analyzed in future studies.

Interestingly all safety variables changed in positive manner, but they were mostly significant only in the school where the distance between pedestrian cross and speed hump was 9m.

On the other hand crossing tempo shifted from walking to jogging in schools where crossing distance between speed hump and pedestrian cross was 5m. In the other site no change was observed. Interpreting the results about crossing tempo; it can be inferred that pedestrians crossing at 5m sites, needed to jog or walk instead of walking. But in 9m situation since there is enough crossing gap pedestrians did not need to shift to jogging tempo while crossing. This finding also supports the idea of instructing speed bump, 9m away from pedestrian cross.

Number of conflicts or in other words high severity conditions decreased in all sites; this decreasement was only significant in School C. Although many pedestrian crashes occur in this site, according to the "behavioral black spot analysis" School C was found to be the safest site compared to other schools. Interpreting results on severity conditions; it can be concluded that, although the improvement is not significant, since there is improvement in all sites; interventions can be counted as successful in reference to conflict rates. In order to get significant results in all sites more effective interventions could have been implicated.

4.2. Suggestions and Limitations

These findings have empirical implications future studies and road safety measures aiming pedestrian safety.

The positive effects of simple implications are clearly presented in the study, unfortunately pedestrians face with similar problems in everyday life. Results of this study indicate that constructing simple implication will be adequate to pedestrian safety; therefore it is crucial to make legal arrangements around the Country.

In addition more data should be collected from other sites with different physical conditions in order to see the effects of implications in broader manner. For instance the effect of hump should be studies in roads where traffic flows faster.

The effect of decreased speed and speed humps on cars forming queue was not predicted. This relation between cars forming queue and types of intervention at different circumstances need to be analyzed in future studies.

This study focused on both driver behavior (eg; yielding, speed etc.) and pedestrian behavior (head movements, crossing speed etc.). Further studies which are examining effects of other type of reinforcements should be studied.

Factors that affect community's possession of interventions should be examined. Eliminating factors affecting the possession or internalization will promote walking and usage of pedestrian crosses.

Although many variables changed in positive manner, one of the most important implications of safety; conflict, did only change significantly in one school. It could have been assumed that longer waiting times, and safety feeling could have suspended the positive effect of implications and other safe behaviors. Therefore eliminating factors influencing safety feeling could have been suggested for further studies. For instance in Sweden after the new Traffic code pedestrian cross are started to be removed from cross in order to minimize false sense of safety (Leden et al., 2006).

Studies assessing children's risk perception; conclude that children and young pedestrian have more positive attitude towards crossing (Diaz, 2002), they are prone to optimism bias, and underestimate their risks in traffic (Deery, 1999; Glendon et al., 1996). Considering these findings, although "behavioral black spot analysis" worked out efficiently, simplified maps of sites could have also been handed out to adults who live in selected school areas.

The unobtrusive observation which is implemented in the study allowed more accurate reporting of real behavior. While questionnaires acquire accurate data reported behavior does not always coincide to actual behavior (Lajunen et al.,1997). However, observational methods, especially when conducted in real-traffic environments, are difficult to carry out, because demographic details of the sample are unobtainable, demographic information relied of estimations.

In addition in unobtrusive observations are impossible to repeat. It is also difficult to control environmental variables that are relevant to the study.

From other point of view, in a further study involving additional techniques must be considered. It is not very easy to stop pedestrians (especially those who have just committed a violation) and ask them to fill a questionnaire. However there is need for demographic details and other questionnaires could also be filled to the students in the school after the study is conducted. This would shed light on the road habits of the pedestrians.

Finally it is important to measures outcomes of implications on the basis of pedestrian crashes. This can be possible by the use of GIS crash analysis.

REFERENCES

Bernhoft, I. M., & Carstensen, G. (2008). Preferences and behaviour of pedestrians and cyclists by age and gender. *Transportation Research Part F, 11,* 83–95.

Björklund , A. M., & Áberg, L., (2005). Formal and informal traffic rules. *Transportation Research Part F, 8,* 239–253.

Bovy, P.H.L., Stern, E., (1990*). Route Choice: Wayfinding in Transport Networks.* Kluwer Academic Publishers, Dordrecht.

Briem, V., Bengtsson, H., (2000). Cognition and character traits as determinants of young children's behaviour in traffic situations. *International Journal of Behavioral Development, 24,* 492–505.

Carsten, O. M. J., Sherborne, D. J., & Rothengatter, J. A. (1998). Intelligent traffic signals for pedestrians: Evaluation of trials in three countries. *Transportation Research Part C, 6,* 213–229.

Chadda, H. S., & Cross, S. E. (1985). Speed (road) bumps: Issues andopinions. *Journal of Transportation Engineering, 111(4),* 410– 418.

Clark, L. K., Hummer, J. E., & Dutt, N. (1996). *Field evaluation of fluorescent strong yellow–green pedestrian warning signs.* Transportation Research Record No. 1538.

Connelly, M.L., Conaglen, H.M., Parsonson, B.S., Isler, R.B., 1998. Child pedestrians' crossing gap thresholds. *Accident Analysis and Prevention, 30,* 443–453.

daSilva, M.P., Smith, J.D., Najm, W.G., 2003. *Analysis of Pedestrian Crashes.* DOT HS 809 585. National Highway Traffic Safety Administration, Washington, DC.

Deery, H.A., 1999. Hazard and risk perception among younger novice drivers. *Journal of Safety Researc, 30 (4),* 225–236.

Diaz, E. M. (2002). Theory of planned behavior and pedestrians' intentions to violate traffic regulations. *Transportation Research Part F, 5*, 169–175.

Economic Commission for Europe, (2005). *Statistics of Road Traffic Crashes in Europe and North America.* Vol L.

Evans, D., & Norman, P. (1998). Understanding pedestrians' road crossing decisions: An application of the theory of planned behaviour. *Health Education Research, 13(4),* 481–489.

Hakkert, S., Gitelman, V., & Ben-Shabat, E. (2002). An evaluation of crosswalk warning systems: Effects on pedestrian and vehicle behaviour. *Transportation Research Part F5*.

Hamed, M. M. (2001). Analysis of pedestrians' behaviour at pedestrian crossings. *Safety Science, 38,* 63–82.

Hatfield, J., & Murphy, S. (2007). The effects of mobile phone use on pedestrian crossing behaviour at signalised and unsignalised intersections. *Accident Analysis and Prevention, 39,* 197–205.

Hill, M.R., 1982. Spatial Structure and Decision-Making of Pedestrian Route Selection Through An Urban Environment, Ph.D. Thesis, *University Microfilms International.*

Himanen, V., & Kulmala, R. (1988). An application of logit models in analysing the behaviour of pedestrians and car drivers on pedestrian crossings. *Accident Analysis and Prevention, 20(3),* 187–197.

Hine, J., & Russel, J. (1993). Traffic barriers and pedestrian crossing behaviour. *Journal of Transport Geography, 1(4),* 230–239.

Hoffrage, U.,Weber, A., Hertwig, R., Chase, V.M., 2003. How to keep children safe in traffic: find the daredevils early. *Journal of Experimental Psychology: Applied 9,* 249–260.

Hoogendoorn, S. P. (2004). Pedestrian flow modeling by adaptive control. *In Proceedings of the TRB 2004 annual meeting,* Washington DC.

Hoogendoorn, S. P. & Bovy, P.H.L., (2002) Pedestrian route-choice and activity scheduling theory and models. *Transportation Research Part B: Methodological, 38,* 169-190

Holland, C., & Hill, R. (2007). The effect of age, gender and driver status on pedestrians' intentions to cross the road in risky situations. *Accident Analysis and Prevention, 39,* 224–237.

Johansson, C., Gárder, P., Leden, L. (2004). Towards a safe environment for children and elderly as pedestrians and cyclists—a synthesis based on an analysis of in-depth studies of fatalities, police-reported crashes and including video recordings of behaviour. *In: ICPTT-Conference, 5–9 September 2004,* Nottingham.

Johansson, C., Leden, L., (2006). Short-term effects of countermeasures for improved safety and mobility at marked pedestrian crosswalks in Borás, Sweden. *Accident Analysis and Prevention, 39,*500–509

Janssen, W., van der Horst, R., Bakker, P., & ten Broeke, W. (1988). *Auto-auto and auto-bicycle interactions in priority situations.* In T. Rothengatter & R. de Bruin (Eds.), Road user behaviour:Theory and research (pp. 639–644).

Karayolları Trafik Kanunu (1983)

Karayolları Trafik Yönetmeliği (1997)

Kaygısız, Ö., Metropoliten alanlarda trafik kazası müdahale birimlerinin yer seçimi; Ankara örneği (2008). *Fen Bilimleri Enstitüsü,* Gazi Üniversitesi.

Keegan, O., & O'Mahony, M. (2003). Modifying pedestrian behaviour. *Transportation Research Part A 37.*

Kim, K., Brunner, I. M., Yamashita, E. (2008). Modeling fault among accident involved pedestrians and motorists in Hawaii, *Accident Analysis and Prevention, 40,* 2043–2049

Kingma, J. 1994 , Age and gender distributions of pedestrian crashes across the life-span. *Perceptual and Motor Skills, 79, Spec Issue.* 1680 -1682.

Kukla, R., Kerridge, J., Willis, A., & Hine, J. (2001). PEDFLOW: Development of an autonomous agent model of pedestrian flow. *Transportation Research, 1774,* 11–17

Lam, L. T., (2005). Parental risk perceptions of childhood pedestrian road safety: A cross cultural comparison. *Journal of Safety Research, 36,* 181 – 187

LaScala, E. A., Gerber, D., & Gruenwald, P. J. (2000). Demographic and environmental correlates of pedestrian injury collision: a spatial analysis. *Accident Analysis and Prevention, 32,* 651–658.

Leaf, W.A., Preusser, D.F., 1999. *Literature review on vehicle travel speeds and pedestrian injuries.* U. S. Department of Transportation National Highway Safety Administration,

Leden, L., 2002. Pedestrian risk decrease with pedestrian flow. A case studybased on data from signalized intersections in Hamilton, Ontario. *Accident Analysis and Prevention, 34*, 457–464.

Leden, L., Garder, P., Johansson, C., (2006). Safe pedestrian crossings for children and elderly. *Accident Analysis and Prevention, 38,*289–294

Li, Y., & Tsukaguchi, H. (2005). Relationships between network topology and pedestrian route choice behaviour. *Journal of the Eastern Asia Society for Transportation Studies, 6*, 241–248.

Matsuda, F., (1996). Duration, distance, and speed judgments of two moving objects by 4–11-year-olds. *Journal of Experimental Child Psychology, 63*, 286–311.

Nasar, J. L. (2003). Prompting drivers to stop for crossing pedestrians. *Transportation Research Part F, 6,* 175–182.

Nee, J., & Hallenberg, M. (2003). A motorist and pedestrian behavioral analysis relating to pedestrian safety improvements. Final Report, Research Project

Preusser, D.F., Wells, J.K., Williams, A.F., Weinstein, H.B., 2002. Pedestrian crashes in Washington, DC and Baltimore. *Accident Analysis Prevention, 34*, 703–710.

Oxley, J., Fildes, B., Ihsen, E., Charlton, J., & Days, R. (1997). Differences in traffic judgements between young and old adult pedestrians. *Accident Analysis and Prevention, 29,* 839–847.

Oxley, J., Fildes, B., Ihsen, E., Charlton, J., & Days, R. (2005). Crossing roads safely: An experimental study of age differences in gap selection by pedestrians. *Accident Analysis and Prevention, 37,* 962–971.

Papadimitriou, E., Yannis, G., Golias, J. (2009). A critical assesment of pedestrian behaviour model. *Transportation Research Part F, In press*.

Parker, D., Manstead, A.S., Stradling, S.G., Reason, J.T., 1992. Determinants of intentions to commit driving violations. *Accident Analysis and Prevention, 24,* 117–131.

Roads and Traffic Authority of NSW, 2005b. Road Users' Handbook. Retrieved 05/04/2009 from http://www.rta.nsw.gov.au/licensing/downloads/road_users_handbook.pdf.

Rosenbloom, T., Nemrodov, D., & Barkan, H. (2004). For heaven's sake follow the rules: pedestrians' behavior in an ultra-orthodox and a non-orthodox city. *Transportation Research Part F: Traffic Psychology and Behaviour, 7,* 395–404.

Rosenbloom, T., Ben-Eliyahu, A., & Nemrodov, D. (2008). Children's crossing behavior with an accompanying adult. *Safety Science, 46,* 1248–1254.

Rosenbloom, T., Nemrodov, D., Ben-Eliyahu, A., & Eldrora, E., (2008b). Fear and danger appraisals of a road-crossing scenario:A developmental perspective. *Accident Analysis and Prevention, 40*,1619–1626

Senevarante, P.N., Morall, J.F., 1986. Analysis of factors affecting the choice of route of pedestrians. *Transportation Planning and Technology 10,* 147–159.

Simpson, G., Johnston, L., & Richardson, M. (2003). An investigation of road crossing in a virtual environment. *Accident Analysis and Prevention, 35*, 787–796.

Slovic, P., 1987. Perception of risk. Science 236, 280–285. Glendon, A.I., Dorn, L., Davies, D.R., Matthews, G.,Taylor, R.G., 1996. Age and gender differences in perceived accident likelihood and driver competences. *Risk Analysis, 16*, 755–762.

Te Velde, A. F., van der Kamp, J., Barela, J. A., & Savelsbergha, G. J. P. (2005). Visual timing and adaptive behavior in a road-crossing simulation study. *Accident Analysis and Prevention, 37*, 399–406.

Tiwari, G., Bangdiwala, S., Saraswat, A., Gaurav, S. (2007). Survival analysis: Pedestrian risk exposure at signalized intersections. *Transportation Research Part F,* 10,77–89

UNICEF (2001). *A league table of child deaths by injury in rich nations.* Innocenti report card no. 2. Florence: UNICEF Innocenti Research Centre.

Varhelyi, A. (1998). Drivers' speed behaviour at a zebra crossing: A case study. *Accident Analysis and Prevention, 30*, 731–743.

Van Berkum, E., Van Der Mede, P., 1993. The Impact of Traffic Information—Dynamics in Route and Departure Time Choice. *Delft University of Technology*. Ph.D. Thesis.

Van Houten, R., & Malenfant, L. (1992). The influence of signs prompting motorists to yield before marked crosswalks on motor vehicle-pedestrian conflicts at crosswalks with flashing amber. *Accident Analysis and Prevention, 24*, 217–225.

Wakim, C. F., Capperon, S., & Oksman, J. (2004). A Markovian model of pedestrian behavior. In Proceedings of the 2004 IEEE lntenational conference on systems, man and cybernetics, 4028–4033.

Xiaoping, Z., Tingkuan, Z., & Mengting, L. (2009). Modeling crowd evacuation of a building based on seven methodological approaches. *Building and Environment*, *44*, 437–445.

Yagil, D. (2000). Beliefs, motives and situational factors related to pedestrians self-reported behavior at signal-controlled crossings. *Transportation Research Part F, 3*, 1–13.

Yang, J., Deng, W., Wang, J., Li, Q., & Wang, Z. (2006). Modeling pedestrians' road crossing behavior in traffic system micro-simulation in China. *Transportation Research Part A*, 40, 280–290