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Pedestrian behaviors at and perceptions towards various pedestrian facilities: an examination based on observation and survey data

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Abstract

This paper presents findings from an observational study of pedestrian behaviors at various urban crosswalks and a pedestrian user survey which sought pedestrian perceptions toward various pedestrian facilities in a divided urban boulevard located next to a large university campus, Michigan State University, East Lansing, MI, USA. Such facilities included signalized and unsignalized intersection crosswalks, unsignalized marked and non-striped midblock crosswalks, physical barriers (vegetation and two-foot high concrete wall), midblock crosswalk shelters, colored paving (red brick pavement) at medians and curbs, and pedestrian warning signs at midblock crossing locations, messaging "cross only when traffic clears." Pedestrian behavior data were obtained from the reduction of video images of pedestrian movements recorded throughout the study site. Pedestrian perceptions information was obtained through a user survey completed by pedestrians using the study site. It was found that unsignalized midblock crosswalks were the treatment of preference to pedestrians (83% reported a preference to cross) and also showed high crossing compliance rate of pedestrians (71.2%). It was also evident that the crosswalk location, relative to the origin and destination of the pedestrian, was the most influential decision factor for pedestrians deciding to cross at a designated location (90% said so). Proper traffic control can further encourage pedestrian crossings at designated locations since the effect of the availability of pedestrian signal to influence pedestrians' decisions to cross at a specific location was quite high (74% said so). Moreover, vegetation and concrete barriers influenced the decision to cross of a significant number of pedestrians surveyed (65%). It is expected that the findings from this study will help traffic engineers, urban planners and policy makers understand pedestrian behaviors and attitudes at/towards pedestrian crosswalks.

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1. Introduction

As traffic congestion and air pollution are becoming growing problems in many cities in the US and worldwide, government agencies of all levels show an increased interest toward promoting non-motorized travel options. Many communities across the nation have started seeking ways to increase pedestrian activities and discourage automobile dependency, particularly for short trips in residential settings. The trend of "new urbanism," for example, encourages developing pedestrian friendly neighborhoods, which would offer proximity of pedestrians to shared neighborhood amenities. A study of consumer attitude survey of Floridians, USA, found that some groups would gladly trade-off the lot size found in ordinary suburbia for pedestrian proximity to community amenities (Audirac, 1999). Initiatives that promote pedestrian travel must provide potential users an assured level of convenience, efficiency, comfort, and security for successful applications. City planners and traffic engineers should take under consideration pedestrian preferences and perceptions when designing efficient and pedestrian friendly facilities.

Governmental as well as societal pressures for developing safer environments for pedestrians and bikers are strongly encouraging traffic engineers and planners to do more research regarding the issues for non-motorized transportation. Zegeer et al. (2002) have recently published a comprehensive guide on pedestrian facilities and pedestrian safety and mobility. The guide is intended to provide information on how to identify safety and mobility needs for pedestrians with the roadway right-of-way. It is expected to be useful for engineers, planners, safety professionals and decision-makers. The guide covers such topics as the walking environment including sidewalks, curb ramps, crosswalks, roadway lighting and pedestrian over and underpasses, roadway design including bicycle lanes, roadway narrowing, reducing the number of lanes, one-way/two-way streets, right-turn slip lanes and raised medians, intersections with roundabouts, T-intersections and median barriers, and traffic calming designs.

1.1. Pedestrian safety

Pedestrian safety is still one of the most important safety concerns in the US and in the world. In 1995 the pedestrian fatality rate per 100,000 population was 2.13 for the US. The state of New Mexico had the highest rate (5.16) and North Dakota had the lowest (0.31) (NHTSA, 1995). In 2000, 4739 pedestrians were killed and 78,000 were injured in traffic crashes in the United States, representing 11% of all the people died in traffic crashes and 2% of all traffic injuries. Pedestrian fatality rate is of decreasing 27% from the 6482 pedestrians killed in 1990. Most pedestrian fatalities in 2000 occurred in urban areas (71%) and at non-intersection locations (78%). Pedestrian fatalities accounted for 85% of all non-occupant fatalities in 2000. The 690 pedal cyclist fatalities accounted for 12%, and the remaining 3% were skateboard riders, roller skaters, etc. (NHTSA, 2000).

Pedestrian safety is being considered as a serious traffic safety problem nationwide and is not confined to urban areas only. Every year many pedestrians are injured or killed in traffic accidents in rural parts of the country. As an example, Ivan, Garder, and Zajac (2001) studied pedestrian related accidents in rural areas of New England, USA. The authors researched the safety of pedestrian crossings in rural areas to discover and confirm factors that help explain high rates of motor vehicle–pedestrian collisions at pedestrian crossings. The following environmental and exposure factors are considered: population density, type of pedestrian crossing, traffic control used at the crossing, surrounding land use type, highway facility type, vehicle travel speed, vehicle volume and pedestrian volume.

In urban, suburban and rural settings, various engineering options exist to assist pedestrian accessibility and ensure safety. Engineering improvements at these facilities should be carefully evaluated to assess the effectiveness of the solutions implemented and their potential value for application in other locations with similar characteristics, needs and limitations. User perceptions toward the operation of pedestrian facilities are of great importance to such an evaluation process. Pedestrians themselves are the most appropriate group to identify treatments that create a safe and/or desirable environment for them and options that increase their likelihood to properly use of pedestrian designated facilities. The latter is crucial toward the improvement of pedestrian safety. When pedestrians use sidewalks and cross at designated locations, the separation of pedestrians and vehicles increases, and thereby pedestrian–vehicle conflicts are minimized. In this context, researchers have always been desirous of designing pedestrian crossings that are responsive to pedestrian needs and thus improve pedestrian safety and comfort.

Among alternative engineering options for pedestrian crossings, intelligent traffic signals can offer choices that are more responsive to pedestrian needs. The European Community Drive II project VRU-TOO (Vulnerable Road Users Traffic Observations and Optimization) carried out trials of innovative signalized crosswalks that aimed to improve pedestrian safety and comfort by being more responsive to pedestrian crossing needs. These crossings were installed at sites in three European countries. Although important differences were observed in the impacts at the various sites, there were general gains in safety and comfort of pedestrians. Detectors installed at the crossings offered reduced delays by extending pedestrian interval for late arrivals. Thus, red light violation at a crossing in Porto decreased substantially from 83% to 67%. However, the results showed that safety and comfort did not go hand-in-hand. An increase in safety sometimes reduced comfort, or vis-à-vis (Carsten, Sherborne, & Rothengatter, 1998). In another work of VRU-TOO, Carsten (1994) showed that the risk of a conflict between pedestrian and vehicle was highest when pedestrian delay was small. This means that if pedestrians do not stop or slow down at the curb when they arrive at the crosswalk to cross a street, they are most likely to be involved in an accident. The risk is particularly high for a pedestrian to cross on red when a free-flowing vehicle or a platoon of vehicles is approaching (Pasanen & Salmivaara, 1993).

As long as the issue of traffic safety stays at the top of the nation's agenda, researchers have been trying several approaches if in order to reduce pedestrian injuries and casualties as pedestrians being the most vulnerable actors in the competitive urban traffic. These approaches range is scope from introducing innovative devices to examining and evaluating current practices. Broyhill, Tan Esse, and Ward (2002) described the experimentation of an innovative traffic control device (TCD), provided an example of a successful experiment and discussed the implementation of a new TCD—the "fluorescent yellow green" warning signs to be used for school, pedestrian, and bicycle related traffic safety. Retting, Nitzburg, Farmer, and Knoblauch (2002) examined the practice of "right-turn-on-red (RTOR)." Although the practice of RTOR has many benefits such as reduced emissions and/or traffic delays, the RTOR is likely to increase the risk of crashes and injuries, especially in urban areas where high pedestrian activities occur. Following the adoption of the national RTOR policy in the US, significant increases in pedestrian and bicycle crashes were reported at signalized intersections. This is due to the fact that many drivers do not come to a full stop before turning right on red. Another negative impact of the RTOR is that drivers tend to fail to stop at/behind the marked stop line due to their habits for turning right on red, thereby blocking the pedestrian crosswalk while waiting to turn. This can impede movement and cause pedestrians to walk outside of designated crosswalks. Relatively little is known about the operational and safety effects of prohibiting the RTOR when pedestrians are present as compared with the unconditional RTOR restrictions or restrictions confined to specified hours.

1.2. Pedestrian behavior and attitude

Literature review indicated that environmental designs and urban forms could play a very crucial role in pedestrian travel behavior. A proper design of facilities can encourage walking without compromising safety and convenience (Handy, 1996; Shriver, 1997). Besides, improvements in safety and comfort for pedestrians can be obtained without major side effects on vehicle travel (Carsten et al., 1998). Also it is evident that pedestrian safety can be affected by changes in the signal settings at signalized crosswalks (Gårder, 1989). A study by Forsythe and Berger (1973) presented the results of interviews with pedestrians crossing unsafely during DON'T WALK signal indication or pedestrian red interval. It was reported that the reason for unsafe crossing was mainly time-related. A need to hurry or a desire to keep moving was the main reason behind the lack of compliance with pedestrian signals. The major responsibility of providing physical facilities that encourage pedestrian travel and help protect the pedestrians resides with traffic engineers. Such facilities include roadways, sidewalks, TCDs, medians, etc. Pedestrian friendly and safe environments involve separation of pedestrian and vehicle traffic, control of flow of pedestrians and vehicles, improvement of visibility, proper communication through signs, and assistance of pedestrians with special needs (US DOT, AAA & NSC, 1994).

Although considerable research has been undertaken in the very recent years to address the problem of pedestrian safety (as a few examples: Ivan et al., 2001; Krabbel, Appel, & Ikels, 1998; Kronborg & Ekman, 1995; Levelt, 1992; Marçal, 1995; Miller, 2000, 1999; Pasanen & Salmivaara, 1993; Retting et al., 2002; Road Information Program, 2001; Schieber & Vegega, 2001; Tan & Zeeger, 1995; Zegeer et al., 2002; Zegeer, Stewart, Huang, & Lagerwey, 2002), limited studies on pedestrian perceptions and attitudes towards facilities for pedestrians are reported in the literature. Among them recent studies by Hine (1996), Hine and Russell (1996) and Russell and Hine (1996) published the impact of traffic on behavior and perceptions of safety of pedestrians. Another study by Tanaboriboon and Jing (1994) reported the attitudes of pedestrians in Beijing, China, towards the sufficiency of crossing facilities and the willingness of pedestrians to use them. The study compared signalized intersection pedestrian crossings to overpass and underpass counterparts and concluded that users preferred the signalized crossings to the overpass or underpass crossings. The authors also reported that the pedestrian crossing compliances with pedestrian signal at two study locations were 70% and 57%. Rouphail (1984) performed a user compliance and preference study on marked midblock crosswalks in downtown Columbus, Ohio. The preference study indicated that users perceived the unsignalized marked midblock crosswalk to be unsafe. However, the same crosswalks were rated highest with respect to crossing convenience. Pedestrian crossing compliance rates at the signalized and unsignalized midblock crosswalks were 85.4%, and 86.4% with pedestrian sign (84.2% without pedestrian sign).

Similar crossing compliance studies were carried out in Europe. Pedestrian push buttons at signalized crosswalks are commonly used to regulate pedestrian crossing demand and to decrease conflicts between pedestrians crossing and vehicles passing through designated crosswalks; hence, to increase safety. Pedestrians are supposed to register their demand manually by activating the push-button when they wish to cross a street in a conflict-free phase; however, they frequently do not do so (Carsten et al., 1998). Davies (1992) observed pedestrian compliance with the push-button installed at signalized crosswalks in the UK and presented the results of his observations that more than half of the pedestrians did not activate the push button to cross. The compliance with the device was 49% in a small town, while in London the rate was 27%. In another location in Toulouse, push button compliance was as low as 18% (Levelt, 1992). Jacobs, Sayer, and Downing (1981) compared road user behavior at traffic signals, uncontrolled pedestrian crossings and priority junctions in a number of cities in developing countries with similar observations in Great Britain. The comparison indicated that fewer pedestrians chose to use the crossings in Third World cities and, on average, they took longer to cross, partly because they were delayed while crossing whereas such delays rarely occurred in Great Britain. Based on these observations it can be said that no two pedestrians at different settings display comparable behavior. Therefore, the phenomenon of pedestrian behavior at crosswalks and crossing compliance with crosswalk location and/or signal setting needs to be investigated with conditions of the environment in which pedestrians are observed as well as with considering pedestrians own characteristics such as age, sex, and socioeconomic situation.

Lam, Lee, and Cheung (2002) examined the relationship between walking speed and pedestrian flow under various flow conditions, and the effects of bi-directional pedestrian flow on signalized crosswalks in Hong Kong. Pedestrian flow measurements were conducted at selected signalized crosswalks in both shopping and commercial areas, and with and without light rail transit (LRT) railway tracks in the median of the carriageway. The bi-directional pedestrian flow effects on signalized crosswalk facilities with LRT tracks were found to be more significant than those without LRT tracks. The results suggested reviewing current transportation and design standards to ensure proper safety at crosswalks with high pedestrian demand.

Some studies collected pedestrian movement and perception data by direct observations of pedestrian behaviors by hidden or disclosed cameras and/or by user surveys or interviews. One of these researches studied elementary school children behaviors during their daily school trips as pedestrians. Routledge, Repetto-Wright, and Howarth (1974) compared data from interviews and direct observations of children aged 5–11 years during their trips from school to home. Comparison was made between children's reported exposure to traffic and observation of their journeys. The results indicated that children slightly under-reported their actual exposure and that there is a highly significant increase in exposure with age but no difference in exposure between boys and girls in the age range studied. Howarth, Routledge, and Repetto-Wright (1974) analyzed road accidents involving children when crossing different types of road. The analysis of measures of exposure obtained from interviews with children and from traffic counts on the roads children crossed showed that raw accident figures greatly underestimated the relative risk to children between the age of 5 and 7, that the greater number of accident to boys of this age is not due to their exposure to traffic, and that by the age of 8, boys are not more at risk than girls, even though boys have greater exposure to traffic.

Considering the studies described above, offering valuable information about pedestrian perceptions but focusing on one type of crossing at a time, this paper aimed at assessing pedestrian perceptions towards and pedestrian behaviors at commonly encountered crossing types in an urban area. These include signalized and unsignalized intersection crosswalks, unsignalized marked midblock crosswalks, and various crossing treatments in the same environment. The results presented herein are from the evaluation of pedestrian behaviors, perceptions and choices in a busy urban boulevard, which included signalized and unsignalized intersection crosswalks, and unsignalized marked midblock crosswalks, in the City of East Lansing, Michigan, USA. The city of East Lansing recently renovated a section of a major corridor, Grand River Avenue, in an effort to improve vehicular and pedestrian traffic flows, to increase pedestrian safety, and to enhance aesthetics in downtown East Lansing. These renovations created a perfect study site for the subject research. Following the renovations, Michigan State University, Department of Civil and Environmental Engineering evaluated the various pedestrian facilities through a research study (Sisiopiku & Akin, 1999) sponsored by the Michigan Department of Transportation.

2. Method

The main objective of this research is to analyze user behaviors, perceptions and preferences toward various pedestrian facilities, including signalized and unsignalized intersection crosswalks, unsignalized midblock crosswalks, physical barriers and crosswalk furniture. Crossing preferences and habits of pedestrians are analyzed to determine their crossing practices and to explain the reasoning behind their choices. Perception and preference information was obtained by surveying users of the study corridor. Reported survey results are based on the responses of 711 daily and occasionally users. Pedestrian crossing behaviors were observed and analyzed through video-camera records taken along the study site. Then, results of the two data sources were compared.

2.1. Study site

The site selected for the evaluation of pedestrian facilities was a 1-km long divided boulevard section of Grand River Avenue, extending from Abbott to Bogue Streets shown in Fig. 1 (highlighted on the map). Grand River Avenue is an east–west corridor at the north boundary of Michigan State University (MSU) campus and at the south boundary of the CBD of East Lansing. The average daily traffic on the study section was approximately 32,000 vehicles in 2000. The section was renovated from 1994 through 1995 to include midblock crosswalks, to deploy pedestrian "warning" signs (messaging "cross only when traffic clears") for pedestrians crossing at midblock crosswalks, to utilize physical barriers, and to mark and stripe designated midblock and intersection crosswalks in order to create effective crossing locations. The site meets the selection criteria for the study scope and purpose in terms of the availability of various alternative designs offered for pedestrian use in the same environment.

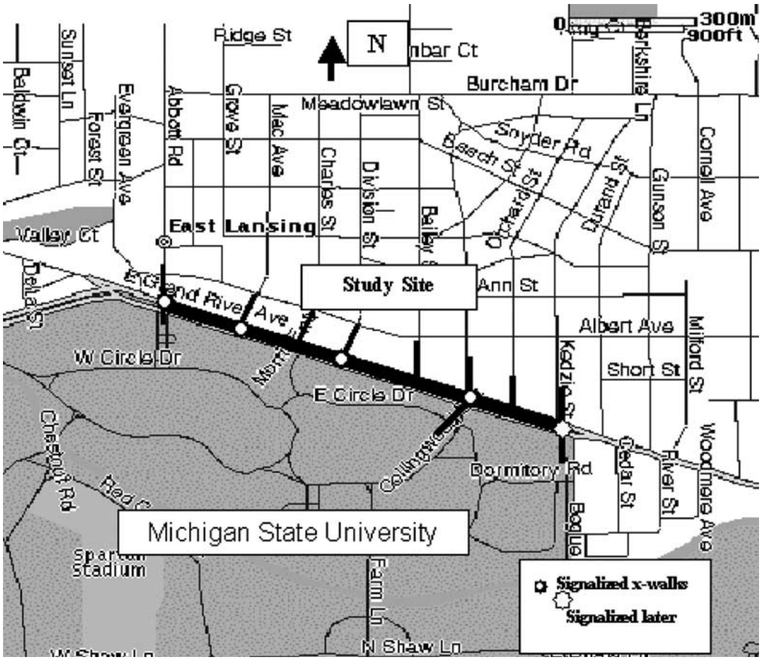


Fig. 1. Site map.

The schematic representations of the study sections are given in Fig. 2a and b. The study site included four signalized intersections, two of which were four-way (╬) intersections at Abbott and Collingwood Street and the other two were T (╨) intersections at M.A.C. and Division Street without the south leg. The four-way intersection at Collingwood Street had a crosswalk on each side, referenced as Collingwood-east and -west in Fig. 2b. Fixed time signal control for all road users was used at all intersections, without a pedestrian push-button device. In addition, there were two unsignalized T (╨) intersections, Charles and Orchard Streets, with a crosswalk on the east side of the intersection; four marked unsignalized midblock crosswalks, two of which have shelters at the median (Student Union, Jacobsons', Berkeley Hall and Bailey Street); and two non-striped midblock crosswalks (see Fig. 2b). Non-striped midblock crosswalks were marked at the median with colored brick pavement but had no stripes on the street and signs at the median. Also, the curbs and median at these locations are not designed for easy access of wheel chairs and bikes. Based on the existing traffic control, vehicles are assumed to have priority in taking the right-of-way over pedestrians, unless a red traffic light indication is on. As observed in the field, vehicles rarely yielded to pedestrians unless the light was red for vehicles at their traveling approach.

2.2. Design of survey questionnaires

Two important considerations were involved in the design of the user survey: (a) developing an effective as well as efficient survey instrument; and (b) selecting an appropriate study group.

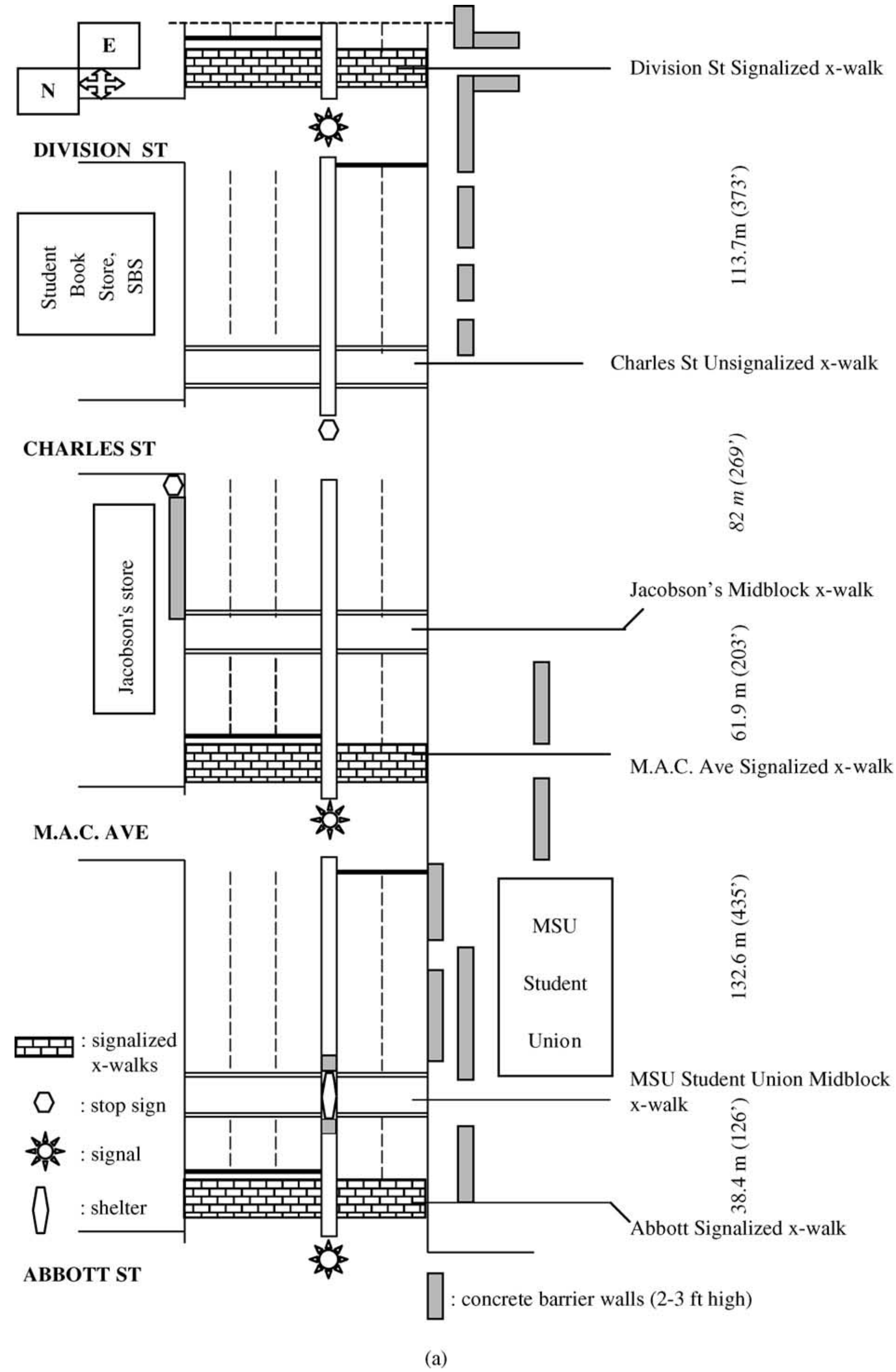
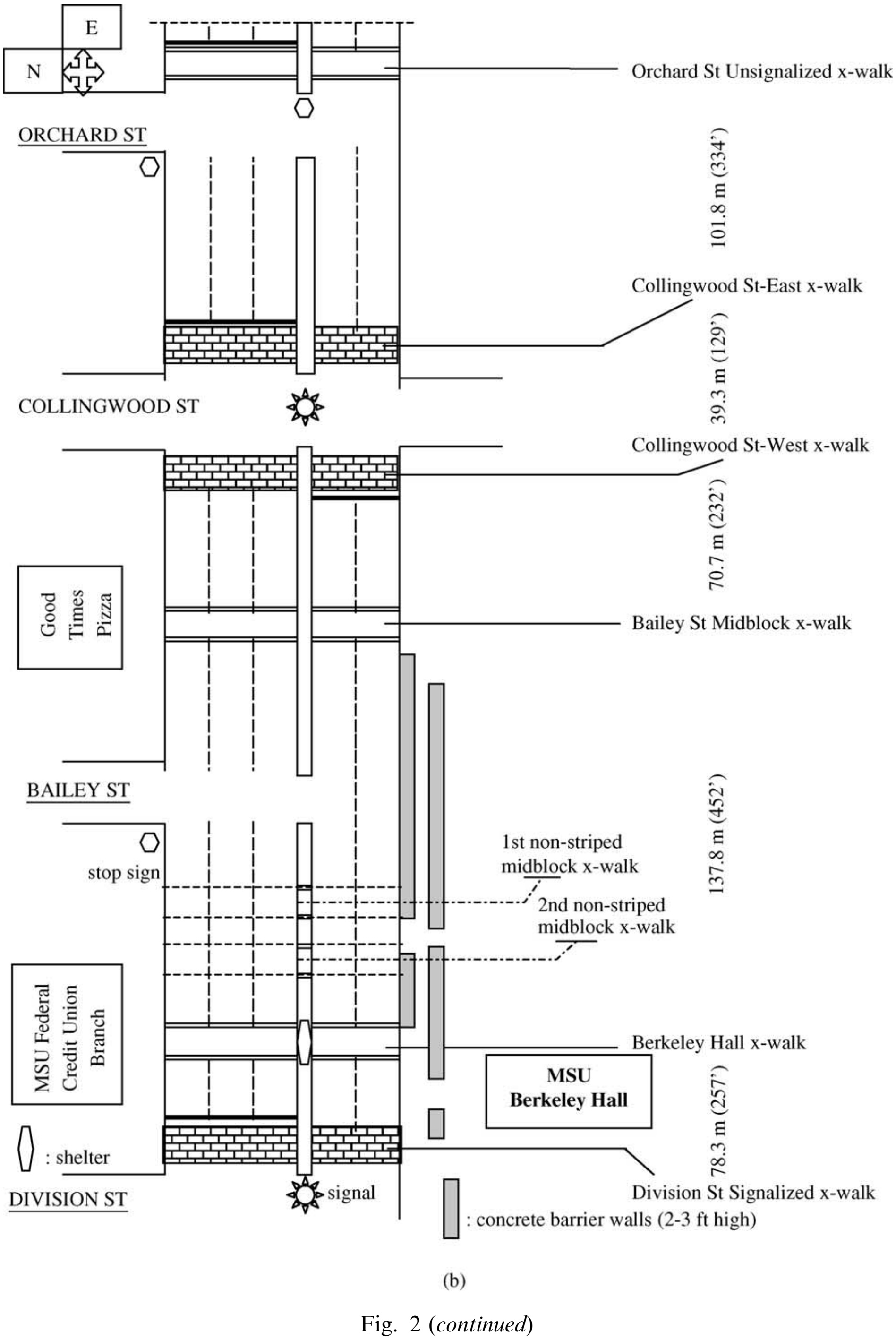


Fig. 2. A scheme of the study site: section 1 (a) and section 2 (b) (not to scale).



(b)

Fig. 2 (*continued*)

The development of the survey instrument met preset criteria such as inclusion of the statement of the study purpose and importance of the participation; clear definition of questions; reasonable length; lack of personal or potentially offensive questions; appropriate format for electronic distribution via e-mail; and appropriate format for data coding into computers.

The questions contained in the questionnaire covered the following areas of interest: (a) user profile (age group, gender, and frequency of use of the facility); (b) user crossing patterns (crossing location, conditions, compliance); (c) factors that affect pedestrian crossing choices (presence of certain types of control and user priorities), and (d) user perceptions with respect to right-of-way and safety.

The survey questionnaire was pre-tested to identify any unclear questions. The survey form included the total of eight questions with several of them soliciting more than one answer (see Fig. 3). During the in vivo interviews it was observed that the questionnaire did not took more than approximately 2–3 min to complete. The selection of the study group took under consideration various criteria including familiarity with the study site, potential use of the site for pedestrian trips, reasonable mix of socioeconomic characteristics (such as age, sex, race, income), and willingness to participate.

2.3. Design of user behavior study

Pedestrian movement data are used to analyze pedestrian crossing compliance behavior at the study crosswalks. Crossing compliance is defined as the percent of pedestrians who crossed the road in compliance with the location of a crosswalk and with the WALK signal indication. In general, the crossing compliance rate (percent) is expressed as the number of pedestrians crossing at a crosswalk area (CA) divided by the number of pedestrians in the "crosswalk influence area (CIA)" in a period of time, usually an hour.

2.3.1. Crosswalk influence area and crosswalk area

The calculation of crossing compliance rates (CCRs) is based on the assumption that each crosswalk has an influence area in which it attracted pedestrians crossing the street. In order to determine the CIA for each crosswalk, the distance between a pair of two consecutive crosswalks is divided into two equal lengths by imaginary lines. As a result, each crosswalk is located between the two consecutive dividing lines serving as the boundaries of the CIA. The area between the lines is the so-called CIA. Fig. 4 demonstrates an example of CIA and CA definitions for crosswalk i. The distances between the three consecutive crosswalks $i-1$, i and $i+1$ are L_{i-1} and L_{i+1}. Then, the (CIA_i) for the crosswalk i is the product of the sum of $L_{i-1}/2$ and $L_{i+1}/2$, and the street width (W) from curb to curb.

2.3.2. Full and partial jaywalkers

Pedestrians complying with the crossing location are those that cross within approximately 3.0 m (10 ft) from both sides of the crosswalk. Jaywalkers are the ones who do not comply with the crosswalk location. In other words, jaywalkers do not walk in the CA at all while crossing the street. On the other hand, partial jaywalkers are those whose crossing paths are partially in the CA. In Fig. 5 pedestrians 1 and 2 are compliers with the CA, but pedestrian 3 is a jaywalker with respect to the crosswalk location (Akin, 2000; Akin & Sisiopiku, 2000).

1. How often do you cross on Grand River Ave between Abbot and Bogue St. on foot? (Please mark your answer by X).
____ 1. Daily ____ 2. Occasionally ____ 3. Almost never

2. Where do you typically cross on Grand River Ave?
____ 1- on designated signalized crosswalks
____ 2- on designated midblock or unsignalized crosswalks
____ 3- at any convenient location

3. When do you typically cross on Grand River Ave?
____ 1- only when pedestrian traffic light is green
____ 2- when traffic clears completely
____ 3- whenever I feel that I can cross with little interference with automobile traffic

4. How often do you cross at a non-designated crosswalk?
____ 1- never ____ 2- rarely ____ 3- sometimes ____ 4- often ____ 5- almost always

5. If you choose to cross at a non-designated crossing location, what is the main reason?
____ 1- convenience ____ 2- to save time ____ 3- traffic is light, there is no risk

6. In you opinion, when should vehicles yield to pedestrians?
____ 1- always ____ 2- at designated crosswalks ____ 3- never, vehicles should have priority

7. Are the following statements true for Grand River Ave.?
_1_ _2
Y__ N__ a- motorists typically yield to pedestrians at designated crosswalks
Y__ N__ b- left-turning vehicles typically yield to pedestrians during pedestrian green
Y__ N__ c- pedestrians typically cross at designated locations
Y__ N__ d- bicycles do not pose a safety risk to pedestrians at designated crosswalks

8. Do the following influence your decision to cross at a certain location?
_1_ _2
Y__ N__ 1- existence of pedestrian signal
Y__ N__ 2- presence of a midblock crosswalk
Y__ N__ 3- red color brick pavement
Y__ N__ 4- shelter over a midblock crosswalk
Y__ N__ 5- "cross only when traffic clears" sign
Y__ N__ 6- presence of other pedestrians that attempt to cross
Y__ N__ 7- distance to the desired location
Y__ N__ 8- vegetation or barriers on median

9. How often are you willing to divert from your path in order to cross at a designated crosswalk?
____ 1- always ____ 2- often ____ 3- sometimes ____ 4- rarely ____ 5- never

10. What is your age group?
____ 1- less than 21 yrs ____ 2- 22-55 yrs ____ 3-over 55 yrs

11. What is your gender?
____ 1- male _____ 2- female

12. Do you perceive Grand River Ave between Abbott and Bogue St as a safe corridor for pedestrians?
____ 1- Yes ____ 2- No

13. If your answer in Q. 12 is No, what is the major problem from your point of view?

Fig. 3. Grand River Avenue pedestrian user survey.

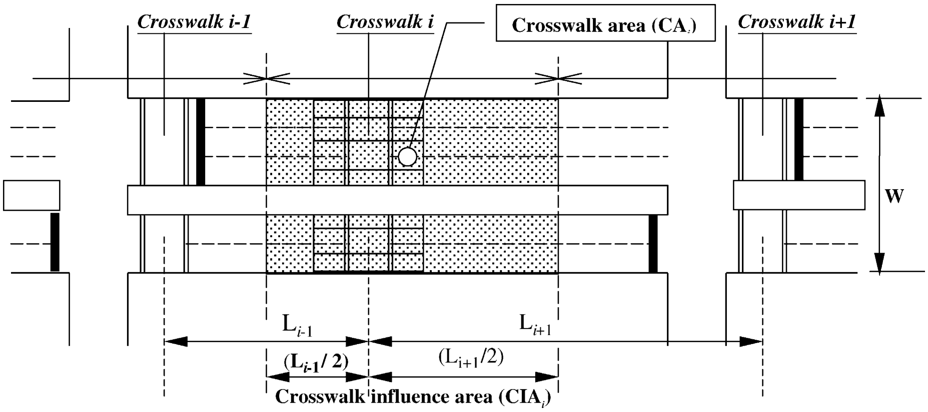


Fig. 4. Definitions of CIA and CA for crosswalk *i*.

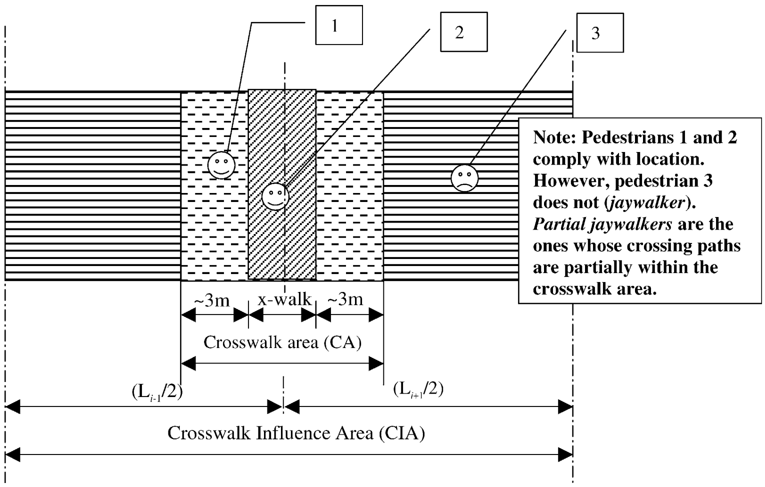


Fig. 5. Definitions of full- and partial-jaywalkers and CA for the calculation of pedestrian crossing compliance.

2.4. Pedestrian crossing compliance rates

The pedestrian crossing compliance rate (PCCR) is defined as *spatial and temporal* crossing compliance rates.

2.4.1. Spatial crossing compliance rate

Spatial compliance refers to crossing compliance of pedestrians with respect to the crossing location or "CA," and spatial crossing compliance rate (SCCR) discloses information on how pedestrians use crosswalks in regarding to the location

$$\mathrm{SCCR}_i = \frac{P_i^L}{P_i^{\mathrm{CIA}}} \tag{1}$$

where SCCR_i = spatial crossing compliance rate at crosswalk i (percent); P_i^L = number of pedestrians crossing within the CA, (ped/hr); and P_i^{CIA} = total number of pedestrians in the CIA of crosswalk i (ped/hr).

2.4.2. Temporal crossing compliance rate

At signalized crosswalks, pedestrian crossing compliance can also be linked to the compliance with the pedestrian WALK signal indication. Thus, TCCR_i is defined as the ratio of the number of the pedestrians (per hour) in the CA who comply with the pedestrian WALK signal indication, P_i^T over the total number of the pedestrians within the CA, P_i^{CA}

$$\mathrm{TCCR}_i = \frac{P_i^T}{P_i^{\mathrm{CA}}} \tag{2}$$

The reason that the denominator in Eq. (2) is different from the one in Eq. (1) is because it is not very meaningful to cite temporal crossing compliance when pedestrians do not comply with the crossing location at all. In other words, spatial compliance is the required condition for temporal compliance. For pedestrians who cross in violation of the crosswalk location, it is irrelevant whether the signal is green or red. Therefore, in determining the TCCR, pedestrians only in the CA are considered.

2.5. Data collection

2.5.1. Survey data collection

The selected study group consisted primarily of undergraduate and graduate students, staff and faculty at Michigan State University (MSU), who composed the majority of pedestrian population using the facility as MSU is just located next to the study site. First, in vivo surveys were conducted by the survey staff who were instructed to randomly approach pedestrians at the study site. Fiftytwo pedestrians were approached and asked for their assistance in completing the survey, 22 out of which agreed to participate. Though the rate in complying to participate the survey was good (42.3%), this data collection approach was found to be time consuming and costly. Thus a decision was made to distribute the survey instrument electronically instead. The survey was distributed to e-mail addresses of the MSU affiliates selected randomly via the MSU computer network. The selection was made by assigning a serial number to each and every one of the e-mail addresses in the computer network (50,000 total). Then 5000 e-mail addresses were selected for survey distribution using a random number generator. The return rate was 17.9%. Given that the typical return rate of mail-in-surveys reported in the literature is between 5% and 30%, the return rate of the subject survey was deemed acceptable. In total, 897 completed questionnaires were received and reviewed.

2.5.2. Movement data collection

Pedestrian crossing activities were studied through the analysis of the field data collected by a direct observation of pedestrian activities using eight video cameras set up at locations on the sidewalks along the study site. The cameras were placed consecutively (four cameras at each side of the study corridor) in such a way that their fields of view were slightly overlapping. This configuration allowed for all pedestrian movements in the study subsection to be captured. Each videotaping session lasted 30 min. Then the cameras were moved to capture the activity of another subsection. Overall, the system of the eight cameras had to be repositioned eight times in order to collect 30-min data for the entire study site. This required a minimum of 2 h of work in the field for filming alone, without considering the time involving to start-up and to move the equipment from place to place, and to set it up properly. As a result of this process, for each data collection session 16–18 h of video images were obtained.

In order to avoid very low pedestrian demand times, surveys were carried out when minimum pedestrian volume of about 40–50 ped/h was expected to be present at the major intersection crosswalks. Pedestrian movements were observed and recorded during the noon-peak (10:30–1:00 pm) and the PM-peak periods (2:30–6:00 pm). Movement data were collected mostly during weekdays. Weekend data collection was limited to Saturdays since some stores in downtown East Lansing are not open on Sundays. Data collection was performed during the months that the Michigan State University was in session (Spring and Fall, 1998). Only two data collection sessions fell in late May in order to recover bad video images from previous data collections. Moreover, football home-game weekends and major holidays were excluded. Data collection was performed under various weather conditions (sunny, cloudy, snow sprinklers, cold, warm, and hot). No data were collected in rainy days in order to protect the video recording equipment from electrical damages that might occur due to rain. Eight video cameras were simultaneously used to record pedestrian movements in the site. Video cameras were consecutively located on both sides of Grand River Avenue on the sidewalks along the study section in order to cover all possible pedestrian movements within the entire study area. The recording areas of consecutive cameras were overlapped slightly to ensure that all pedestrians in the study section were captured.

2.6. Data reduction

2.6.1. Survey data reduction

Returned questionnaires were first screened to assess their completeness and ensure their uniqueness. During this process, duplicate copies and forms with several unanswered critical questions were eliminated. Eligible questionnaires were assigned a serial number. That allowed for future tracking of the surveys to check for coding errors if any suspicious or unusual code were encountered. After eliminating duplicate and incomplete survey forms, a total of 871 questionnaires remained. A decision was made to analyze responses from daily and occasional users only. Another 166 questionnaires were excluded from the study because they expressed opinions of non-users and, thus, could introduce some bias to the results. In total 711 questionnaires were used in the analysis. The sample size was deemed adequate to provide a fairly accurate picture of the users' crossing habits, observations and perceptions toward the pedestrian facilities in the study site.

SPSS statistical software was used to create a file containing the responses from each questionnaire. This package has the capability to perform statistical analysis as well as produce graphs and data summaries. Each survey form was coded to a single raw and a serial number was assigned in the first column as tracking ID. There were 22 fields per questionnaire and about one (1) min was required to complete a typical data entry for each form.

2.6.2. Movement data reduction

Data reduction offered information about pedestrian crossing volumes, crossing locations, crossing behaviors and pedestrian to vehicle conflicts. Using the data obtained from the videotape reduction, values of the degree of pedestrian compliance were calculated for various types of crosswalks based on pedestrian activity in the area of influence of each crosswalk. The degree of pedestrian compliance was defined as the number of pedestrians crossing at a crosswalk location over the total number of pedestrians crossing in the area of influence of the subject crosswalk.

Special efforts were made to avoid double counting of pedestrians that started to cross within the field of view of one camera and completed the crossing within the field of the following camera(s). In some cases, two VCR/TV sets were used to resolve double counting. While watching each tape separately, a record was kept of the time when each and every pedestrian appeared on the screen and significant characteristics of him/her (e.g., wearing red T-shirt or blue jacket, etc.). Using such information, pedestrians that appeared in more than one tape in the CIA were not counted more than once. Though this type of data reduction process was a tedious and labor-intensive task, it was very beneficial as it allowed detecting every pedestrian movement in the entire study site during the data collection sessions. Not only the information on pedestrian volume and crossing locations became available but also additional data about conditions during crossing (such as pedestrian signal indication, the presence of other pedestrians and motor

GD RIVER AVE (M-43) PEDESTRIAN CROSSWALKS (ABBOTT - BOGUE STS)

Date: 2/23/98, Monday, 35 °F, cold, partly sunny **Time:** 2:46pm

1- Abbott St. Signalized Intersection Crosswalk

Pedestrian counts-30 min	On-crosswalk	Partial Jaywalkers	Jaywalkers around CA	Total
RU + PS (VS)	47	2	0	**49**
PS (VR)	14	1	0	**15**
S	32	2	2	**36**
LS	9	1	0	**10**
Total 102		**6**	**2**	**110**

RU: Regular users **S: Sneakers**

PS (VS): Partial sneakers (vehicles stopped) **LS: Late starters**

PS (VR): Partial sneakers (vehicles running)

Jaywalkers from west side of the crosswalk = 5 peds in 30 min

Jaywalkers from east side of the crosswalk = 3 peds in 30 min

Total pedestrians in the Crosswalk Area = 102 + 6 = 108 peds in 30 min

Total pedestrians in the Crosswalk Influence Area = 110 + 5 + 3=118 peds in 30min

Vehicular Volume (VV) = 2427 veh/hr, L_{CIA} = 38.4 m (126.0 ft)

$$\text{Overall Crossing Compliance Rate} = \frac{\textit{No of RUs + no PS(VS)s on-crosswalk}}{\textit{Total peds in the crosswalk influence area}} = \frac{47}{118} = 39.8\%$$

Total Pedestrian Volume in the Crosswalk Area = 108 * 2 = 216 peds / hr

Total Pedestrian Volume in the Crosswalk Influence Area = 118 * 2 = 236 peds / hr

Spatial Compliance Rate =102 / 118 = 86.4%, Violation of flashing red signal = 10/108=9.3%
Temporal Compliance Rate= 49/108 = 45.4%.

Fig. 6. Data summary sheet for signalized crosswalks.

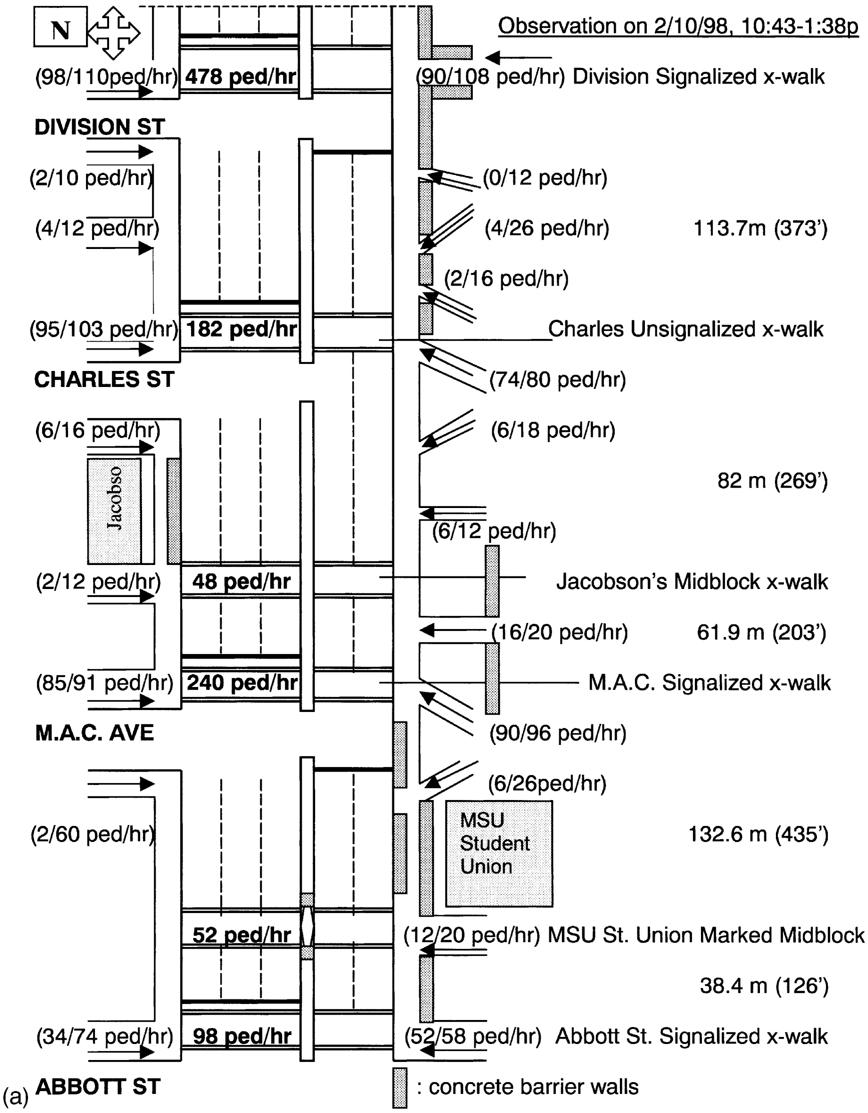


Fig. 7(a). A snapshot of volumes in the crosswalks and paths in Sections 1 (the first number in the parentheses shows the number of pedestrians crossed the street and the second number represents the total number of pedestrians that came through the path).

vehicles, etc.) were obtained through a careful processing of the videotapes in the lab. The following types of data were recorded for the analysis of pedestrian movements: number of pedestrians who started crossing the street during pedestrian WALK signal (regular users); partial jaywalkers; jaywalkers; number of pedestrians crossing in the CA during pedestrian DON'T WALK signal (sneakers); number of pedestrians who crossed a first portion of the crosswalk during DON'T WALK signal and then continued crossing during the WALK signal (partial

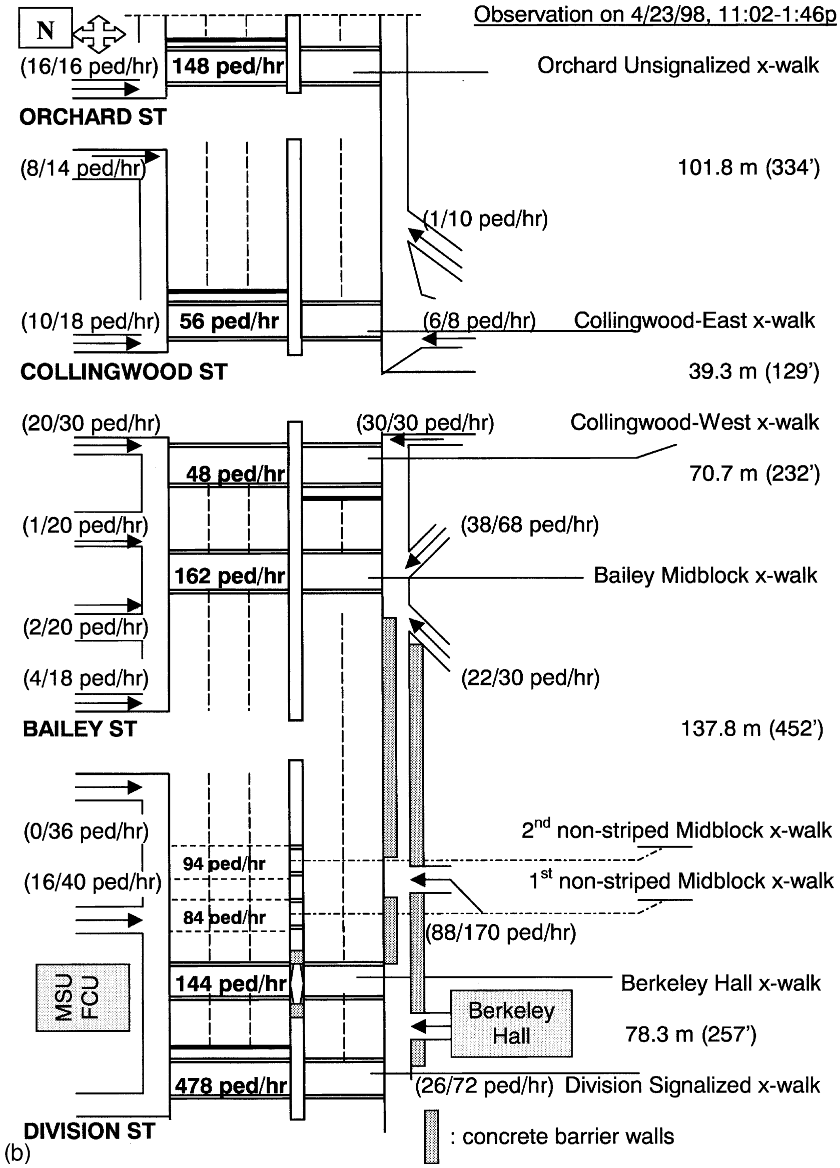


Fig. 7(b). A snapshot of volumes in the crosswalks and paths in Section 2 (the first number in the parentheses shows the number of pedestrians crossed the street and the second number represents the total number of pedestrians came through the path).

sneakers); number of pedestrians who crossed from a curb to the median during the "flashing" DON'T WALK signal (late starters); and the total number of pedestrians within the CA and CIA. Data summary forms were developed to report summarized data and to calculate the PCCRs. An example of such a data reduction form is given in Fig. 6 and summary pedestrian counts are shown in Fig. 7a,b.

3. Results

3.1. Descriptive of survey respondents

Out of the 711 pedestrians studied, 254 (36%) crossed the street daily and the rest (457 pedestrians, or 64%) were classified as occasional users; i.e., they crossed the street a couple of days a week. The percentage of respondents 21 years or younger was 32.7%, between 21 and 55 years of age was 61.6%, and the remaining 5.7% was over 55 years of age. The fairly normal distribution of age data of the survey respondents is an indication of a representative and properly diverse sample population. Given the fact that the study population primarily belongs to a university community, age distribution may be closely related to other socioeconomic factors such as occupation, income and sex.

3.2. Pedestrian crossing patterns and crossing compliance

Characteristics of a location where pedestrians prefer to cross a road, conditions under which pedestrians decide to cross and pedestrian crossing compliance with traffic control are extremely important factors both from the safety and operational perspectives under the assumption that pedestrians have always more than one alternative to choose for their crossing activity. As Table 1 shows a majority of pedestrians surveyed typically cross at designated locations (23% at signalized crosswalks, 31% at unsignalized and midblock crosswalks, and 5% at crosswalks of any type). The remaining 41% cross at any convenient location. This means that the crossing compliance rate with respect to the crosswalks location is 59%, based upon the user survey data.

Table 2 shows that the average of the spatial crossing compliance rates (SCCRs) calculated using Eq. (1) at the crosswalks throughout the study site is 71.4%. This means that approximately 71% of the observed pedestrians used the crosswalks at the study section to cross the Grand River Avenue. Comparing the pedestrian crossing compliance rates based on the two different data sources, the spatial compliance rate from the survey data (58.7%) is 17.8% less than the calculated SCCRs (71.4%).

Table 3 depicts typical crossing conditions for the respondents who chose to cross at signalized crosswalks. Fortyfive percent of the respondents (166 pedestrians) admitted to cross when they

Table 1
Crossing locations of pedestrians—survey respondents

Location	Frequency	Percent	Valid percent
Signalized intersection x-walks	166	23.3	23.4
Midblock or unsignalized intersection x-walks	217	30.5	30.6
Any type of crosswalk	35	4.9	4.9
Subtotal-pedestrians complied		(58.7)	(58.9)
Any convenient location	290	40.8	41.0
Missing	3	0.4	–
Total	711	100	100

Table 2
Pedestrian spatial crossing compliance rates (SCCRs)—movement data

Location	Number of observations	Mean (%)	SD
Signalized intersection x-walks	36	82.8	8.321
Midblock x-walks	28	71.2	11.062
Unsignalized intersection x-walks	14	67.5	6.348
Non-striped midblock x-walk	12	64.2	3.487
Average		71.4	

Table 3
Crossing conditions of the pedestrians at signalized crosswalks—survey respondents

Condition	Frequency	Valid percent
When pedestrian light is green	16	9.6
When traffic clears completely	75	45.2
When an acceptable gap occurs	75	45.2
Total	166	100.0

perceived an acceptable gap in the vehicle traffic stream. On the other hand, 45% said they crossed only when all traffic completely cleared, and an approximately 10% was willing to wait for a green pedestrian light indication in order to cross. According to these figures, the crossing compliance rate with respect to the pedestrian signal can be calculated as

$$\mathrm{TCCR}_{\mathrm{survey}-1} = 45 + 10 = 55\%$$

The reason that the percentage of pedestrians who crossed the street when all traffic cleared is included in this calculation is due to the fact that pedestrian signal design allowed pedestrians to cross half of the signalized crosswalks during "pedestrian red" signal since the westbound traffic on Grand River Avenue is stopped for eastbound vehicles turning left onto cross streets.

Table 4 gives the averages of the temporal crossing compliance rates (TCCRs) calculated using Eq. (2) at the signalized intersection crosswalks. Comparing the pedestrian crossing compliance rates based on the two different data sources, the temporal compliance rate based on the survey data (55%) is only 8.1% higher than the observed rate (50.9%).

Pedestrians were also asked about the frequency of crossing at non-designated crossing locations. Table 5 summarizes the responses that were obtained. 29.6% of the users replied that they rarely (or never) cross at a non-designated crossing point. Approximately a quarter of the respondents said that they often or almost always jaywalk. 45.7% of the respondents appeared not having a predetermined crossing preference on the use of designated facilities in order to cross. The temporal crossing compliance based on the frequency numbers from Table 5 can be calculated as

$$\mathrm{TCCR}_{\mathrm{survey}-2} = 5.8 + 23.8 + (45.7/2) = 52.5\%$$

The rate of 52.5% is only 4.5% less than the temporal compliance rate calculated from Table 3 (55%). Therefore, it can be said that the compliance rates based on the survey data are very comparable. This shows a very good consistency inside the survey data and increases the

Table 4
Temporal crossing compliance rates (TCCRs)—movement data

Location	Number of observations	Mean (%)	SD
Abbott Street	8	43.4	9.020
MAC Avenue	8	46.8	9.432
Division Street	8	57.6	7.999
Collingwood-west	6	52.1	8.214
Collingwood-west	6	54.5	15.338
Average		50.9	

Table 5
Frequency of crossing at non-designated crossing locations—survey respondents

Frequency of crossing	Frequency	Valid percent
Never	41	5.8
Rarely	169	23.8
Sometimes	325	45.7
Often	146	20.5
Almost always	30	4.2
Total	711	100.0

reliability of the survey results. The results in Table 5 are also in reasonable agreement with the responses regarding preferred crossing locations presented above and the users' willingness to divert from their path in order to cross at a designated location. Thirtyeight percent of the users replied that they are willing to divert, 20% refused to do so, and 42% said that they would sometimes divert from their path in order to use a crosswalk. Based on these data, spatial crossing compliance rate can be calculated as

$$\mathrm{SCCR}_{\mathrm{survey}} = 38 + (42/2) = 59\%$$

It should be noted that the compliance rate calculated just above (59%) is almost exactly equal to the spatial compliance rate estimated based on Table 1 (58.7%). Again, this agreement between the compliance rates based on the survey data strengthens the reliability of the perception data.

It is also interesting to note that occasional users appear to be more conservative in their crossing choices. For example, only 18% of occasional users admit to cross frequently at non-designated locations, compared to 34% of daily users. This leads to the conclusion that when pedestrian facilities are designed for primary use by commuters more intensive efforts should be made in order to discourage pedestrians from crossing at non-designated locations. Such behavior may pose a risk for the personal safety of pedestrians and create undesirable disruptions of traffic flow.

3.3. Assessment of factors that affect pedestrian crossing choices

Pedestrians were asked to state the main reason based on which they make a decision to cross at a non-designated crosswalk location. The answers to this question were indented to assess users'

Table 6
Main reason to cross at a non-designated crossing location—survey respondents

Reason	Frequency	Percent	Valid percent
Convenience	281	39.5	41.8
To save time	184	25.9	27.4
Light traffic; no risk	204	28.7	30.4
Other	3	0.4	0.4
Missing cases	39	5.5	–
Total	711	100.0	100.0

priorities during their crossing activities. Convenience is the number one priority sited by users (42%) while time-savings were of major importance to 27% of the respondents. Interestingly enough, 30% responded that they do not perceive any major risk crossing the facility at any convenient location since traffic is light enough to allow for safe crossing. These results are summarized in Table 6.

The effect of the presence of certain types of control on the decision of pedestrians to use pedestrian facilities properly (or not) is of major importance to traffic engineers designing such facilities. Thus, the subjects were asked a series of yes-or-no questions about treatments that influence their decision to cross at a certain location. Such treatments included existence of pedestrian signal, presence of midblock crosswalk, red color brick pavement or shelter on the median at midblock crosswalk locations, vegetation or barriers on the median, and the location of the crosswalk relative to the desired destination. The results indicate that the distance of the crosswalk to the desired destination is a major crossing choice determinant for the vast majority of pedestrians surveyed (90% of total). Therefore, city planners and traffic engineers should place the crosswalks as close as possible to major pedestrian paths. Fig. 4a and b shows volumes on the pedestrian paths observed on February 10, 1998, between 10:43–1:38 pm and April 23, 1998, between 11:02–1:46 pm. It can be easily seen that major pedestrians paths are always leaded to pedestrian crosswalks. The first number on the paths represents the number of pedestrians that crossed the street with or without using the crosswalks, and the second one indicates the total pedestrian volume on the pedestrian paths.

Grand River users appreciated the midblock crosswalks and 83% of the survey respondents said that the presence of a midblock crosswalk affected their decision cross at a specific location. The same is true with the presence of a pedestrian traffic light for 74% of the survey respondents. Comparing these numbers with the spatial compliance rates based on the movement data in Table 2 for midblock (71.2%) and signalized intersection crosswalks (82.8%), it is seen that survey results are 16.6% higher and 10.6% lower than the calculated compliance rates.

Vegetation and barriers influenced the decision to cross of a significant number of pedestrians surveyed (65%). On the other hand, respondents had mixed opinions about shelters and red brick paving. Only 34% replied that shelters positioned in the median influenced their decision to cross at the designated location and 41% favored colored paving. It is interestingly to note that the crossing rate (42.3% = 104 out of 246 pedestrians crossed the street at the location; for details see Fig. 4b; [(16 + 88 = 104)/(36 + 40 + 170 = 246)] at the non-striped crosswalks is only 2.4% higher than the percent of people (41.3%) favoring color paving. This agreement between the observed pedestrian volume and the preference data increases the reliability of the user survey.

Table 7
Effect of age and gender on survey responses

Most influential factors	Age group			Gender		
	Chi-square	Significance level	Comment (95% CL)[a]	Chi-square	Significance level	Comment (95% CL)[a]
Distance to destination	10.780	0.005	$0.005 < 0.05$ differences statistically significant	0.892	0.345	$0.345 > 0.05$ differences statistically not significant
Midblock crosswalk presence	4.550	0.103	$0.103 > 0.05$ differences statistically not significant	0.433	0.510	$0.510 > 0.05$ differences statistically not significant
Pedestrian signal presence	1.223	0.542	$0.542 > 0.05$ differences statistically not significant	1.799	0.180	$0.180 > 0.05$ differences statistically not significant

[a] Confidence level.

3.3.1. Gender and age factors

Statistical tests were performed to study if there is any significant difference between responses obtained from responders in different age groups or gender classification. The results from the analysis are summarized in Table 7. In summary, it was found that differences in the responses obtained by age classification and gender are not statistically significant at the 95% confidence level. Thus the use of aggregated results appears to be appropriate. The only exception occurred to the question about the effect of the distance to the desired location on the decision of an individual to cross. 92% and 90% of respondents in the age group below 21 and between 21 and 55 years of age responded positively, while 74% of elderly gave a positive response to this question. The analysis indicated that the response of elderly pedestrians to this question was statistically different from the other two study groups at the 95th confidence level (significance level $0.005 < 0.05$).

3.4. Users' perceptions with respect to right-of-way and safety

A number of questions were asked in order to assess the perceived level of safety and users opinions regarding right-of-way. It was found that a 45% of pedestrians using the study site believe that drivers typically yield to pedestrians in designated locations, especially at midblock crossings when stopped queues could otherwise occupy the crosswalk. It should be noted that, except from the pavement markings, motorists do not see any positive type of control indicating that pedestrians should be offered priority.

When asked, "when should motorists yield to pedestrians", the majority (61%) of respondents answered that this should happen only at designated crosswalks. Thirtyone percent felt that pedestrians should always have priority over motorized traffic, and 7% responded that vehicles should always receive the right-of-way. Pedestrian replies show that the majority of users understand the purpose of streets with mixed traffic and are willing to compromise in order to help create a fair and safe travel environment for all users.

With respect to turning vehicular traffic, half of the respondents complained that turning vehicles do not respect pedestrians that attempt to cross at signalized intersections during green. This has been, also, verified by field observations. In most cases pedestrians and right- or left-turning vehicles share the same green phase with pedestrians. This situation is sited as a reason for pedestrians choosing to cross the road at locations other than signalized intersection crosswalks during green. This is an important finding that demonstrates the important role of proper signal timing settings toward the improvement of safety and efficiency.

Moreover, only 35% of the users replied that a pedestrian sign displaying the message "Cross only when traffic clears" made a difference in their decision to cross. Analysis of respondents' comments further indicates that this sign often confused or frustrated pedestrians that have selected to cross at a designated crosswalk under the impression that they have the right-of-way.

As pedestrians often compete with bicycles for the same space, the subjects were also asked to provide their input regarding safety issues that may result from this type of interaction. Fiftynine percent of the users were not concerned with the interaction between pedestrians and bicycles and did not perceive bicycles as a safety risk factor to pedestrians that cross at designated locations.

Finally, over two thirds of the respondents (68%) agreed that the study site is a safe corridor for pedestrians to use. This response is a sign of approval of the facility for pedestrian use and an indication that pedestrians appreciated the recent improvements along the study corridor and enjoy using it for pedestrian trips.

4. Conclusions

This research studied pedestrians' perceptions toward the operation of various pedestrian treatments such as signalized and unsignalized intersection crosswalks, marked and non-striped midblock crosswalks, use of physical barriers, shelters and colored paving at medians, and pedestrian warning signs. Information was obtained through surveying users and observing pedestrian movements at a study site in East Lansing, Michigan. All the aforementioned facilities and crossing treatments were present at the study site. The following conclusions are drawn based upon the results:

(a) The results from the survey analysis support the notion that properly designed and placed pedestrian facilities encourage users to cross at a certain location. Midblock crosswalk is found to be the most influential pedestrian facility. This finding is also supported by actual movement data analysis.
(b) Signalized intersections with crosswalks help channelize pedestrian traffic; however, prove to be unable to persuade pedestrians to comply with the signal indication, particularly under low traffic demand conditions.
(c) The most influential factor sited by pedestrians in making a decision to cross at a designated crossing location is the distance of the crosswalk to desired destinations of pedestrians. Also, added convenience was rated as the number one factor for jaywalking. These results indicate that proper selection of the position of a crosswalk with respect to adjacent land use that

generate or attract pedestrian traffic has the potential to improve the rate of pedestrian compliance significantly.
(d) Pedestrians disapprove of the use of warning pedestrian signs at midblock locations. Although such signs may not be popular among pedestrians they often have a safety value while used as means of positive enforcement. Additional crash and conflict analysis is recommended to assess clearly the value of these signs and provide warrants for their use.
(e) The vast majority of turning vehicles fail to give priority to pedestrians during the pedestrian green phase. This increases the chance that pedestrians will not select to cross at signalized crosswalks during green, if they have a crossing alternative that reduces their delays and provides safer crossing conditions. To improve the situation, leading pedestrian intervals may need to be considered when significant turning vehicular and/or pedestrian crossing volumes exist. Leading pedestrian intervals are expected to assist in reducing the number of conflicting movements with a potential to improve safety as well as pedestrian crossing compliance. Significant enhancement of pedestrian traffic flow may be possible through signal coordination (Virkler, 1998). Careful design of signal phasing plans and proper installation of signs can greatly help to improve travel conditions for pedestrians and turning motorists alike. Furthermore, it is recommended that additional surveys be conducted to examine differences between drivers and pedestrians regarding right of way at intersections.
(f) It should be noted that although user preferences are important, they may not correlate highly with safety considerations. It is recommended that additional analysis be performed to examine the relationship between safety and pedestrian acceptance in future research.

Several conclusions can be drawn from the comparison of survey and movement analysis results.

(a) First, there is a relatively good agreement between the responses of users and their actual behavior in terms of their crossing choices. This observation is very encouraging because it shows that the survey analysis results can be trusted and that respondents, in general, answered the questions honestly and in good faith.
(b) Second, both survey and movement data indicated that midblock crosswalks are more effective in accomplishing their design purpose compared to signalized crosswalks. Signalized crosswalks, on the other hand, appear the most efficient facilities for pedestrian channelization. However, a large number of pedestrians who select to cross at signalized crosswalks tend to disobey the pedestrian signal indication in an effort to decrease their delay.
(c) Finally, with respect to the distance between the crosswalk location and the desired destination, it is clear that traffic engineers should pay extra attention to land uses that may generate increased needs for pedestrian movement and consider these needs when making decisions on placement of pedestrian crosswalks at certain locations.

The findings from this study are expected to help traffic engineers and planners understand pedestrian behaviors and attitudes at/towards pedestrian crosswalks. Thereby policy makers and advocates interested in promoting walkable communities can support researchers to provide the foundation for future research towards the development of guidelines for pedestrian control at corridors with major pedestrian crossing volumes.

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