Technical Report Documentation Page

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| FHWA/TX-04/0-4286-3 | | |

| 4. Title and Subtitle | 5. Report Date |
|---|---|
| OPERATIONS AND SAFETY AROUND SCHOOLS: OVERVIEW OF PROJECT ACTIVITIES AND FINDINGS | January 2004 |
| | 6. Performing Organization Code |
| 7. Author(s)<br>Scott A. Cooner, Mark D. Wooldridge, Kay Fitzpatrick, Jason A. Crawford, and Garry L. Ford | 8. Performing Organization Report No.<br>Report 0-4286-3 |
| 9. Performing Organization Name and Address<br>Texas Transportation Institute<br>The Texas A&M University System<br>College Station, Texas 77843-3135 | 10. Work Unit No. (TRAIS)<br><br>11. Contract or Grant No.<br>Project No. 0-4286 |
| 12. Sponsoring Agency Name and Address<br>Texas Department of Transportation<br>Research and Technology Implementation Office<br>P. O. Box 5080<br>Austin, Texas 78763-5080 | 13. Type of Report and Period Covered<br>Research:<br>September 2002 - August 2003<br><br>14. Sponsoring Agency Code |

15. Supplementary Notes

Research performed in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.
Research Project Title: Operational and Safety Guidelines for Roadway Facilities around Schools

16. Abstract

The state of Texas, particularly the large urban areas, has experienced considerable population growth in recent years. This growth has produced new schools in areas near highways originally designed for low volumes and relatively high speeds. Another trend is the higher proportion of children being transported to and from schools in private vehicles. These realities, and many of the other issues associated with traffic around schools, make it important to aggressively consider the design of roadways within and around schools to ensure the safest possible traffic environment. Equally important is the consideration of the location and design of the school site, preferably during the planning stages, in order to establish safe and efficient operations.

The Texas Department of Transportation (TxDOT) is currently focusing attention on these issues through its Precious Cargo Program. Precious Cargo allows TxDOT staff to review school site plans and make recommendations before they are built. Since the program's inception, more than 180 schools in 70 various school districts statewide have seen traffic safety improvements around their schools or future school sites.

This report provides an overview of the project activities and findings. In the first year, researchers performed a state-of-the practice literature review; interviews and surveys with architects, school district personnel, and consulting engineers with considerable experience in school site planning and design; surveys of site review practices of TxDOT and municipal engineers; findings and observations from case studies of 14 school campuses; and a review of existing guidelines. In the second year, the research team conducted field studies at 20 school sites concentrating on operations and conflicts in parent pick-up and drop-off areas. Based on the findings, researchers developed school site planning and design guidelines for transportation-related elements such as site selection, general site requirements and design, bus operations, parent drop-off/pick-up zones, driveways, turn lanes, signing and marking, parking, and pedestrian and bicycle access.

| 17. Key Words | 18. Distribution Statement |
|---|---|
| School, Safety, Drop-off, Pick-up, Design Guidelines, School Bus, Site Plan | No restrictions. This document is available to the public through NTIS:<br>National Technical Information Service<br>5285 Port Royal Road<br>Springfield, Virginia 22161 |

| 19. Security Classif.(of this report) | 20. Security Classif.(of this page) | 21. No. of Pages | 22. Price |
|---|---|---|---|
| Unclassified | Unclassified | 126 | |

# OPERATIONS AND SAFETY AROUND SCHOOLS: OVERVIEW OF PROJECT ACTIVITIES AND FINDINGS

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Report 0-4286-3
Project Number 0-4286
Research Project Title: Operational and Safety Guidelines for Roadway Facilities around Schools

Sponsored by the
Texas Department of Transportation
In Cooperation with the
U.S. Department of Transportation
Federal Highway Administration

November 2003

TEXAS TRANSPORTATION INSTITUTE
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# ACKNOWLEDGMENTS

The research reported herein was performed by the Texas Transportation Institute (TTI) as part of a project titled *Operational and Safety Guidelines for Roadway Facilities around Schools* sponsored by the Texas Department of Transportation and Federal Highway Administration. Mr. Scott A. Cooner, P.E. #86225 (Texas) and Dr. Kay Fitzpatrick, P.E. #86762 (Texas) served as co-research supervisors; Ms. Terry Sams, P.E. (TxDOT Dallas District) served as project coordinator; and Mr. Linden Burgess (TxDOT Dallas District) served as project director.

The authors wish to acknowledge the following individuals, who served on an advisory panel, for their assistance and guidance throughout the first year of the project:

- Mr. Mark Cantebury, A.I.A., Keller Independent School District (ISD).
- Mr. Larry Colclasure, P.E., TxDOT, Waco District.
- Mr. Wade Odell, P.E., TxDOT Research and Technology Implementation Office – Austin.
- Mr. Craig Reynolds, A.I.A., BRW Architects.
- Mr. Steve Taylor, P.E., Carter & Burgess, Inc. – Dallas.
- Mr. Scott Young, City of Frisco.

The research team extends a special thanks to the principals and other district administrators who allowed TTI researchers access to their campuses to observe and collect data during the year two work tasks.

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# CHAPTER 1. INTRODUCTION

## BACKGROUND AND SIGNIFICANCE OF RESEARCH

The state of Texas, particularly the large urban areas, has experienced considerable population growth in recent years. This growth has produced new schools in areas near highways originally designed for lower volumes and relatively high speeds. Another trend is the higher proportion of children being transported to and from schools in private vehicles. These realities, and many of the other issues associated with traffic around schools, make it important to aggressively consider the design of roadways within and around schools to ensure the safest possible traffic environment. Equally important is the consideration of the location and design of the school site, preferably during the planning stages, in order to establish safe and efficient operations.

The Texas Department of Transportation (TxDOT) is currently focusing attention on these issues through its Precious Cargo Program (*1, 2*). The Precious Cargo Program (see logo in Figure 1) allows TxDOT staff to review school site plans and make recommendations before the schools are built. Since the program's inception, more than 180 schools in 70 various school districts statewide have seen traffic safety improvements around their schools or future school sites (*3*). Precious Cargo reviews are conducted at no cost to schools and have been endorsed by the Federal Highway Administration (FHWA) and National Highway Traffic Safety Administration (NHTSA). The program has also won numerous awards and citations including (*4*):

- National Quality Initiative – Silver Award;
- Texas Quality Initiative Award – Partnering;
- American Association of State Highway and Transportation Officials (AASHTO) Presidents Award;
- AASHTO Pathfinder for Innovation and Quality – Team Award;
- Transportation for Livable Communities Award – Best in State (awarded by the Trans Texas Alliance);
- 2000 Communication Award (TxDOT);
- Journey Toward Excellence – 2000 Work Group/Team Award (TxDOT);
- Brazos Bravo – Community Relations Award (awarded by the International Association of Business Communicators – Brazos Valley Chapter); and
- Certificate of Quality Service (awarded by Western Association of State Highway and Transportation Officials (WASHTO)).

The Precious Cargo Program has been so successful that it is being considered in several other states, including Wisconsin (*3, 5*). Even with the overall success of the program, improvements can still be made, and that is an objective of this research. Through Precious Cargo, TxDOT staff assist school districts with application of transportation principles and fundamentals. However, their efforts are sometimes limited by the lack of knowledge of the specific problems associated with school transportation needs, the lack of acceptable guidelines, and the lack of examples using proven designs. This research addresses these limitations and offers an opportunity to enhance the Precious Cargo Program by providing TxDOT staff, school district personnel, and the other stakeholders with guidelines and good examples for the design and operation of roadway facilities around schools.


**Figure 1. Precious Cargo Program Logo.**

Solutions to traffic-related concerns around schools typically cut across lines of responsibility, influence, and authority. Stakeholders such as traffic engineers, police officers, school district personnel, parent organizations, community associations, and other groups are often times involved. Solutions to these concerns can be expensive, especially if they are being retrofit to an existing school site. The relatively low cost of school traffic control devices (TCDs) frequently makes them the first option, even if they do not really solve the problem. This research also addresses cost and coordination issues associated with safety and operational improvements around schools.

## RESEARCH PLAN

The primary goal established for this project was:

> **Develop guidelines and good examples for the design and operation of roadway facilities within and around schools in order to improve safety and reduce local congestion**.

Using this goal as the overall guide, the research team:

- Identified current planning methods and resources for the location and design of new school facilities used by architects, consulting engineers, and school district personnel.
- Identified current school site plan review practices used by TxDOT and cities.
- Documented good and inadequate examples of school site design.

- Collected safety and operational data at school sites to assess typical traffic demands and patterns and the associated problems.

- Developed guidelines for school sites that address the following issues:

    - separation of passenger cars, school buses, pedestrians, and bicyclists;
    - storage of queues within the school site rather than on a high-speed roadway;
    - site selection process to minimize access from high-speed roadways;
    - spacing, number, and location of school driveways;
    - designs and operational practices for pedestrians and bicycles near schools;
    - best practices in signing and marking;
    - purpose and use of reduced-speed school zones;
    - parking needs (both visitor and staff parking); and
    - recommended operation of school parking lots.

- Documented the developed guidelines and other significant project findings and recommendations so that they are understandable and useful to all interested stakeholders (i.e., engineers, architects, school district personnel, and the public).

### State-of-the-Practice Literature Review

In the second task of the project, researchers gathered information from various sources to establish the state-of-the-practice on safety and operational problems related to the presence and design of school facilities.

### Identify Current School Site Planning Methods and Resources Used by Architects and Consulting Engineers

Through a combination of mail, telephone, fax, and Internet sources, researchers identified and evaluated current transportation-related school site planning methods and procedures used by architects, consulting engineers, and school district personnel. By using a combination of interviews and surveys, the research team gathered information from a broad cross-section of current practitioners within Texas. The scope of the information obtained during the interviews and surveys concentrated on the following two issues:

- resources used for site selection, planning, and layout; and
- specific guidelines, methods, or analyses relating to school traffic issues.

This task focused on the construction of new school campuses near state-owned roadways.

### Identify Existing Site Review Practices Used by TxDOT and Municipalities

A combination of mail-out surveys and interviews identified existing site review practices used by TxDOT and municipalities. The scope of the information obtained during the interviews and surveys concentrated on the following issues:

- resources used for the site review;
- specific guidelines, methods, or analyses relating to school traffic issues; and
- field studies and data collection practices.

### Perform Case Studies

To gain a better understanding of good and inadequate examples of school site design, the research team conducted a number of observational studies at school facilities throughout the state. Another objective of the case studies was to test and evaluate different data collection procedures and methods in order to optimize efforts in the second-year field studies.

### Perform Field Studies

Based on information developed in the tasks described above, the research team conducted field studies to develop an understanding of the effects of design and operational strategies on queuing and conflicts in drop-off and pick-up areas.

### Develop Guidelines

Finally, the research team developed guidelines for the design and operation of roadway facilities within and around schools in order to improve safety and reduce local congestion.

## REPORT ORGANIZATION

This report is divided into six chapters. Chapter 1 contains the background and significance of this research and the research plan.

Chapter 2 (Summary of First-Year Findings and Conclusions) provides a brief review of the year one findings from the project.

Chapter 3 (Second-Year Field Studies) provides a description of the field studies conducted at school campuses in year two. The studies examined ridership, conflicts, and queuing performance in parent pick-up and drop-off areas at elementary and middle schools.

Chapter 4 (Field Studies Results) presents the results of the analysis of the data collected in the field studies.

Chapter 5 (School Site Planning: Guidelines and Best Practices) contains the recommended school site planning guidelines and best practices. The researchers based the recommended guidelines on a comprehensive review of existing guidelines, interview and survey results, and analysis of data collected at school campuses throughout Texas.

Chapter 6 (Site Plan Review Checklist) provides a checklist developed to ensure that reviews of site plans include critical issues related to transportation needs within the school site.

# CHAPTER 2. SUMMARY OF FIRST-YEAR FINDINGS AND CONCLUSIONS

This chapter documents the key findings and conclusions from the activities conducted during the first year of the project. The chapter summarizes the state-of-the-practice literature review; interviews and surveys of architects, school district personnel, consulting engineers, state DOT engineers, and municipal staff; observational studies at 14 school sites in Texas; and a review of existing guidelines for transportation-related elements at schools. For further information the year one report from this project should be consulted (*6*).

## KEY FINDINGS AND CONCLUSIONS

### State-of-the-Practice Literature Review

- Much of the state-of-the-practice on design and operations issues around schools was found in non-traditional sources such as Internet sites for the various state DOTs and state and local school sources.
- Several state DOTs (North Carolina and South Carolina) have dedicated units for review of school site plans and school-related transportation issues (*7*, *8*).
- A recently completed Transportation Research Board (TRB) study indicated that school buses are the safest mode for getting children to and from school (*9*).

### Architect Interviews and Surveys

- There were a number of resources cited by the interview and survey participants used for the planning and design of K–12 educational facilities; however, most of these do not provide any substantial guidance on transportation-related issues.
- Only three of the 10 architects surveyed indicated an awareness/familiarity with the TxDOT Precious Cargo Program; however, half of the architects had at least one school site plan reviewed by a TxDOT representative prior to construction of a new school campus.
- The majority of architects surveyed (70 percent) stated that the most challenging problem with traffic access and circulation at educational facilities relates to separating vehicle, bus, and pedestrian traffic. One respondent indicated that working with TxDOT was the most challenging because reviewers were inconsistent in their comments and required actions.
- The three most important issues to the architect participants for a symposium were:
    1. coordination between designers, schools, and state and city transportation departments;
    2. design and operation of drop-off/pick-up zones; and
    3. retrofit options (design and operations) for schools with existing transportation problems.

**School District Interviews and Surveys**

- The State of Texas has led in the development and renovation of school campuses. Between 1992 and 2000, no state has spent more money (over $19 billion) on construction of K–12 school facilities than Texas.
- Within the range of site access issues, separation of traffic types (vehicles, school buses, day care vans, and pedestrians) was the highest rated problem area at all campus types (i.e., elementary, middle/junior, and high schools).
- Slightly more than half (56 percent) of the interview and survey participants indicated an awareness/familiarity with the TxDOT Precious Cargo Program; however, only 40 percent had at least one school site plan reviewed by a TxDOT representative prior to construction of a new school campus.
- Demographics (i.e., location of existing and future students) are the most important factor in the selection of future land parcels for development of new school campuses.
- The three most important issues to the school district personnel for a symposium were:
    1. design and operation of drop-off/pick-up zones;
    2. retrofit options (design and operations) for schools with existing transportation problems; and
    3. traffic impact analysis (volumes, modal estimation) and Safe Routes to School (recently passed Matthew Brown Act in the Texas legislature).

**Consulting Engineers Interviews**

- The integration of traffic circulation with the school building's location and orientation is very important, but consulting engineers are typically brought in late into the design process if at all. Engineers may be called upon after construction to devise solutions to access and circulation problems.
- Design guidelines for drop-off/pick-up zones are sketches or other in-house sources; no written guidelines are used.
- The three most important issues to the consulting engineers for a symposium were:
    1. coordination between designers, schools, and state and city transportation departments;
    2. design and operation of drop-off/pick-up zones; and
    3. Safe Routes to School (recently passed Matthew Brown Act in the Texas legislature).

**TxDOT and Municipal Surveys**

- Several TxDOT respondents indicated that they need to be involved very early in the school site planning process. Several respondents commented on the need for guidelines for traffic and pedestrian designs in and around schools.
- Approximately half of the TxDOT respondents had reviewed a school site plan in the previous six months.

### Observation Studies at School Campuses

- The preferred data collection methodology is for TTI personnel to use travel time software on a laptop or handheld computers.
- At almost all sites, the average service time (i.e., amount of time spent on-site in the main parent drop-off/pick-up zone) was significantly more variable for afternoon pick-up operations as opposed to the morning drop-off period.
- There were a wide variety of design, operations, and traffic control/markings practices at the school sites studied.
- Some of the schools used proactive practices such as placement of traffic cones, use of gates and/or other barriers, and use of student and staff for on-site traffic control to improve the safety and flow of traffic within their campus.
- In general, schools that had separation of the basic traffic types appeared to have fewer safety conflicts than those where separation was not present.

### Review of Existing Guidelines

- To obtain information on existing guidelines for transportation-related elements at schools, the research team used a variety of methods including review of published documents, Internet searches, survey instruments, and direct correspondence.
- Several agencies provided general site requirements and design for separation of transport modes; service, delivery, and maintenance issues; emergency access issues; weather protection; and general site design and layout.
- The review of existing guidelines produced a significant number of bus-related design and operations guidelines.
- General information on parent drop-off/pick-up zones is included in several sources; however, specific guidance is limited. South Carolina DOT has a specific guideline for on-site stacking length ranging from 800 to 1500 ft (244 to 458 m) depending on school type and student population (*7*).
- A number of studies and programs have been dedicated to bicycle and pedestrian issues for schools (generally under the Safe Routes to School umbrella).
- About half of the department of transportation respondents to a survey indicated they have existing design guidelines for the number and spacing of driveways. Over 70 percent indicated that they have existing guidelines for when turn lanes are to be installed. Several indicated that they treat schools the same as other land uses in determining number and spacing of driveways and turn lanes.

# CHAPTER 3. SECOND-YEAR FIELD STUDIES

Primary schools frequently have queues that can lead to substantial impacts on the local transportation infrastructure. Queuing issues appear to be critical at primary schools, with substantial queues developing at both pick-up and drop-off times at most schools. Operational and design strategies vary substantially among schools, with some schools providing aggressive supervision, multiple queue lanes, etc.

This chapter documents the field studies conducted during the second year of the project. These studies included examinations of school bus and vehicle ridership, conflicts, and queuing in parent pick-up and drop-off areas at 13 elementary and 5 middle schools. The studies were generally performed in both an AM and PM period. The schools examined included sites in both large and small cities in Texas.

The studies provide an examination of the effects various operational and design characteristics had on queue performance. Researchers documented the design characteristics of the queuing areas (i.e., number of lanes), operational strategies (i.e., presence of school personnel supervising the loading/unloading operation), and ridership (the number of students loaded into individual vehicles). The research team measured the performance of the queues through studies of the formation and dissipation of the queues at the observed schools and the incidence of conflicts between pedestrians and motor vehicles.

## DATA COLLECTION COORDINATION

The wide separation of the site locations required that three teams be used to collect the field data. Because of concerns of inconsistencies in the way the data were collected by the teams, the data collection at one school was used as a training tool. Researchers assembled three teams and briefed them regarding collecting the data. Next, the teams collected both AM and PM data at the site, coordinating their efforts to ensure that each team thoroughly understood the data collection methodology.

## RIDERSHIP STUDY

The objective of the ridership study was to develop an understanding of the number of students being loaded and unloaded from individual vehicles. The determination of representative ridership values for school areas can help planners better predict the number of private vehicles being used to transport students to and from schools. The research team conducted ridership studies at 12 elementary schools and 5 middle schools in the AM period and 11 elementary schools and 5 middle schools in the PM period.

### Methodology

The research team performed ridership studies using the data collection form shown in Table 1. The form allowed observers to manually record the number of students entering or exiting individual vehicles. It should be recognized that the presence of other persons in the vehicles was not recorded; the ridership values reported only refer to the students entering or leaving the vehicles.

**Table 1. Ridership Data Collection Form.**

| **School Name:** | **City:** |
|---|---|
| **Data Collector:** | **Date:**<br>**AM / PM** |
| **Cars in Queue** | |
| 1 student | |
| 2 students | |
| 3 students | |
| 4 students | |
| 5 students | |
| **Cars that dropoff/pickup in parking lot or other areas** | |
| 1 student | |
| 2 students | |
| 3 students | |
| 4 students | |
| 5 students | |

## QUEUING STUDY

The objective of the queuing study was to develop recommendations for the operation and design of queuing areas at elementary and middle schools. Determining the characteristics of the queuing behaviors observed at schools will enable the prediction of the length of queues likely to occur in parent pick-up/drop-off lines.

### Methodology

The research team collected data for the queuing study through the use of handheld computers. TTI has developed a license plate matching computer program that was used to record the times that vehicles entered and left the parent pick-up and drop-off queues. Researchers keyed in four digits of the vehicles' license plates as they entered and left the queue. Secondary characteristics such as vehicle type and color could also be recorded. The program recorded the license plate numbers together with the time that the data were entered. Researchers were stationed at the entry and exit points for the queue. The time spent in the queue by individual vehicles could thus be determined during data reduction through use of software that matched up recorded license plate digits. Researchers used the secondary characteristics to help match up vehicle entries in the case of digit transposition or minor errors (i.e., a "D" was recorded instead of an "O"). Table 2 provides a sample of the matched input and output data for an example site.

**Table 2. Example of Matched Entry and Exit Queuing Data.**

| License | Date/Time 1 | Date/Time 2 | Time Lapsed | Color 1 | Car Type 1 | Color 2 |
|---|---|---|---|---|---|---|
| 052D | 7:38:31 AM | 7:40:05 AM | 0:01:34 | White | Auto | White |
| 11CB | 7:44:58 AM | 7:47:22 AM | 0:02:24 | Green | Auto | Green |
| 14VE | 7:54:02 AM | 7:54:21 AM | 0:00:19 | White | Auto | White |
| 1587 | 7:06:54 AM | 7:09:00 AM | 0:02:06 | Black | Auto | Black |

## CONFLICT DATA

The research team also completed a conflict study. Conflicts between pedestrians and motor vehicles were observed, using a methodology based largely on work reported by Zegeer (*10*). Conflicts were recorded and described according to type and severity.

### Methodology

Data collection personnel recorded descriptive data using the form shown in Table 3. The information recorded indicated operational and design characteristics of the pick-up or drop-off zone. Data collection personnel recorded actual conflict data using the form shown in Table 4. Using the attached key, data collection personnel noted the type, location, and severity of observed conflicts between pedestrians (or bicyclists) and motor vehicles. Comment fields were provided on both forms to allow descriptive notes to be recorded regarding specific entries.

## INDIVIDUAL SITE SUMMARIES

A brief descriptive summary of the site characteristics observed in the study is shown in Tables 5 through 26. Some sites had more than one pick-up or drop-off queue, as documented in the tables by designation with site suffixes "a" and "b."

**Table 3. Conflict Site Characteristics Form.**

<table>
<tr><td colspan="3">Conflict Study Descriptive Data</td></tr>
<tr><td colspan="3">School:</td></tr>
<tr><td>City:</td><td>Data Collector:</td><td>Date: AM/PM</td></tr>
<tr><td>Factor</td><td>Response</td><td>Comment</td></tr>
<tr><td>Presence of crossing guard</td><td>Y / N</td><td></td></tr>
<tr><td>Supervision provided at loading/unloading area for cars and buses<br><br>If yes, estimate number of students and adults helping</td><td>Y / N<br><br>Adults:_________<br><br>Students: ________</td><td></td></tr>
<tr><td>Bus parking strategy<br>1. Single file right-side loading<br>2. Multiple bus columns<br>3. Buses forward movement only<br>4. Other (describe)</td><td>____</td><td></td></tr>
<tr><td>Do students have to cross queuing area to reach parking lot?</td><td>Y / N</td><td></td></tr>
<tr><td>Is parking permitted directly adjacent to queuing areas?<br>• Bus loading/unloading<br>• Parent drop-off/pick-up</td><td>Bus: Y / N<br><br>Parent: Y / N</td><td></td></tr>
<tr><td>Are bus and car operations separated?</td><td>Y / N</td><td></td></tr>
</table>

**Table 4. Conflict Data Form.**

| School Name:<br><br>Area Observed: | | | | City: |
|---|---|---|---|---|
| Data Collector: | | | | Date: AM/PM |
| Type* | Time | Severity ** | Location *** | Comment |
| | | | | |
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# Conflict Study Key.

| *Car and Pedestrian Conflict Type | *Car and Bicycle Conflict Type | **Severity of Conflict |
|---|---|---|
| P1. Veh slow or stop for ped.<br>P2. Veh weave for ped crossing road<br>P3. Brake or weave—ped standing.<br>P4. Vehicle ignore crossing guard.<br>P5. Vehicle ignore loading/unloading supervisor.<br>P6. Ped run across street or driveway.<br>P7. Ped stop in street or driveway.<br>P8. Ped traffic signal violation.<br>P9. Ped false start across street.<br>P10. Jay-walking<br>P11. Other (describe) | B1. Veh slow or stop for bike.<br>B2. Veh weave for bike crossing.<br>B3. Brake or weave—bike standing.<br>B4. Vehicle ignore crossing guard.<br>B5. Bike crosses street or driveway without looking.<br>B6. Bike stop in street or driveway.<br>B7. Traffic signal violation.<br>B8. Bike false start across street.<br>B9. Mid-block crossing.<br>B10. Other (describe) | 1. Severe conflict.<br>2. Moderate conflict.<br>3. Routine conflict.<br><br>***Location of Conflict<br><br>1. Jaywalker.<br>2. Bike mid-block crossing.<br>3. Legal crossing.<br>4. Normal loading/unloading. |

**Table 5. Site 1 – Elementary School.**

| | General School Information | |
|---|---|---|
| **School Type** | Elementary | |
| **Setting Type** | Urban | |
| **Student Population** | 250 | |
| **Sidewalk** | Yes | |
| **Crosswalk** | Yes | |
| **Length of Drop-off (ft)** | 50 ft. | |
| **Storage Length (ft)** | 426 ft.-Down street to next block | |
| **Number of Lanes** | 1 | |
| **Method of Demarcation** | Informal - front of school under awning | |
| **Crosswalk in Loading Area** | No | |
| **Number Arriving in Vehicle** | 250 | |
| **Number of Bus Riders** | 0 | |
| **Number of Walkers** | 0 | |
| **Number of Bike Riders** | 0 | |
| | **AM Data** | **PM Data** |
| **Number of Staff** | 1 | 3 |
| **Number of Assistants** | 2 | 0 |
| **Total Number of Cars** | 95 | 42 |
| **Queue Length** | | |
| **- Maximum** | 10 | 12 |
| **- 95th Percentile** | 8 | 11.95 |
| **- Average** | 4.17 | 5.64 |
| **Conflicts** | | |
| **- Car/Pedestrian** | 1 | 4 |
| **- Car/Bicycle** | N/A | N/A |

**Table 6. Site 2a – Middle School.**

| | General School Information | |
|---|---|---|
| **School Type** | Middle | |
| **Setting Type** | Urban | |
| **Student Population** | 585 | |
| **Sidewalk** | Yes | |
| **Cross Guard** | Yes | |
| **Number of Lanes** | 1 | |
| **Number Arriving in Vehicle** | 225 | |
| **Number of Bus Riders** | 167 | |
| **Number of Walkers** | 27 | |
| **Number of Bike Riders** | 35 | |
| | **AM Data** | **PM Data – Day 1** |
| **Number of Staff** | 0 | 5 |
| **Number of Assistants** | 0 | 5 |
| **Total Number of Cars** | 250 | 73 |
| **Queue Length** | | |
| **- Maximum** | 14 | 73 |
| **- 95th Percentile** | 13 | 48.2 |
| **- Average** | 6.5 | 6.12 |
| **Conflicts** | | |
| **- Car/Pedestrian** | 9 | 6 |
| **- Car/Bicycle** | 0 | 0 |

**Table 7. Site 2b – Middle School.**

| | General School Information | |
| --- | --- | --- |
| **School Type** | Middle | |
| **Setting Type** | Urban | |
| **Student Population** | 585 | |
| **Sidewalk** | Yes | |
| **Cross Guard** | Yes | |
| **Number of Lanes** | 1 | |
| **Number Arriving in Vehicle** | 225 | |
| **Number of Bus Riders** | 167 | |
| **Number of Walkers** | 27 | |
| **Number of Bike Riders** | 35 | |
| | **AM Data** | **PM Data – Day 2** |
| **Number of Staff** | N/A | 3 |
| **Number of Assistants** | N/A | 0 |
| **Total Number of Cars** | N/A | 56 |
| **Queue Length** | | |
| **- Maximum** | N/A | 36 |
| **- 95th Percentile** | N/A | 35.4 |
| **- Average** | N/A | 19.9 |
| **Conflicts** | | |
| **- Car/Pedestrian** | N/A | 1 |
| **- Car/Bicycle** | N/A | 0 |

**Table 8. Site 3 – Middle School.**

| | General School Information | |
|---|---|---|
| **School Type** | Middle | |
| **Setting Type** | Urban | |
| **Student Population** | 650 | |
| **Sidewalk** | Yes | |
| **Cross Guard** | Yes | |
| **Number of Lanes** | 1 | |
| **Number Arriving in Vehicle** | 200 | |
| **Number of Bus Riders** | Approximately 200 | |
| **Number of Walkers** | N/A | |
| **Number of Bike Riders** | N/A | |
| | **AM Data** | **PM Data** |
| **Number of Staff** | 1 | 3 |
| **Number of Assistants** | 0 | 0 |
| **Total Number of Cars** | 269 | 106 |
| **Queue Length** | | |
| **- Maximum** | 21 | 29 |
| **- 95th Percentile** | 18 | 28 |
| **- Average** | 10.19 | 11.17 |
| **Conflicts** | | |
| **- Car/Pedestrian** | 1 | N/A |

**Table 9. Site 4 – Elementary School.**

| | General School Information | |
|---|---|---|
| **School Type** | Elementary | |
| **Setting Type** | Urban | |
| **Student Population** | 551 | |
| **Sidewalk** | Yes | |
| **Cross Guard** | Yes | |
| **Number of Lanes** | 2 | |
| **Number Arriving in Vehicle** | 130 | |
| **Number of Bus Riders** | N/A | |
| **Number of Walkers** | 20 | |
| **Number of Bike Riders** | 6 | |
| | **AM Data** | **PM Data** |
| **Number of Staff** | 2 | 4 |
| **Number of Assistants** | 0 | 0 |
| **Total Number of Cars** | 180 | 70 |
| **Queue Length** | | |
| **- Maximum** | 16 | 29 |
| **- 95th Percentile** | 13.05 | 26.55 |
| **- Average** | 7.12 | 12.97 |
| **Conflicts** | | |
| **- Car/Pedestrian** | 6 | 6 |
| **- Car/Bicycle** | 0 | 0 |

**Table 10. Site 5 – Elementary School.**

| | General School Information | |
|---|---|---|
| **School Type** | Elementary | |
| **Setting Type** | Urban | |
| **Student Population** | 620 | |
| **Sidewalk** | Yes | |
| **Cross Guard** | Yes | |
| **Number of Lanes** | 1 | |
| **Number Arriving in Vehicle** | 300+ | |
| **Number of Bus Riders** | N/A | |
| **Number of Walkers** | 25+ | |
| **Number of Bike Riders** | 50+ | |
| | **AM Data** | **PM Data** |
| **Number of Staff** | 2 | 6 |
| **Number of Assistants** | 0 | 0 |
| **Total Number of Cars** | 161 | 47 |
| **Queue Length** | | |
| **- Maximum** | 10 | 30 |
| **- 95th Percentile** | 8 | 29 |
| **- Average** | 4.34 | 17.64 |
| **Conflicts** | | |
| **- Car/Pedestrian** | 0 | 0 |
| **- Car/Bicycle** | 0 | 0 |

**Table 11. Site 6 – Elementary School.**


| | General School Information | |
|---|---|---|
| **School Type** | Elementary | |
| **Setting Type** | Urban | |
| **Student Population** | 400 | |
| **Sidewalk** | Yes | |
| **Cross Guard** | Yes | |
| **Number of Lanes** | 1 | |
| **Number Arriving in Vehicle** | 250 | |
| **Number of Bus Riders** | N/A | |
| **Number of Walkers** | 100 | |
| **Number of Bike Riders** | 50 | |
| | **AM Data** | **PM Data** |
| **Number of Staff** | 1 | 2 |
| **Number of Assistants** | 3 | 4 |
| **Total Number of Cars** | 146 | 52 |
| **Queue Length** | | |
| **- Maximum** | 2 | 25 |
| **- 95th Percentile** | 1.52 | 24 |
| **- Average** | 0.87 | 12 |
| **Conflicts** | | |
| **- Car/Pedestrian** | 1 | 1 |

Table 12. Site 7a – Middle School.

| | General School Information | |
|---|---|---|
| School Type | Middle | |
| Setting Type | Urban | |
| Student Population | 1200 | |
| Sidewalk | No | |
| Cross Guard | No | |
| Number of Lanes | 2 | |
| Number Arriving in Vehicle | 300 | |
| Number of Bus Riders | 77 | |
| Number of Walkers | 0 | |
| Number of Bike Riders | 0 | |
| | AM Data | PM Data |
| Number of Staff | 1 | 5 |
| Number of Assistants | 0 | 0 |
| Total Number of Cars | 267 | 137 |
| Queue Length | | |
| - Maximum | 13 | 61 |
| - 95th Percentile | 10 | 61 |
| - Average | 5.7 | 29.96 |
| Conflicts | | |
| - Car/Pedestrian | 22 | 4 |

**Table 13. Site 7b – Middle School.**

| | General School Information | |
|---|---|---|
| School Type | Middle | |
| Setting Type | Urban | |
| Student Population | 1200 | |
| Sidewalk | No | |
| Cross Guard | No | |
| Number of Lanes | 1 | |
| Number Arriving in Vehicle | 300 | |
| Number of Bus Riders | 77 | |
| Number of Walkers | 0 | |
| Number of Bike Riders | 0 | |
| | **AM Data** | **PM Data** |
| Number of Staff | 0 | 0 |
| Number of Assistants | 0 | 0 |
| Total Number of Cars | 108 | 54 |
| Queue Length | | |
| - Maximum | 11 | 30 |
| - 95$^{th}$ Percentile | 9 | 29 |
| - Average | 5.61 | 15.78 |
| Conflicts | | |
| - Car/Pedestrian | 3 | 9 |
| - Car/Bicycle | 0 | 0 |

**Table 14. Site 8 – Elementary School.**

| | General School Information | |
|---|---|---|
| **School Type** | Elementary | |
| **Setting Type** | Urban | |
| **Student Population** | 592 | |
| **Sidewalk** | Yes | |
| **Cross Guard** | Yes | |
| **Number of Lanes** | 1 | |
| **Number Arriving in Vehicle** | 330 | |
| **Number of Bus Riders** | 150 | |
| **Number of Walkers** | 150 | |
| **Number of Bike Riders** | 15 | |
| | **AM Data** | **PM Data** |
| **Number of Staff** | 1 | 8 |
| **Number of Assistants** | 0 | 0 |
| **Total Number of Cars** | 120 | 51 |
| **Queue Length** | | |
| **- Maximum** | 14 | 27 |
| **- 95th Percentile** | 12 | 25 |
| **- Average** | 6.8 | 14.55 |
| **Conflicts** | | |
| **- Car/Pedestrian** | 7 | 1 |

**Table 15. Site 9 – Middle School.**


| | General School Information | |
|---|---|---|
| **School Type** | Middle | |
| **Setting Type** | Urban | |
| **Student Population** | 750 | |
| **Sidewalk** | No | |
| **Cross Guard** | Yes | |
| **Number of Lanes** | 2 | |
| **Number Arriving in Vehicle** | 375 | |
| **Number of Bus Riders** | 560 | |
| **Number of Walkers** | N/A | |
| **Number of Bike Riders** | N/A | |
| | **AM Data** | **PM Data** |
| **Number of Staff** | 3 | 3 |
| **Number of Assistants** | 2 | 2 |
| **Total Number of Cars** | 223 | 81 |
| **Queue Length** | | |
| **- Maximum** | 7 | 36 |
| **- 95th Percentile** | 7 | 34 |
| **- Average** | 4.12 | 16.95 |
| **Conflicts** | | |
| **- Car/Pedestrian** | 38 | 18 |

**Table 16. Site 10 – Elementary School.**

| | General School Information | |
|---|---|---|
| **School Type** | Elementary | |
| **Setting Type** | Urban | |
| **Student Population** | 910 | |
| **Sidewalk** | Yes (across the street) | |
| **Cross Guard** | Yes | |
| **Number of Lanes** | 1 | |
| **Number Arriving in Vehicle** | 125 | |
| **Number of Bus Riders** | 775 | |
| **Number of Walkers** | 10 | |
| **Number of Bike Riders** | N/A | |
| | **AM Data** | **PM Data** |
| **Number of Staff** | 5 | 5 |
| **Number of Assistants** | 9 | 9 |
| **Total Number of Cars** | 227 | 48 |
| **Queue Length** | | |
| **- Maximum** | 21 | 28 |
| **- 95th Percentile** | 17 | 27.65 |
| **- Average** | 8.79 | 14.29 |
| **Conflicts** | | |
| **- Car/Pedestrian** | 7 | 11 |

**Table 17. Site 11 – Middle School.**


| | General School Information | |
|---|---|---|
| **School Type** | Middle | |
| **Setting Type** | Urban | |
| **Student Population** | 600 | |
| **Sidewalk** | No | |
| **Cross Guard** | Yes | |
| **Number of Lanes** | 3 | |
| **Number Arriving in Vehicle** | N/A | |
| **Number of Bus Riders** | N/A | |
| **Number of Walkers** | N/A | |
| **Number of Bike Riders** | N/A | |
| | **AM Data** | **PM Data** |
| **Number of Staff** | 0 | 7 |
| **Number of Assistants** | 0 | 0 |
| **Total Number of Cars** | 282 | 83 |
| **Queue Length** | | |
| **- Maximum** | 12 | 44 |
| **- 95th Percentile** | 9 | 41 |
| **- Average** | 4.88 | 20.48 |
| **Conflicts** | | |
| **- Car/Pedestrian** | 42 | 26 |
| **- Car/Bicycle** | 0 | 0 |

**Table 18. Site 12 – Middle School.**


| | General School Information | |
|---|---|---|
| School Type | Middle | |
| Setting Type | Urban | |
| Student Population | 738 | |
| Sidewalk | Yes | |
| Cross Guard | No | |
| Number of Lanes | 1 | |
| Number Arriving in Vehicle | 259 | |
| Number of Bus Riders | 295 | |
| Number of Walkers | 177 | |
| Number of Bike Riders | 7 | |
| | **AM Data** | **PM Data** |
| Number of Staff | 6 | 6 |
| Number of Assistants | 0 | 0 |
| Total Number of Cars | N/A | 65 |
| Queue Length | | |
| - Maximum | N/A | 18 |
| - 95th Percentile | N/A | 16 |
| - Average | N/A | 9.69 |
| Conflicts | | |
| - Car/Pedestrian | 25 | 15 |
| - Car/Bicycle | 2 | 1 |

**Table 19. Site 13 – Elementary School.**

| | General School Information | |
|---|---|---|
| **School Type** | Elementary | |
| **Setting Type** | Urban | |
| **Student Population** | 1090 | |
| **Sidewalk** | Yes | |
| **Cross Guard** | Yes | |
| **Number of Lanes** | 2 | |
| **Number Arriving in Vehicle** | 87 | |
| **Number of Bus Riders** | 981 | |
| **Number of Walkers** | 22 | |
| **Number of Bike Riders** | 0 | |
| | **AM Data** | **PM Data** |
| **Number of Staff** | All Teachers | All Teachers |
| **Number of Assistants** | 0 | 0 |
| **Total Number of Cars** | 93 | 44 |
| **Queue Length** | | |
| **- Maximum** | 8 | 21 |
| **- 95th Percentile** | 7 | 19.85 |
| **- Average** | 4.03 | 10 |
| **Conflicts** | | |
| **- Car/Pedestrian** | 0 | 6 |

**Table 20. Site 14 – Elementary School.**

| | General School Information | |
|---|---|---|
| **School Type** | Elementary | |
| **Setting Type** | Urban | |
| **Student Population** | 690 | |
| **Sidewalk** | Yes | |
| **Cross Guard** | Yes | |
| **Number of Lanes** | 1 | |
| **Number Arriving in Vehicle** | 449 | |
| **Number of Bus Riders** | 69 | |
| **Number of Walkers** | 104 | |
| **Number of Bike Riders** | 6 | |
| | **AM Data** | **PM Data** |
| **Number of Staff** | 4 | 8 |
| **Number of Assistants** | 2 | 0 |
| **Total Number of Cars** | 134 | 67 |
| **Queue Length** | | |
| **- Maximum** | 36 | 40 |
| **- 95th Percentile** | 20.9 | 39 |
| **- Average** | 10.29 | 23.61 |
| **Conflicts** | | |
| **- Car/Pedestrian** | 3 | 7 |
| **- Car/Bicycle** | 0 | 0 |

**Table 21. Site 15 – Elementary School.**

| | General School Information | |
|---|---|---|
| **School Type** | Elementary | |
| **Setting Type** | Urban | |
| **Student Population** | 510 | |
| **Sidewalk** | No | |
| **Cross Guard** | Yes | |
| **Number of Lanes** | 1 | |
| **Number Arriving in Vehicle** | 342 | |
| **Number of Bus Riders** | 153 | |
| **Number of Walkers** | 10 | |
| **Number of Bike Riders** | 5 | |
| | **AM Data** | **PM Data** |
| **Number of Staff** | 2 | 12 |
| **Number of Assistants** | 0 | 0 |
| **Total Number of Cars** | 105 | 117 |
| **Queue Length** | | |
| **- Maximum** | 26 | 70 |
| **- 95$^{th}$ Percentile** | 23 | 68.2 |
| **- Average** | 9.4 | 39.06 |
| **Conflicts** | | |
| **- Car/Pedestrian** | N/A | 4 |
| **- Car/Bicycle** | N/A | 0 |

**Table 22. Site 16 – Elementary School.**

| | General School Information | |
|---|---|---|
| **School Type** | Elementary | |
| **Setting Type** | Urban | |
| **Student Population** | 616 | |
| **Sidewalk** | Yes | |
| **Cross Guard** | No | |
| **Number of Lanes** | 2 | |
| **Number Arriving in Vehicle** | 591 | |
| **Number of Bus Riders** | 3 | |
| **Number of Walkers** | 31 | |
| **Number of Bike Riders** | 3 | |
| | **AM Data** | **PM Data** |
| **Number of Staff** | 3 | 10 |
| **Number of Assistants** | 0 | 0 |
| **Total Number of Cars** | 131 | 77 |
| **Queue Length** | | |
| **- Maximum** | 25 | 32 |
| **- 95th Percentile** | 22.5 | 31 |
| **- Average** | 11.11 | 17.81 |
| **Conflicts** | | |
| **- Car/Pedestrian** | 3 | 7 |
| **- Car/Bicycle** | 1 | 1 |

Table 23. Site 17 – Elementary School.

| | General School Information | |
|---|---|---|
| School Type | Elementary | |
| Setting Type | Urban | |
| Student Population | 783 | |
| Sidewalk | Yes | |
| Cross Guard | Yes | |
| Number of Lanes | 4 | |
| Number Arriving in Vehicle | 720 | |
| Number of Bus Riders | 47 | |
| Number of Walkers | 47 | |
| Number of Bike Riders | 0 | |
| | **AM Data** | **PM Data** |
| Number of Staff | 1 | 12 |
| Number of Assistants | 10 | 10 |
| Total Number of Cars | 96 | 62 |
| Queue Length | | |
| - Maximum | 27 | 36 |
| - 95$^{th}$ Percentile | 15.25 | 34 |
| - Average | 7.54 | 20.76 |
| Conflicts | | |
| - Car/Pedestrian | 8 | 11 |
| - Car/Bicycle | 0 | 0 |

**Table 24. Site 18 – Elementary School.**

| | General School Information | |
|---|---|---|
| **School Type** | Elementary | |
| **Setting Type** | Urban | |
| **Student Population** | 626 | |
| **Sidewalk** | No | |
| **Cross Guard** | Yes | |
| **Number of Lanes** | 1 | |
| **Number Arriving in Vehicle** | 332 | |
| **Number of Bus Riders** | 294 | |
| **Number of Walkers** | 0 | |
| **Number of Bike Riders** | 6 | |
| | **AM Data** | **PM Data** |
| **Number of Staff** | 2 | 8 |
| **Number of Assistants** | 0 | 0 |
| **Total Number of Cars** | 160 | 102 |
| **Queue Length** | | |
| **- Maximum** | 17 | 70 |
| **- 95th Percentile** | 16 | 66.9 |
| **- Average** | 12.96 | 36.06 |
| **Conflicts** | | |
| **- Car/Pedestrian** | 1 | 1 |
| **- Car/Bicycle** | 0 | 0 |

**Table 25. Site 19 – Elementary School.**

| | General School Information | |
|---|---|---|
| **School Type** | Elementary | |
| **Setting Type** | Urban | |
| **Student Population** | 590 | |
| **Sidewalk** | Yes | |
| **Cross Guard** | Yes | |
| **Number of Lanes** | 1 | |
| **Number Arriving in Vehicle** | 40 | |
| **Number of Bus Riders** | 500 | |
| **Number of Walkers** | 25 | |
| **Number of Bike Riders** | 25 | |
| | **AM Data** | **PM Data** |
| **Number of Staff** | 3 | 6 |
| **Number of Assistants** | 0 | 0 |
| **Total Number of Cars** | 95 | 103 |
| **Queue Length** | | |
| **- Maximum** | 23 | 22 |
| **- 95$^{th}$ Percentile** | 22 | 21 |
| **- Average** | 13.19 | 11.71 |
| **Conflicts** | | |
| **- Car/Pedestrian** | 1 | 1 |
| **- Car/Bicycle** | 0 | 0 |

**Table 26. Site 20 – Elementary School.**

| | General School Information | |
|---|---|---|
| **School Type** | Elementary | |
| **Setting Type** | Urban | |
| **Student Population** | 590 | |
| **Sidewalk** | Yes | |
| **Cross Guard** | Yes | |
| **Number of Lanes** | 1 | |
| **Number Arriving in Vehicle** | 40 | |
| **Number of Bus Riders** | 500 | |
| **Number of Walkers** | 25 | |
| **Number of Bike Riders** | 25 | |
| | **AM Data** | **PM Data** |
| **Number of Staff** | 4 | 10 |
| **Number of Assistants** | 0 | 0 |
| **Total Number of Cars** | 39 | 86 |
| **Queue Length** | | |
| **- Maximum** | 7 | 23 |
| **- 95th Percentile** | 6 | 21 |
| **- Average** | 4.66 | 15.41 |
| **Conflicts** | | |
| **- Car/Pedestrian** | 11 | 16 |
| **- Car/Bicycle** | 0 | 0 |

# CHAPTER 4. FIELD STUDIES RESULTS

Researchers analyzed the data collected as described in Chapter 3 to examine the impact of various operational and design characteristics on queuing operations. The analyses reviewed the effects of those characteristics on queue development and conflicts.

## RIDERSHIP STUDY RESULTS

The summarized ridership values for the field studies are shown in Table 27. It is apparent that ridership values are somewhat higher in the AM time period than the PM time period. As shown, elementary school ridership tended to be somewhat higher than middle school ridership; the difference was statistically significant (p=0.003). There was no significant difference between the AM and PM time periods.

**Table 27. Ridership Values.**

| | Elementary | Middle School |
|---|---|---|
| PM | 1.33 | 1.24 |
| AM | 1.38 | 1.15 |

## QUEUING STUDY RESULTS

The queuing study data analysis was separated by time period. Functionally, the AM and PM time periods behaved quite differently. In the AM the queues were characterized by lower peaks and relatively quick service, while in the PM initial queues were substantial as parents lined up to pick up their children prior to the dismissal time. Researchers measured queues in terms of vehicles. The research team used stepwise regression techniques to determine whether individual independent variables were entered into the statistical models cited.

### AM Queuing

The research team investigated several models in an attempt to explain the development of the AM queues that were observed:

Dependent Variables

- Maximum queue length (MAXQUE)
- $95^{th}$ percentile queue (NINEFIVQ)
- Average queue (AVGQUE)

Independent Variables

- Presence of parking adjacent to the queue
- Number of students at the school
- Number of loading operations performed
- School type (elementary/middle school)
- Supervision (provided/not provided)

None of the models examined were significant at the 95th percentile level. Reviewing a plot of the data for each dependent variable (Figures 2 to 4), no patterns were apparent by school type or loading operations.

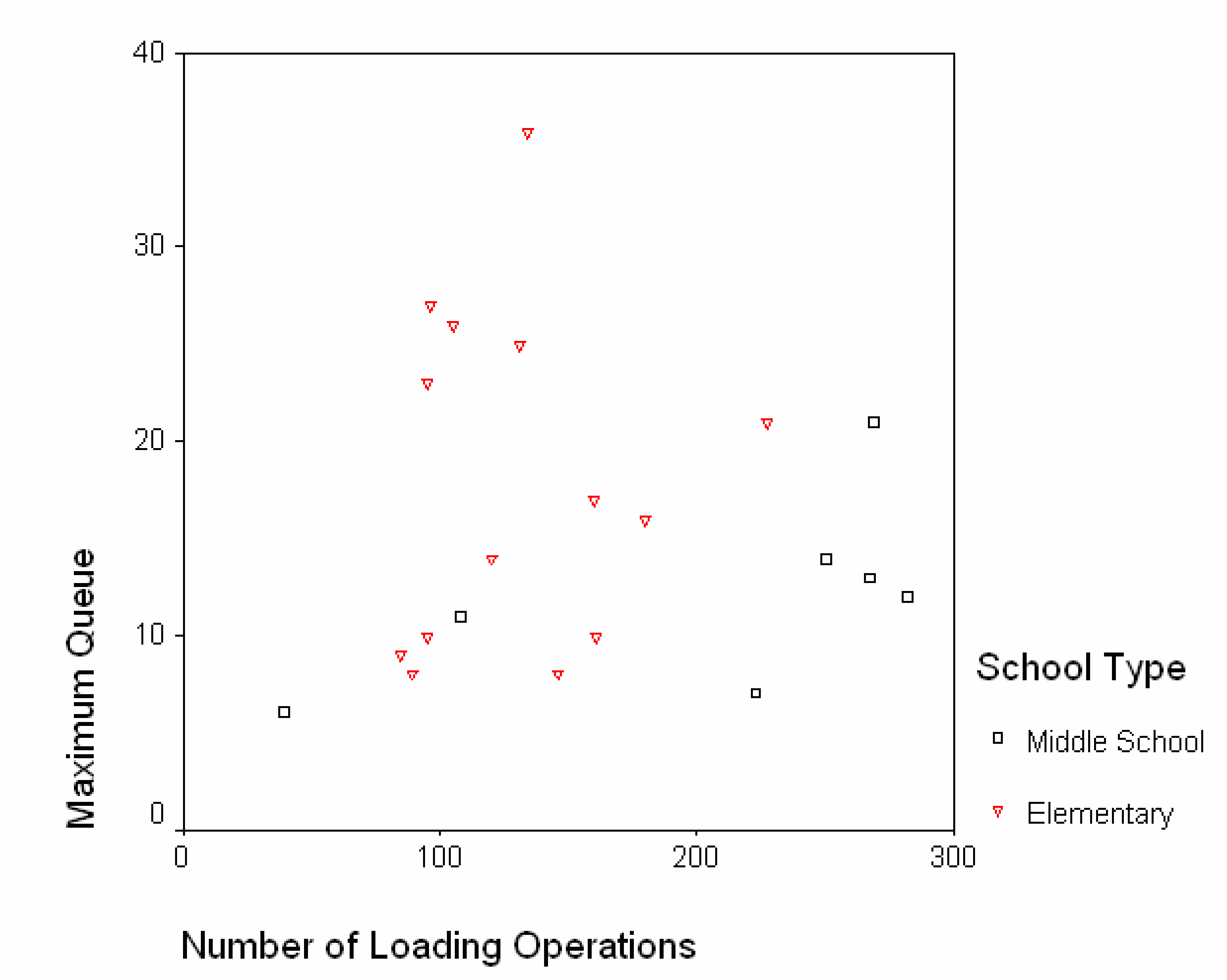


**Figure 2. Maximum Queue Length.**

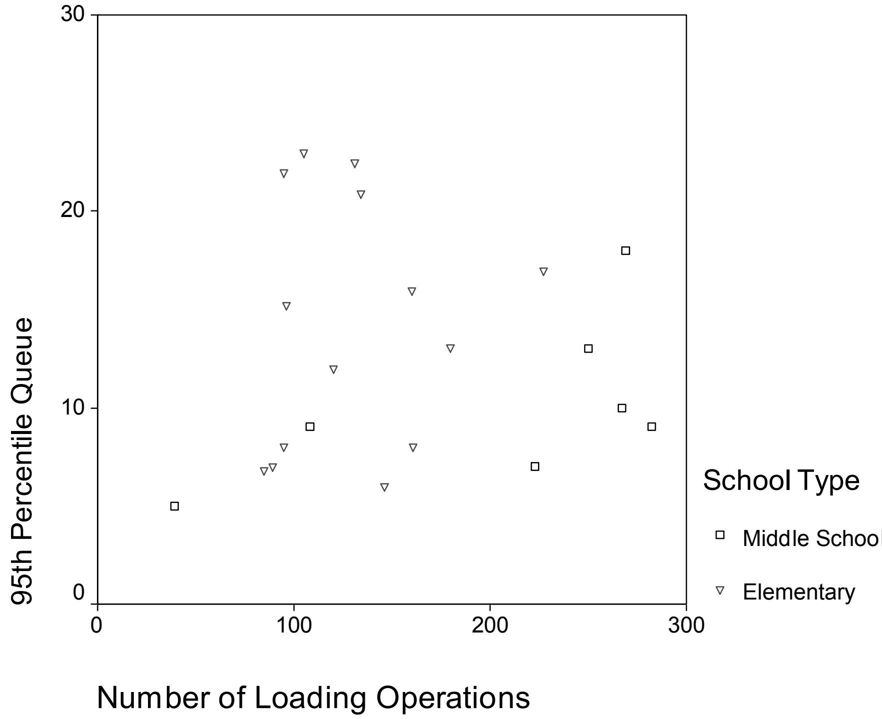


**Figure 3. 95th Percentile Queue Length.**

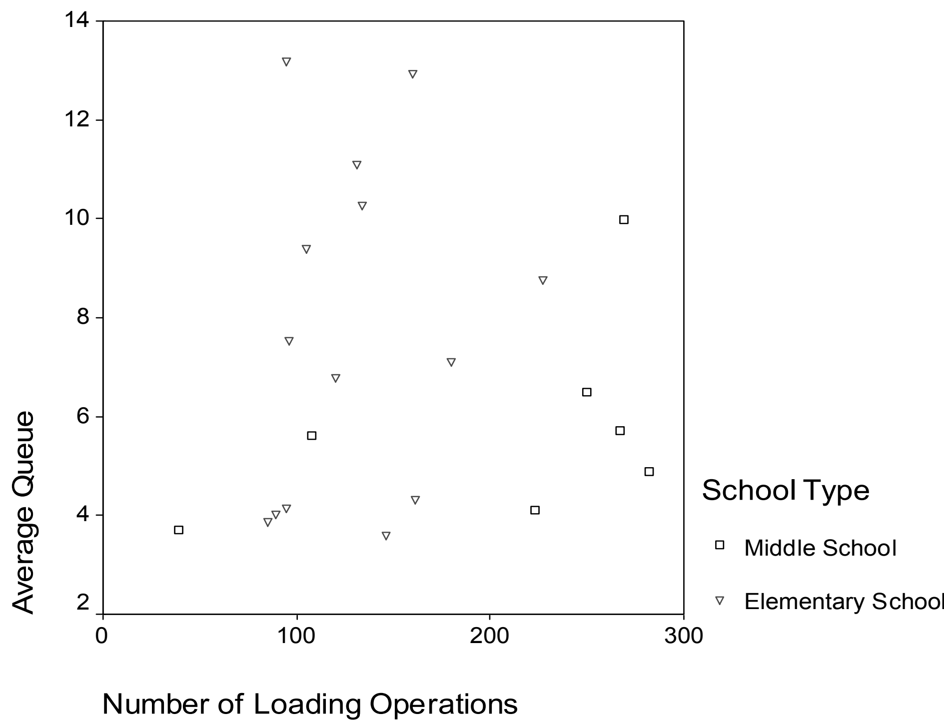


**Figure 4. Average Queue Length.**

**PM Queuing**

Researchers performed a similar analysis of the PM queuing observations. Using the same variables:

Dependent Variables

- Maximum queue length (MAXQUE)
- 95th percentile queue (NINEFIVQ)
- Average queue (AVGQUE)

Independent Variables

- Presence of parking adjacent to the queue (0 if parking is not allowed, 1 if parking is allowed)
- Number of students at the school
- Number of loading operations performed
- School type (elementary/middle school)
- Supervision (provided/not provided)

*Maximum Queue Length*

Shown in Table 28, the two significant models relating the independent variables tested to the maximum PM queue length were those including either the number of loading operations (NUMLOAD)/(Model 1) and the presence of parking adjacent to the queue (PARKADJ)/(Model 2). Model 1 as defined in the table had an adjusted $R^2$ of 0.312 while Model 2 had an adjusted $R^2$ of 0.450. Increases in the number of loading operations and the presence of adjacent parking were both associated with increased maximum queues. Figure 5 shows the relationship between these variables.

**Table 28. Statistical Models Predicting Maximum PM Queue Length.**

**ANOVA[c]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 2179.734 | 1 | 2179.734 | 10.509 | .004[a] |
| | Residual | 4148.266 | 20 | 207.413 | | |
| | Total | 6328.000 | 21 | | | |
| 2 | Regression | 3178.257 | 2 | 1589.128 | 9.586 | .001[b] |
| | Residual | 3149.743 | 19 | 165.776 | | |
| | Total | 6328.000 | 21 | | | |

a. Predictors: (Constant), NUMLOAD

b. Predictors: (Constant), NUMLOAD, PARKADJ

c. Dependent Variable: MAXQUE

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 7.000 | 9.458 | | .740 | .468 |
| | NUMLOAD | .393 | .121 | .587 | 3.242 | .004 |
| 2 | (Constant) | 8.364 | 8.474 | | .987 | .336 |
| | NUMLOAD | .293 | .116 | .438 | 2.535 | .020 |
| | PARKADJ | 14.632 | 5.962 | .424 | 2.454 | .024 |

a. Dependent Variable: MAXQUE

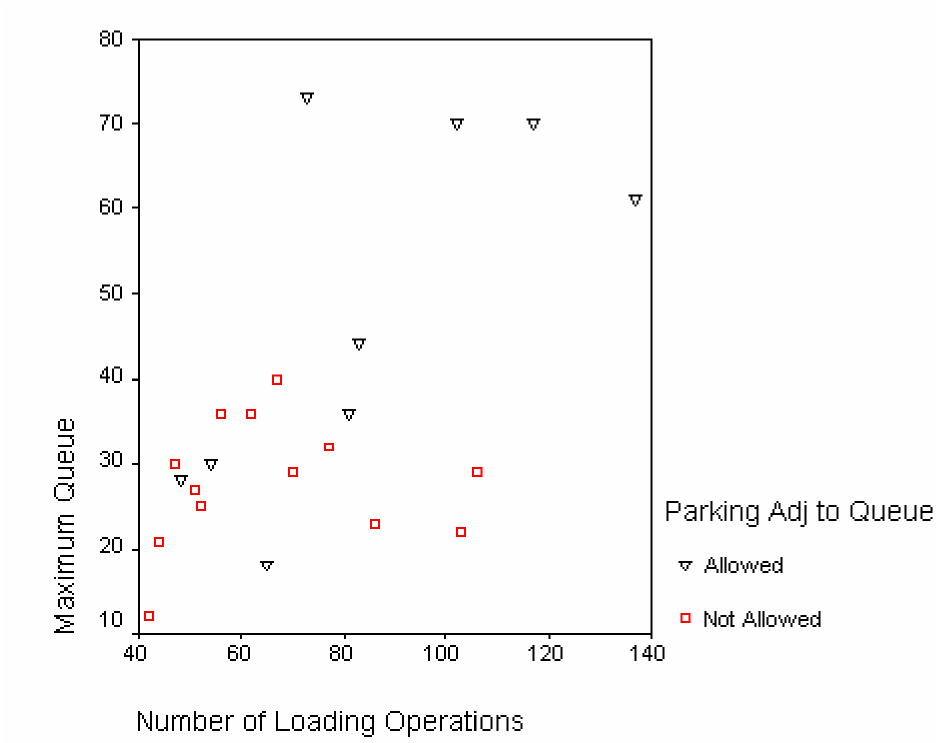


**Figure 5. Maximum Queue Length versus Number of Loading Operations.**

*95th Percentile Queue Length*

Researchers also found significant models relating 95th percentile queue length to the number of loading operations and parking adjacent to the queue. Shown in Table 29, Model 1 had an adjusted $R^2$ of 0.402 while Model 2 had an adjusted $R^2$ of 0.503. Increases in loading operations and the presence of adjacent parking were again associated with an increase in queue length (in this case the 95th percentile queue length). Figure 6 shows a scatter plot of the relationship between these variables.

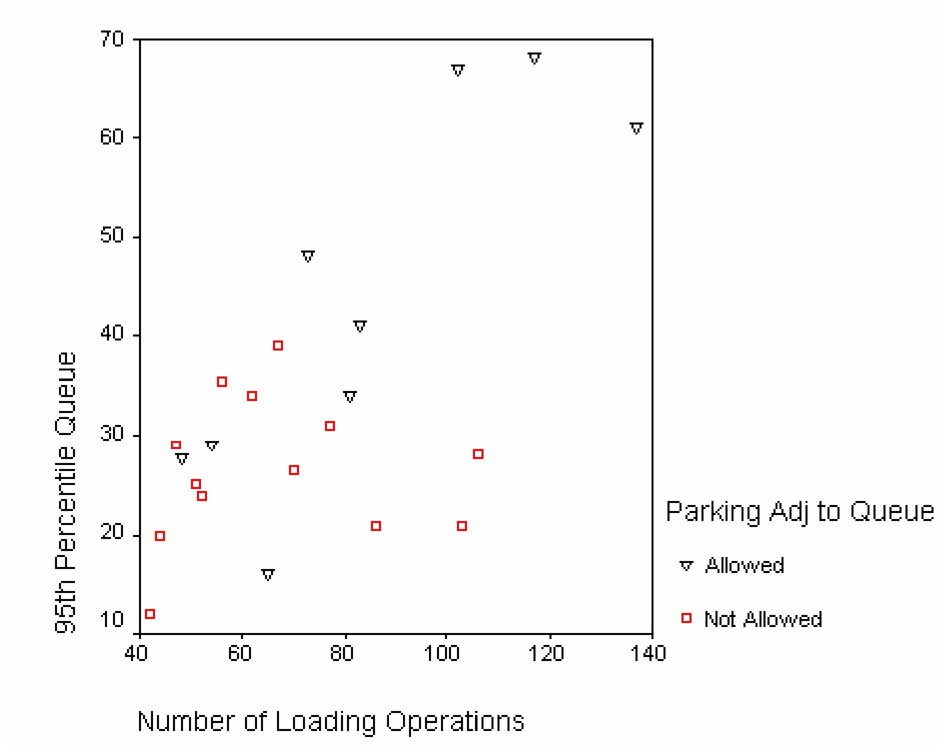


**Figure 6. 95th Percentile Queue versus Number of Loading Operations.**

**Table 29. Statistical Models Predicting 95th Percentile PM Queue Length.**

**ANOVA[c]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 2139.868 | 1 | 2139.868 | 15.100 | .001[a] |
| | Residual | 2834.210 | 20 | 141.710 | | |
| | Total | 4974.078 | 21 | | | |
| 2 | Regression | 2736.560 | 2 | 1368.280 | 11.619 | .001[b] |
| | Residual | 2237.517 | 19 | 117.764 | | |
| | Total | 4974.078 | 21 | | | |

a. Predictors: (Constant), NUMLOAD

b. Predictors: (Constant), NUMLOAD, PARKADJ

c. Dependent Variable: NINEFIVQ

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 4.798 | 7.818 | | .614 | .546 |
| | NUMLOAD | .389 | .100 | .656 | 3.886 | .001 |
| 2 | (Constant) | 5.853 | 7.142 | | .819 | .423 |
| | NUMLOAD | .312 | .098 | .526 | 3.203 | .005 |
| | PARKADJ | 11.311 | 5.025 | .370 | 2.251 | .036 |

a. Dependent Variable: NINEFIVQ

*Average Queue Length*

The research team found a model predicting average queue (AVGQUE) to be significantly related to the number of loading operations (NUMLOAD). Shown in Table 30, the factor was positively related to the length of the average queue with an adjusted $R^2$ of 0.307. The relationship between the variables is illustrated in Figure 7.

**Table 30. Statistical Model Predicting Average PM Queue Length.**

**ANOVA[b]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 532.664 | 1 | 532.664 | 10.318 | .004[a] |
| | Residual | 1032.456 | 20 | 51.623 | | |
| | Total | 1565.119 | 21 | | | |

a. Predictors: (Constant), NUMLOAD

b. Dependent Variable: AVGQUE

**Coefficients[a]**

| Model | | Unstandardized Coefficients B | Unstandardized Coefficients Std. Error | Standardized Coefficients Beta | t | Sig. |
|---|---|---|---|---|---|---|
| 1 | (Constant) | 3.010 | 4.718 | | .638 | .531 |
| | NUMLOAD | .194 | .060 | .583 | 3.212 | .004 |

a. Dependent Variable: AVGQUE

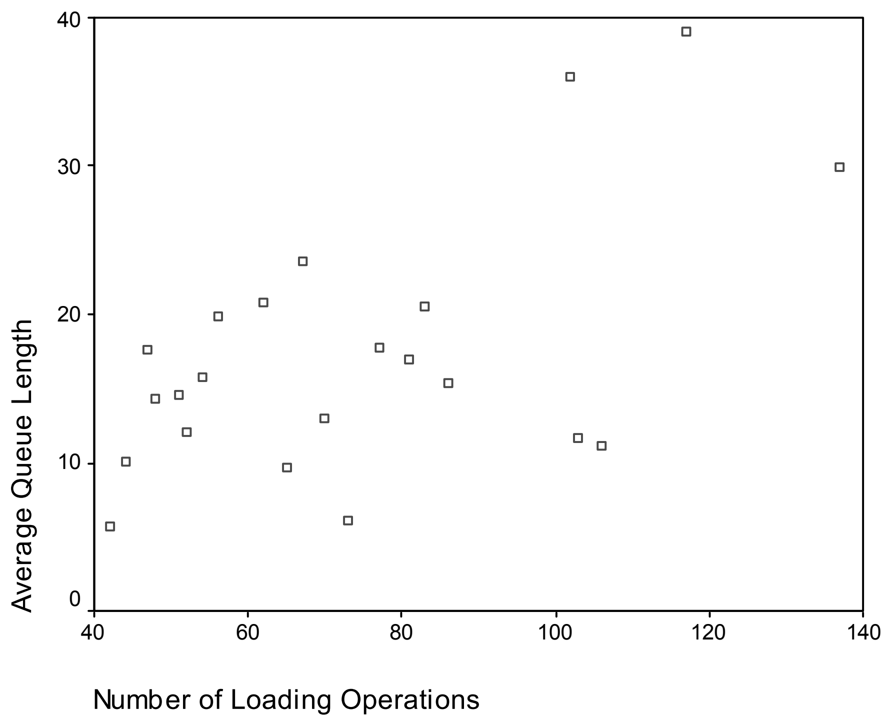


**Figure 7. Average Queue Length versus Number of Loading Operations.**

### Summary of Queuing Results

As shown, researchers found significant relationships relating PM queue lengths to the number of loading operations and in two cases to the presence of parking adjacent to the queue. Although no significant relationships were found for AM queues, PM queue lengths are typically greatly in excess of those found in the AM time period and tend to be the predominant factor in the design of queuing areas.

## CONFLICT STUDY RESULTS

The conflict study data analysis was separated by time period because of the differences in operation cited under the queuing study description (AM queues were characterized by lower peaks and relatively quick service, while PM initial queues were substantial as parents lined up to pick up their children prior to the dismissal time). Researchers used stepwise regression techniques to determine whether individual independent variables were entered into the statistical models cited.

### AM Conflicts

The research team investigated several models in an attempt to explain the AM conflicts that were observed:

Dependent Variables
- Total conflicts (TOTCONF)
- Total conflicts per loading operation (CONFPLD)

Independent Variables
- Presence of parking adjacent to the queue
- Number of students at the school
- Number of loading operations performed
- School type (elementary/middle school)
- Supervision (provided/not provided)

Although data collection personnel assigned the conflicts observed in the study a severity, the number of medium- and high-severity conflicts was very low and in the analysis all conflicts were summed to provide the variables listed. The research team tested dependent variables for inclusion in the regression models using the stepwise regression technique.

*Total Conflicts*

Summarized in Table 31, number of lanes, school type, and provision of supervision were all significantly related to conflict. Observed conflicts were higher for greater number of lanes and for middle schools and were also higher if supervision was provided. The adjusted $R^2$ for Models 1, 2, and 3 were 0.598, 0.718, and 0.809, respectively.

**Table 31. AM Total Conflicts.**

**ANOVA[d]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 1617.307 | 1 | 1617.307 | 27.815 | .000[a] |
| | Residual | 988.483 | 17 | 58.146 | | |
| | Total | 2605.789 | 18 | | | |
| 2 | Regression | 1952.462 | 2 | 976.231 | 23.908 | .000[b] |
| | Residual | 653.327 | 16 | 40.833 | | |
| | Total | 2605.789 | 18 | | | |
| 3 | Regression | 2190.028 | 3 | 730.009 | 26.338 | .000[c] |
| | Residual | 415.761 | 15 | 27.717 | | |
| | Total | 2605.789 | 18 | | | |

a. Predictors: (Constant), LANENUM

b. Predictors: (Constant), LANENUM, SCHLTYPE

c. Predictors: (Constant), LANENUM, SCHLTYPE, SUPRVIS

d. Dependent Variable: TOTCONFL

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | -12.310 | 4.421 | | -2.784 | .013 |
| | LANENUM | 16.276 | 3.086 | .788 | 5.274 | .000 |
| 2 | (Constant) | -12.150 | 3.706 | | -3.279 | .005 |
| | LANENUM | 13.558 | 2.755 | .656 | 4.922 | .000 |
| | SCHLTYPE | 9.274 | 3.237 | .382 | 2.865 | .011 |
| 3 | (Constant) | -8.528 | 3.294 | | -2.589 | .021 |
| | LANENUM | 10.453 | 2.505 | .506 | 4.173 | .001 |
| | SCHLTYPE | 17.956 | 3.988 | .740 | 4.502 | .000 |
| | SUPRVIS | -12.994 | 4.438 | -.452 | -2.928 | .010 |

a. Dependent Variable: TOTCONFL

*Conflicts per Loading Operation*

Summarized in Table 32, school type and the provision of supervision were significantly related to conflicts per loading operation. Observed conflicts were higher for middle schools but were smaller if supervision was not provided. The adjusted $R^2$ for Models 1 and 2 were 0.263 and 0.748, respectively.

**Table 32. AM Total Conflicts per Loading Operation.**

**ANOVA[c]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 2.838E-02 | 1 | 2.838E-02 | 7.436 | .014[a] |
| | Residual | 6.488E-02 | 17 | 3.817E-03 | | |
| | Total | 9.327E-02 | 18 | | | |
| 2 | Regression | 7.238E-02 | 2 | 3.619E-02 | 27.721 | .000[b] |
| | Residual | 2.089E-02 | 16 | 1.305E-03 | | |
| | Total | 9.327E-02 | 18 | | | |

a. Predictors: (Constant), SCHLTYPE

b. Predictors: (Constant), SCHLTYPE, SUPRVIS

c. Dependent Variable: CONFPLD

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 2.880E-02 | .018 | | 1.615 | .125 |
| | SCHLTYPE | 8.012E-02 | .029 | .552 | 2.727 | .014 |
| 2 | (Constant) | 2.880E-02 | .010 | | 2.761 | .014 |
| | SCHLTYPE | .172 | .023 | 1.182 | 7.361 | .000 |
| | SUPRVIS | -.160 | .028 | -.932 | -5.805 | .000 |

a. Dependent Variable: CONFPLD

## PM Conflicts

*Total Conflicts*

Summarized in Table 33, lane number and school type significantly related to total conflicts. Observed conflicts were higher for middle schools and higher for an increase in the number of lanes used for queuing. The adjusted $R^2$ for Models 1 and 2 were 0.270 and 0.473, respectively.

**Table 33. PM Total Conflicts.**

**ANOVA[c]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 250.788 | 1 | 250.788 | 7.038 | .016[a] |
| | Residual | 677.022 | 19 | 35.633 | | |
| | Total | 927.810 | 20 | | | |
| 2 | Regression | 439.049 | 2 | 219.525 | 8.085 | .003[b] |
| | Residual | 488.760 | 18 | 27.153 | | |
| | Total | 927.810 | 20 | | | |

a. Predictors: (Constant), LANENUM

b. Predictors: (Constant), LANENUM, SCHLTYPE

c. Dependent Variable: TOTCONFL

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 1.129 | 2.819 | | .401 | .693 |
| | LANENUM | 4.353 | 1.641 | .520 | 2.653 | .016 |
| 2 | (Constant) | -.654 | 2.552 | | -.256 | .801 |
| | LANENUM | 3.974 | 1.439 | .475 | 2.761 | .013 |
| | SCHLTYPE | 6.197 | 2.353 | .453 | 2.633 | .017 |

a. Dependent Variable: TOTCONFL

*Conflicts per Loading Operation*

No models were found to be statistically significant for conflicts per loading operation.

**Summary for Conflict Studies**

The data analysis found several factors to be significantly related to conflicts: number of lanes, school type, and supervision. Lane number and school type were both found in the direction expected (e.g., larger number of queuing lanes was associated with increased numbers of conflicts and more conflicts occurred at middle schools rather than elementary schools). The presence of supervision, however, was unexpectedly found to be associated with larger numbers of conflicts. Reviewing the records used to develop the reported models, it was noted that the effect associated with presence of supervision was somewhat uneven. At elementary schools every school queuing operation was supervised. The middle schools sometimes had supervision and sometimes not; those schools with supervision frequently only provided general behavioral supervision (i.e., preventing fighting or quarrels). Accordingly, the researchers consider the significance of the results related to supervision of the loading operation to be reduced in importance.

# CHAPTER 5. SCHOOL SITE PLANNING: GUIDELINES AND BEST PRACTICES

This chapter contains the primary product of Project 0-4286 – the recommended school site planning guidelines and best practices. The research team developed these guidelines to provide a source for those interested in the safety and efficiency of student transportation at school sites. Researchers intend for the recommended guidelines to capture the mainstream guidance on how to design and operate roadway facilities within and around schools in order to improve safety and reduce local congestion.

The researchers based the recommended guidelines on a comprehensive review of existing guidelines, interview and survey results, and analysis of data collected at school campuses throughout Texas. The guidelines are relevant to all of the basic school types (elementary, middle, and high schools); however, they are most applicable to elementary schools because of the amount of data collected at this school type during the project. The research team organized the recommended guidelines into nine categories including:

- site selection;
- general site requirements and design;
- bus-related design and operations;
- parent drop-off/pick-up zones;
- bicycle/pedestrian;
- driveways;
- turn lanes;
- traffic control, signing, and pavement markings; and
- parking requirements and design.

The remainder of this chapter synthesizes the recommended guidelines for each of the nine categories listed above. Researchers placed the guidelines in tables, with the written guideline and the corresponding sources where the guideline was found. Some of the recommended guidelines are also supplemented with a best practices section. Guidelines in the tables that have a star next to them indicate that they have a best practices section. The best practices section uses information gathered during the field studies to illustrate the application of the guideline with an example to avoid and a good example.

## CRITERIA AND GUIDELINES FOR SELECTION OF SCHOOL SITES

From a practical standpoint, the selection of a site for a new school dictates the resulting design and operations of the facility. A member of the research team conducted interviews with several independent school district (ISD) representatives regarding how future school sites are obtained and selected. These interviews revealed the following key findings:

- Future ISD school sites are acquired through (in order of decreasing frequency): negotiated purchase, donation, and exchange. Some ISDs consult their own staff architect or an independent architect prior to the parcel's acquisition.

- The criteria for selecting a future school site are (in order of decreasing importance): demographics, utility and roadway access, parcel size, and topography.

The research team's review of site selection criteria and guidelines produced information in the following categories:

- site size and frontage space,
- building setback requirements, and
- location and accessibility.

**Site Size**

The overall size of a school site is important to the design and layout of the necessary facilities (buildings, roadways, parking lots, recreational areas, etc.). Several agencies have existing guidelines indicating the number of acres required based on the type of school being built. The most used guidelines are those published by the Council of Educational Facility Planners International (CEFPI), a professional society composed primarily of school district personnel, architects, engineers, and contractors. Table 34 provides the CEFPI guidelines (*11*). Several agencies have also adopted other general guidelines for site size including:

- preference for rectangular shape (length to width ratio does not exceed 2:1), and
- adequate land for parking of buses and queuing space for parent pickup (*12*, *13*, *14*).

**Table 34. Site Size Guidelines for New School Sites.**

| School Type | Number of acres (hectares) required CEFPI Guidelines[2] (*11*) |
|---|---|
| Elementary (K-6) | 10[1] (4.05) |
| Middle (5-8) | 20[1] (8.1) |
| Junior High (7-9) | 20[1] (8.1) |
| Senior High (9-12) | 30[1] (12.15) |
| Vocational Center | 10[1] (4.05) |

[1] Plus 1 acre (0.405 ha) per 100 students on maximum projected enrollment
[2] Where a school district intends to build two schools on a single site, it is permissible to reduce the total combined acreage by 15% based on the following groupings (elementary/middle, middle/junior high, junior high/senior high, or senior high/vocational center)

Closely related to the overall size of the site is the amount of frontage space (width). Only a few agencies had existing guidelines for the required frontage space based on the school type. The City of Mississauga, Canada, ranged from 350 ft (106.75 m) for an elementary school to 600 ft (183 m) for secondary (i.e., middle, junior high, and senior high) school (*15*). The amount of frontage space is important to the transportation operations and design (primarily on-site queuing space/stacking length) of the site. Several other agencies have also adopted general guidelines relating to frontage space including:

- provide ample frontage to allow for separate car and bus entrances and exits (*16*),

**Guideline 1: School buildings should be set back on the site a sufficient distance from the adjacent roadways to ensure safe and adequate site storage for stacking of loading and unloading vehicles. (DESIGN)**

- provide adequate frontage to avoid congestion at site entrances/exits, and
- provide adequate frontage to provide safe access from roads or streets.

**Building Setback Requirements**

The review of existing guidelines for building setback requirements showed that no agencies had specific values for how far back from the roadway the school building needed to be placed. Building setback is an important consideration because the placement of the building significantly affects the traffic circulation and amount of on-site space for stacking of vehicles. One agency had a general guideline that school buildings be set back on the site a sufficient distance from the adjacent roadways to ensure safe and adequate site storage or stacking of loading and unloading vehicles.

***Best Practice for Application of Guideline 1***

Figure 8 and Figure 9 show examples of school sites located in the same ISD. Both schools are elementary schools that used the same prototype design for the school building.

*Example to Avoid*

The school site shown in Figure 8 was the first prototype elementary school built in the suburban ISD. In this case the architect placed the school building near the front of the site, set back approximately 150 feet from the adjacent two-lane roadway. This site regularly had the queue of vehicles in the front loop driveway spill back out onto the adjacent roadway during morning drop-off and afternoon pick-up operations, blocking through traffic.

*Example of Good Practice*

Based on this experience, the ISD built the next prototype elementary on a similar site but placed the building approximately 350 feet farther back on the site (see Figure 9 – school is located in middle of the aerial photograph). The increased setback distance provides more on-site stacking space and has resulted in better operations at the school.

**Location and Accessibility**

Another area of concern in the site selection process for schools is the location and accessibility of the site in relation to the nearby land uses and the adjacent roadway network. In the review of existing guidelines, a number of organizations had transportation-related guidelines for site location and accessibility. Some of the guidelines were specific to the type of school facility (i.e., elementary vs. secondary) while others were more general in nature.

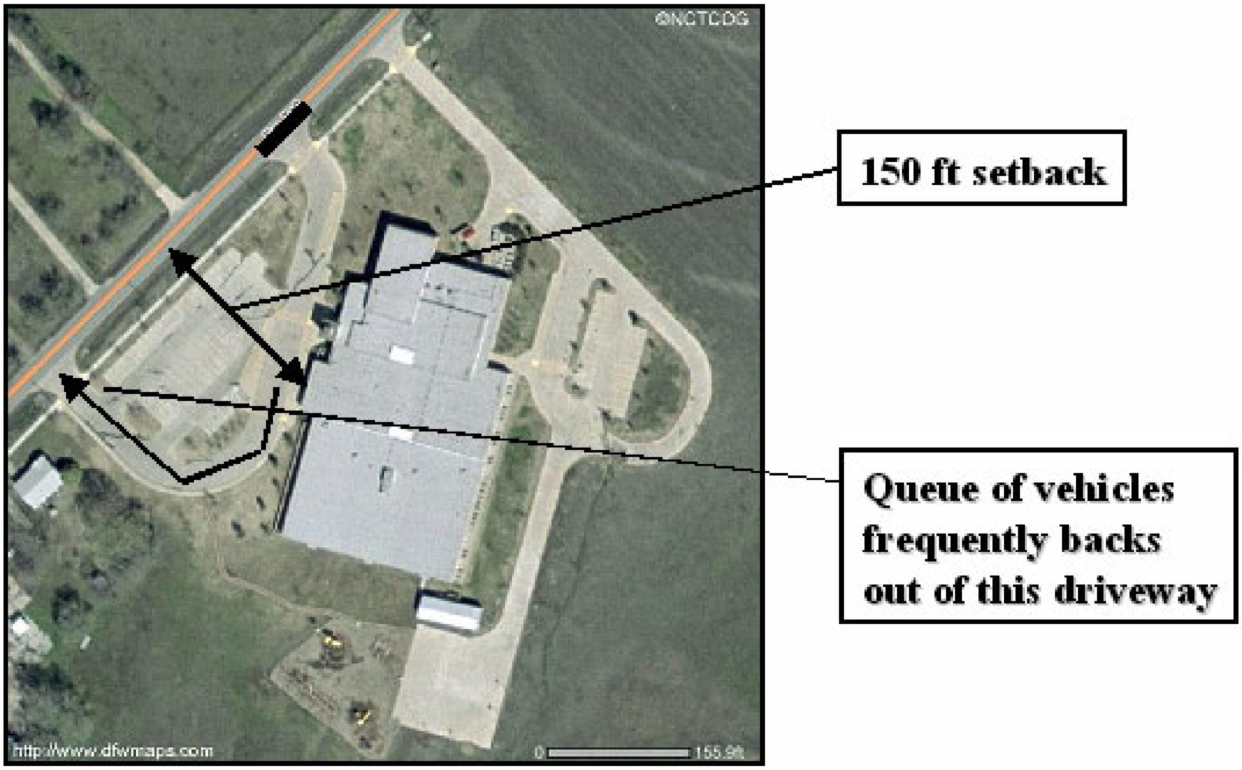


**Figure 8. School Building Located near the Front of the Site – Frequent Spillback (*17*).**


**Figure 9. School Building Pushed Back on the Site – Better Operations (*17*).**

Table 35 provides a listing of guidelines and their corresponding source(s) specific to elementary school facilities. The four primary sources of these guidelines were two Canadian agencies (Region of York and City of Mississauga); Douglas County, Colorado; the Institute of Transportation Engineers (ITE) Michigan Section; and the New South Wales Road Authority (*18*, *19*, *20*, *21*, *22*, *23*). Most of these guidelines relate to choosing elementary school sites as close as possible to the residential areas where students live and away from high-volume roadways.

Table 36 records the existing guidelines and their corresponding source(s) specific to secondary (i.e., middle, junior high, and senior high) school facilities. In contrast to the elementary school guidelines, the secondary school guidelines promote access from high-volume roadways (e.g., arterials) to accommodate school-generated traffic. Table 37 lists general (i.e., not specific for school type) guidelines for school site location and accessibility.

**Table 35. Site Location and Accessibility Guidelines for Elementary School Facilities.**

| Guideline | Source(s) |
|---|---|
| Should be situated centrally to a neighborhood, abutting and having access to a collector street. | Region of York–Canada (*18*) |
| Access to major collectors akin to minor arterials should be avoided due to the volume of traffic. | Region of York–Canada (*18*) |
| Access should be via the collector street and ideally a main driveway should align with a street (i.e., 4th leg of a T intersection) with stop control on all approaches. | Region of York–Canada (*18*) |
| Avoid high-volume traffic flow near elementary school entrances and exits. | Douglas County–Colorado (*19*) |
| Avoid elementary school site along local streets opposite residential driveways. | Douglas County–Colorado (*19*) |
| Elementary school sites should desirably be located as close as possible to the residential areas with provision for safe pedestrian and bicycle accessibility. This will minimize walking distances and also reduce traffic congestion. | New South Wales–Australia (*21*), ITE Michigan Section (*20*), Arizona DOT (*24*) |
| Should not be located on arterial or major collector roads. | City of Mississauga–Canada (*15*), City of Phoenix–Arizona (*25*) |
| Provide bussing for elementary students who cross busy major streets or use major streets as school attendance or bussing boundaries. | City of Phoenix–Arizona (*25*) |

**Table 36. Site Location and Accessibility Guidelines for Secondary School Facilities.**

| Guideline | Source(s) |
|---|---|
| Should be located centrally to the catchment area close to the intersection of an arterial and a continuous collector street, with access provided from the collector. The access should be located far enough from the intersection (preferably signalized) so as not to impact operations. | Region of York–Canada (*18*) |
| Justify a traffic signal (where vehicle volumes warrant) during peak periods at schools with access from an arterial. | Douglas County–Colorado (*19*) |
| Consider pedestrian travel desire lines when locating schools near commercial centers. | City of Mississauga–Canada (*15*) |
| A high school site should be readily accessible from a street system capable of handling school-generated traffic, and the use of local residential streets for primary access should be avoided. | Arizona DOT (*24*) |

**<u>Guideline 2</u>: Avoid locations with direct access to high-speed roadways. (DESIGN)**

**Table 37. General Guidelines for School Site Location and Accessibility.**

| Guideline | Source(s) |
|---|---|
| ★ School site should be situated where the road alignment provides good visibility. | Region of York–Canada (*18*), New South Wales–Australia (*21*) |
| ★ Provide access from more than one direction to the immediate vicinity of the site, and provide access to the site from at least two adjacent streets. | Douglas County–Colorado (*19*) |
| ★ School entrances should not be placed on trunk highways (major roads). Locations should be chosen on roadways with the lowest speed limit and/or lowest average daily traffic. | Minnesota DOT (*26*), New South Wales–Australia (*21*) |
| High-density traffic flow near school exits and entrances due to the proximity of highways, periodic commercial traffic, or high commuter traffic from industrial plants should be avoided. | National Safety Council (NSC) (*27*), City of Mississauga–Canada (*15*), North Carolina Department of Education (DOE) (*12*), Minnesota DOE (*28*) |
| Locate schools adjacent to other community facilities where there is potential for shared use parking (e.g., parks, churches, etc): coordinate with the operation and layout of adjacent uses. | City of Mississauga–Canada (*15*), Minnesota DOE (*28*) |
| Avoid locating school sites abutting each other on the same road frontage: separate with parks or other land uses. | City of Mississauga–Canada (*15*) |
| Accessible at reasonable cost to public roads that are adequate to accommodate the added traffic generated by the school. | North Carolina DOE (*12*), Minnesota DOE (*28*) |
| Be adjacent to or readily accessible to modes of transport useful to students and staff: school buses, vehicles, public transit, bicycles, and/or pedestrians. | North Carolina DOE (*12*) |
| Not be too close to congested traffic arteries or highways that are noisy and will cause delays or special hazards. | North Carolina DOE (*12*) |
| Students approaching on foot should not have to cross main traffic arteries. | North Carolina DOE (*12*) |
| Site is located to efficiently and safely serve the school population. | Massachusetts DOE (*29*) |
| Locate site near bus routes to limit student travel time, whenever possible. | Minnesota DOE (*28*) |

★ Guidelines with this star symbol also have a best practice section

### *Best Practice for Application of Guideline 2*

It is desirable to locate school sites with appropriate accessibility from the adjacent roadway network based on the type of school. One of the prominent site selection criteria found in numerous sources was to avoid locations with direct access to high-speed roadways (e.g., trunk highways and frontage roads). This criterion is consistent with promotional materials for the TxDOT Precious Cargo Program.

*Example to Avoid*

Figure 10 provides a picture of a bad example of following Guideline 2. In this case, a school district planned a new school for a site located on a high-speed two-lane roadway with no turning lanes. This is a typical example of a situation that is becoming more common in Texas, particularly in suburbs located on the fringe of rapidly growing metropolitan areas. The right panel of the picture shows a vehicle passing a truck adjacent to a school driveway – not a desirable condition.

**Guideline 3: Provide access from more than one direction to the immediate vicinity of the site, and provide access to the site from at least two adjacent streets. (DESIGN)**


**Figure 10. School Site Located on High-Speed Roadway without Turn Lanes.**

***Best Practice for Application of Guideline 3***

The majority of schools where researchers collected data during this project had access driveways from only one adjacent roadway. As stated in Guideline 3, it is desirable to provide access to the school site from at least two adjacent streets. Having access from more than one street has several potential benefits including: easier separation of parent and bus operations, better driveway spacing, and greater dispersion of traffic into and out of the site.

*Example to Avoid*

Figure 11 shows an aerial of an elementary school site where the access driveway is provided from a local street. The site is located on a corner lot; however, it only has access from the roadway on the eastern side of the lot. No access driveways are provided from the roadway on the southwestern portion of the picture.

*Example of Good Practices*

Figure 12 shows an elementary school site where access is provided from a minor collector street and a local street. This site layout is the default standard for this school district for elementary schools. Having access driveways from two adjacent streets allows this site to function well operationally.


**Figure 11. Elementary Site with Access from One Adjacent Roadway (*17*).**

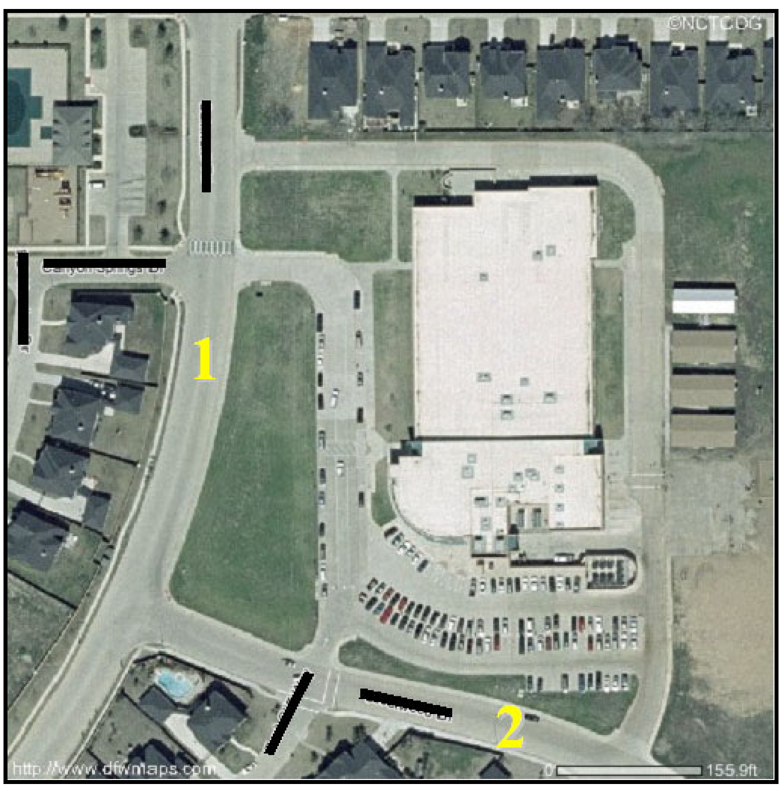


**Figure 12. Elementary School Site with Access from Two Adjacent Roadways (*17*).**

**<u>Guideline 4</u>: School site should be situated where the road alignment provides good visibility. (DESIGN)**

***Best Practice for Application of Guideline 4***

The provision of adequate sight distance near school exits and entrances is important for safe and efficient traffic operations. If the school site is located on a tangent section of roadway that is relatively flat then sight distance is typically not going to be an issue. If the site is located along a road with horizontal and/or vertical curvature then good visibility might pose a problem. There are several other sight distance and visibility-related guidelines similar to Guideline 4 that should also be applied to enhance safety. These guidelines include:

- All roads within the school site should be graded with a maximum grade of 5 percent to avoid configurations that could impair a motorist's vision.
- The location of drives, buildings, equipment, landscaping, and school sign that typically marks the main entrance must permit adequate sight distances for drivers and pedestrians.

*Example of Good Practice*

Figure 13 shows views from both directions from a school driveway where adequate sight distance was provided. Most of the field study sites had good sight distance from driveways.

**Figure 13. Good Example of School Driveway with Good Sight Distance in Both Directions.**

*Example to Avoid*

One of the schools included in the observational case studies had undesirable sight distance in the vicinity of the entrance-only driveway. Figure 14 provides a picture of the entrance driveway with a sharp curve located approximately 150 ft upstream (dump truck just coming into view). This situation becomes a safety issue when the queue of vehicles in the parent drop-off zone backs up out of this driveway and vehicles on the adjacent roadway encounter stopped traffic just after rounding the sharp curve.

**<u>Guideline 5</u>: The physical routes provided for the basic modes (buses, cars, pedestrians, and bicycles) of the traffic pattern should be separated as much as possible from each other. (DESIGN)**

**Figure 14. Site with Driveway Located near Horizontal Curve – Inadequate Sight Distance.**

## GENERAL SITE REQUIREMENTS AND DESIGN GUIDELINES

The second category of guidelines is related to general site requirements and design. The guidelines tend to fall into one of the following topic areas: (1) separation of transport modes; (2) service, delivery, and maintenance issues; (3) emergency access issues; (4) weather protection; or (5) general site design and layout. Table 38 provides the guidelines for the first four topic areas in the previous list and also provides the source(s). Table 39 provides guidelines and corresponding source(s) for the fifth topic area, the general site design and layout category. The research team also reviewed two ITE publications that contained general guidelines for school sites that are not listed in either table but provide useful information:

- Survey of Traffic Circulation and Safety at School Sites (*30*), and
- A Survey of Establishing Reduced Speed School Zones (*31*).

### *Best Practice for Application of Guideline 5*

In the research team's opinion, perhaps the most universal guideline involving design and operations at schools is summarized in Guideline 5 above. Almost every source, whether from architecture, transportation, or educational professions, had some guidance on providing for separation of the basic modes of travel for students within the school site. Providing for physical separation of the basic modes is both a design issue (e.g., layout of separate driveways, loading areas, etc.) and an operations issue (e.g., enforcement of bus-only zones, supervision of crosswalks, etc.).

**Table 38. School Site Requirements and Design Guidelines–Sorted into Specific Categories.**

| Guideline | Source(s) |
|---|---|
| *Separation of Transport Modes* | |
| ★ The physical routes provided for the basic components (buses, cars, pedestrians/bicycles, and service vehicles) of the traffic pattern should be separated as much as possible from each other. | Miami-Dade County–Florida (*32*), Wake County–North Carolina (*33*), South Carolina DOE (*16*) and DOT (*7*), School Bus Fleet (*34*, *35*, *36*), Douglas County–Colorado (*19*), New South Wales–Australia (*21*), NSC (*27*), ITE Michigan Section (*20*), City of Mississauga–Canada (*15*), North Carolina DOE (*12*), California DOE (*13*), Kentucky DOE (*37*), Minnesota DOE (*28*) and DOT (*26*), Missouri DOT (*38*), Arizona DOT (*24*) |
| *Service, Delivery, and Maintenance Issues* | |
| An independent service drive, two lanes wide, shall access a fenced service yard with a loading zone.<br>(1) Locate the service yard next to the kitchen.<br>(2) The service yard shall contain parking for kitchen personnel and maintenance vehicles.<br>(3) Provide a loading zone for two maximum-length delivery trucks and a 50 ft (15.25 m) radius turnabout. | Miami-Dade County–Florida (*32*), North Carolina DOE (bullet #1 only) (*12*) |
| Provide dumpster area with enclosure and/or concrete-filled bollards. | Kentucky DOE (*37*) |
| Flush ribbon curbed turnouts from roadways and parking areas shall be provided to allow for maintenance without climbing over raised curbing. | Seminole County–Florida (*39*) |
| Locate site utilities and physical plant components to avoid conflict with student and vehicular traffic, future growth of play areas, building expansion, etc. | Kentucky DOE (*37*) |
| *Emergency Access Issues* | |
| It is recommended that all roadways, with the exception of loading zones, on school properties be signed 'No Parking or Standing, Fire Lane'. | ITE Michigan Section (*20*) |
| It is recommended that where parking lots or driveways do not lie contiguous to the school, consideration should be given to the use of high-strength sidewalks, 15 ft (4.575 m) wide, with radii that accommodate an emergency vehicle. | ITE Michigan Section (*20*), Arizona DOT (*24*) |
| Provide adequate site lighting at night: at all driveway intersections and bus loop for emergency vehicle access. | Kentucky DOE (*37*) |
| Plans for roads and loading areas should accommodate emergency vehicles–must have access at all times. | NSC (*27*) |
| *Weather Protection* | |
| ★ All primary building entrances for students shall be weather protected by overhead cover or soffit. | Wake County–North Carolina (*33*), North Carolina DOE (*12*), Miami-Dade County–Florida (*32*) |

★ Guidelines with this star symbol also have a best practice section

### *Example of Good Practice*

Most of the sites included in the field studies had good separation of the basic arrival modes. Figure 15 is an aerial photo of an elementary school site that shows a good example of separation of parent vehicles, school buses, and pedestrians/bicyclists. The basic design of this school site provided for good separation; however, an operational change from the original layout improved the function of the site from the perspective of separating the basic modes of the traffic pattern.

The school principal made the operational change from the original layout because the queue in the loop driveway in front of the school was frequently stacking out onto the adjacent roadway. The operational change involved closing this loop driveway to parent traffic and making it a pedestrian/bicycle-only zone. The driveway on the south side of the school, labeled with the number 1 in Figure 15, was then opened to be the parent drop-off/pick-up zone. This site had a higher than average percentage, with just over 20 percent of students, arriving by walking or cycling, which is at least partly attributable to the system of sidewalks, bicycle racks, and the creation of the pedestrian/bicycle-only zone. The driveway labeled with the number 2 in Figure 15 serves as the entrance and exit for all of the school buses into the site.

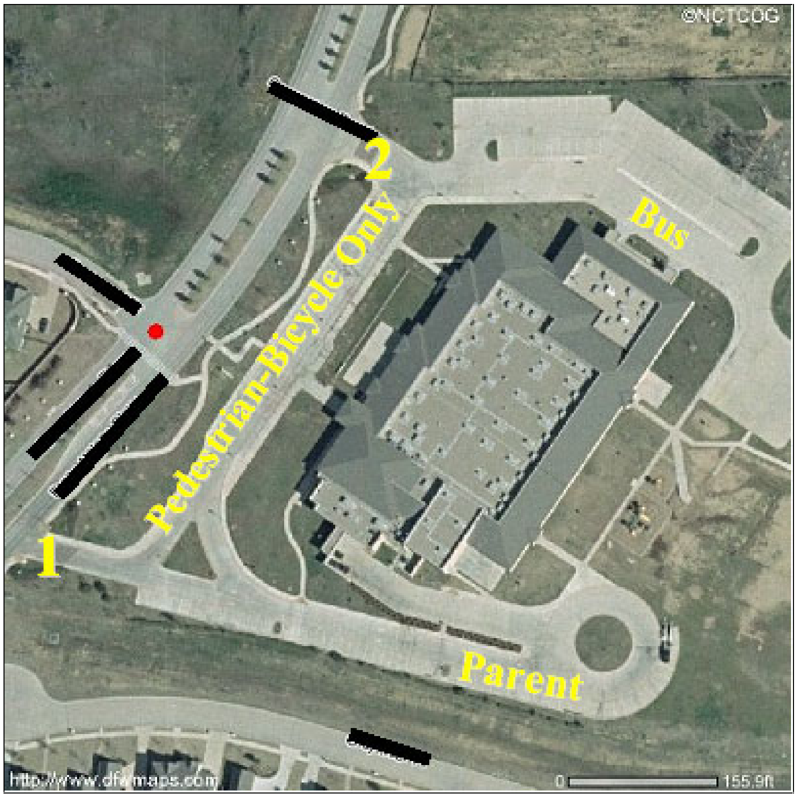


**Figure 15. School with Good Physical Separation of Basic Modes of Traffic Pattern (*17*).**

*Examples to Avoid*

Figure 16 shows photographs of a junior high school site with a design that should be avoided. This site actually has some physical separation of modes in place – bus and parent zones are separated via a raised median and have separate entrance driveways. The layout at this site has the bus zone adjacent to the school entrance with the parent zone separated via a raised concrete median. While these loading zones are physically separated, students dropped off in the parent zone have to cross the bus zone driveway to access the school entrance. This layout promotes pedestrian/bus conflicts. The other element of this site that did not work well and violates the guideline of trying to separate modes is that parent vehicles and buses utilize the same exit driveway. This created unnecessary on-site congestion, particularly in the afternoon when buses and parent vehicles are trying to exit at the same time.


**Figure 16. Site with a Layout to Avoid – Bus and Parent Zones Adjacent to Each Other.**

Researchers visited several sites where the layout had good separation; however, parent or staff vehicles circumvented traffic control devices (e.g., bus-zone only signs, do not enter signs, no parking signs, etc.) or the school staff did not enforce procedures, which caused vehicles, buses, and pedestrians to be unnecessarily mixed while on site. Several schools had loading zones signed as bus-only but did not enforce it and allowed parent cars to use the zone (see Figure 17).


**Figure 17. Site Where Parents Use the Bus-Only Loading Zone.**

**Guideline 6: All primary building entrances for students shall be weather protected by overhead cover or soffit. (DESIGN)**

***Best Practice for Application of Guideline 6***

Several sources included a guideline related to providing covered walkways or soffits near school entrances to provide protection for students during rain and other types of inclement weather. Guideline 6 has relevance from a transportation perspective because it is intuitive that sites with weather protection operate better during rainy weather than those without, particularly during the afternoon pick-up period.

*Example of Good Practice*

Figure 18 provides a picture of a school site with a covered walkway that runs along the entire length of the parent drop-off/pick-up zone. The covered walkway is approximately 10 ft wide between the columns and has a lot of space available for storage of waiting students. This design is a good example of fulfillment of Guideline 6. Researchers performed field studies at several school sites with some weather protection, particularly newer facilities constructed within the last five years.

**Figure 18. Covered Walkway Adjacent to the Parent Loading Zone.**

**Guideline 7: The school site and proposed plans should be reviewed by the proper road agency. (PLANNING and DESIGN)**

**Table 39. General School Site Requirements and Design Guidelines.**

| Guideline | Source(s) |
|---|---|
| Utilize all potential drop-off zones to reduce congestion. | Katz, Okitsu, & Associates–California (*40*) |
| Avoid transit stops, vending/mailboxes, or on-street parking between drop-off entrance and exits along the school frontage. | Miami-Dade County–Florida (*41*), City of Mississauga–Canada (*15*) |
| Orient and locate playfields, parking, service drives, drop-off zones, and bus zones to reduce the cost of connecting elements without requiring pedestrians to cross vehicular traffic lanes. | Miami-Dade County–Florida (*32*) |
| Provide a paved standing area for 25% of the student population next to the main student entry area. | Miami-Dade County–Florida (*32*) |
| Provide adequate on-site parking and loading/unloading space designed for all modes of transportation. | New South Wales–Australia (*21*), South Carolina DOT (*7*), Arizona DOT (*24*) |
| Whenever possible, roads should not be constructed that completely encircle a school. Areas that students must cross for outside activities should be free of all vehicular traffic. | NSC (*27*), North Carolina DOE (*12*), Little Institute for School Facilities Research (*11*), California DOE (*13*) |
| All roads within the school site should be graded to avoid configurations that could impair a motorist's vision. It is suggested that a maximum 5% grade be allowed for on-site roads. | NSC (*27*), ITE Michigan Section (*20*) |
| Internal two-way roadways to two-lane one-way roadways on a school site should have a minimum width of 26 ft (7.93 m) face-to-face of curb, or 24 ft (7.32 m) edge-to-edge for an uncurbed facility. Consideration of wider pavement widths should be made when the roadway is curvilinear in design. | ITE Michigan Section (*20*), Missouri DOT (*38*) |
| The location of drives, buildings, equipment, and landscaping must permit adequate sight distances for drivers and pedestrians. | NSC (*27*), ITE Michigan Section (*20*), School Bus Fleet (*36*) |
| ★ The site and proposed plans should be reviewed by the proper road agency. | ITE Michigan Section (*20*), Precious Cargo–Texas (*1*), Oregon DOT (*42*) |
| Buildings should be parallel to the street and have parking located at the side or rear of the property. | City of Mississauga–Canada (*15*) |
| Provide at least a 50 ft (15.25 m) tangent between reverse curves. | California DOE (*13*), NSC (*27*) |
| Avoid excess paving or concrete curbing. | Kentucky DOE (*37*) |
| Check contours for drainage away from the building. | Kentucky DOE (*37*) |

★ Guidelines with this star symbol also have a best practice section

### *Best Practice for Application of Guideline 7*

Coordination between school district representatives and transportation agencies is critical to planning for safe and efficient access to and from school sites. This process is particularly critical when a new school is being constructed. Several sources had something similar to Guideline 7, which advocates that plans for a proposed school site need to be reviewed by the appropriate roadway agencies. The TxDOT Precious Cargo Program is essentially designed to foster coordination between school districts and TxDOT representatives during the planning stages for new school sites, particularly when they are going to be located on state-maintained roadways.

*Example of Good Practices*

There have been numerous success stories and awards associated with the TxDOT Precious Cargo Program. More than 180 schools in over 70 school districts statewide have seen traffic safety improvements around their schools or future school sites as a result of the Precious Cargo Program. Table 40 provides the mailing addresses and telephone numbers to contact each of the 25 TxDOT districts regarding participation in the Precious Cargo Program. The following list provides some examples of the types of benefits and partnerships schools have experienced from participation in the TxDOT Precious Cargo Program:

- necessary labor and equipment for construction of turn lanes supplied by TxDOT while the ISD provided the funding;
- recommendations for traffic improvements based on review of 15 schools included in a district-wide bond campaign;
- installation of traffic signals based on early coordination that allowed for TxDOT funding to be programmed; and
- changes to circulation patterns to improve safety and congestion on adjacent roadways.

**Table 40. List of Precious Cargo Contact Information for Each TxDOT District.**

| District | Mailing Address | Telephone Number |
|---|---|---|
| Abilene | P.O. Box 150 Abilene, TX 79604-0150 | (915) 676-6800 |
| Amarillo | P.O. Box 2708 Amarillo, TX 79105-2708 | (806) 356-3200 |
| Atlanta | P.O. Box 1210 Atlanta, TX 75551-1210 | (903) 796-2851 |
| Austin | P.O. Drawer 15426 Austin, TX 78761-5426 | (512) 832-7000 |
| Beaumont | 8350 Eastex Fwy. Beaumont, TX 77708 | (409) 892-7311 |
| Brownwood | P.O. Box 1549 Brownwood, TX 76804-1549 | (915) 646-2591 |
| Bryan | 1300 N. Texas Ave. Bryan, TX 77803-2760 | (979) 778-2165 |
| Childress | P.O. Box 900 Childress, TX 79201-0900 | (940) 937-7100 |
| Corpus Christi | P.O. Box 9907 Corpus Christi, TX 78469-9907 | (361) 808-2300 |
| Dallas | P.O. Box 133067 Dallas, TX 75313-3067 | (214) 320-6100 |
| El Paso | 13301 Gateway West El Paso, TX 79928-5410 | (915) 790-4200 |
| Fort Worth | P.O. Box 6868 Fort Worth, TX 76115-0868 | (817) 370-6500 |
| Houston | P.O. Box 1386 Houston, TX 77251-1386 | (713) 802-5000 |
| Laredo | 1817 Bob Bullock Loop Laredo, TX 78043 | (956) 712-7400 |
| Lubbock | P.O. Box 771 Lubbock, TX 79408-0771 | (806) 745-4411 |
| Lufkin | 1805 N. Timberland Dr. Lufkin, TX 75901 | (936) 634-4433 |
| Odessa | 3901 E. U.S. 80 Odessa, TX 79761 | (915) 332-0501 |
| Paris | P.O. Box 250 Paris, TX 75461-0250 | (903) 737-9300 |
| Pharr | P.O. Drawer EE Pharr, TX 78577-1231 | (956) 702-6100 |
| San Angelo | P.O. Box 61550 San Angelo, TX 76906-1550 | (915) 944-1501 |
| San Antonio | P.O. Box 29928 San Antonio, TX 78229-0928 | (210) 615-1110 |
| Tyler | 2709 W. Front St. Tyler, TX 75702 | (903) 510-9100 |
| Waco | 100 South Loop Dr. Waco, TX 76704 | (254) 867-2700 |
| Wichita Falls | P.O. Box 660 Wichita Falls, TX 76307-0660 | (940) 720-7700 |
| Yoakum | P.O. Box 757 Yoakum, TX 77995-0757 | (361) 293-4300 |

## SCHOOL BUS-RELATED DESIGN AND OPERATIONS GUIDELINES

The subject areas of bus operations, safety planning, and facilities design have all received considerable research in the past. There are a number of prominent groups and organizations, such as the Pupil Transportation Safety Institute (PTSI), dedicated to school bus-related issues (*43*). The review of existing guidelines produced a significant number of bus-related design and operations guidelines. Table 41 lists these guidelines. Researchers found some differences when it came to recommended guidelines for the width and number of lanes for on-site bus facilities.

**Table 41. Bus-Related Design and Operations Guidelines.**

| Guideline | Source(s) |
|---|---|
| Drop-off area design does not require backward movement by buses. | Katz, Okitsu, & Assoc.–California (*40*), Miami-Dade County–Florida (*41*), South Carolina DOE (*16*), Wake Co.–North Carolina (*33*), North Carolina DOE (*12*), Douglas County–Colorado (*19*), Missouri DOT (*38*), Minnesota DOT (*26*), Arizona DOT (*24*), NSC (*27*) |
| Bus drop-off areas should be one-way in a counterclockwise direction to assure the loading/unloading of students occurs from the right-hand side of the vehicle adjacent to the building (children should never have to walk between buses). | Miami-Dade County–Florida (*41*), South Carolina DOE (*16*), Region of York–Canada (*18*), School Bus Fleet (*35*), New South Wales–Australia (*21*), NSC (*27*), ITE Michigan Section (*20*), North Carolina DOE (*12*), California DOE (*13*), Missouri DOT (*38*), Minnesota DOT (*26*), Arizona DOT (*24*) |
| Maximize fronting curb space as loading zone – have enough space to stage all buses on a daily basis. | Katz, Okitsu, & Associates–California (*40*), Missouri DOT (*38*), Minnesota DOT (*26*) |
| The school bus loading zone may be located further from the school entrance. | City of Edmonton–Canada (*44*), School Bus Fleet (*35*) |
| Each parking stall for a full-size bus shall be a minimum of 15 ft (4.575 m) wide. | South Carolina DOE (*16*), Wake County–North Carolina (*33*) |
| Required drop-off and pick-up areas for schools shall include at least: (1) 5 school bus spaces or (2) 2 school bus spaces for every 50 students, whichever results in the greater number (no more than 12 spaces required). | City of Henderson–Nevada (*45*) |
| On-site bus loading zones shall have two lanes – one for travel and one for stopping. The facility should be sized for the expected number of buses. | Region of York–Canada (*18*), School Bus Fleet (*35*) |
| ★ Single-file right wheel to the curb is the preferred staging method for buses. | School Bus Fleet (*35*), ITE Michigan Section (*20*), Arizona DOT (*24*) |
| Locate the bus area so that buses exit upstream of automobiles and gain priority, thereby reducing delay. | Douglas County–Colorado (*19*) |
| Avoid crosswalks at entry to and exit from bus zone. | Douglas County–Colorado (*19*) |
| Curbing, with suitable drainage, is recommended on all roads utilized by school buses within the site. | NSC (*27*) |
| Attention should be given in planning bus parking, loading, and unloading zones to encourage diagonal parking (minimum of 60 ft [18.3 m] paved surface). | NSC (*27*), California DOE (*13*) |
| The type of pavement and base should conform to the local state highway department specification for buses. | NSC (*27*) |
| Provide buses only/no entry signs at ends of bus loop. | Kentucky DOE (*37*) |
| Consider two outbound lanes if possible, one for left-turning buses and one for right turns. | Minnesota DOT (*26*) |

★ Guidelines with this star symbol also have a best practice section

**Guideline 8: Single-file right wheel to the curb is the preferred staging method for buses. (DESIGN and OPERATIONS)**

***Best Practice for Application of Guideline 8***

Guideline 8 refers to the preferred staging method for school buses while loading or unloading students at school sites. The preferred method of staging buses is single-file right wheel to the curb because students are not required to pass between buses.

**Figure 19** shows the different staging methods for buses for loading and unloading students at school sites. The bus-loading zone needs to be designed for the expected number of buses to accommodate Guideline 8.

*Example of Good Practice*

Many schools where researchers performed field studies staged buses in a single-file right wheel to the curb formation. Figure 20 provides a picture of a site where two of the buses were staged in a single-file formation adjacent to the curb for afternoon loading.

*Examples to Avoid*

The research team observed several sites where the preferred staging method was not employed. The most likely reason for using other staging methods, such as multiple-lane parallel, was lack of space to accommodate the number of buses serving the school campus. In the opinion of the research team, staging methods such as the one shown in Figure 21 should be avoided if possible to minimize the risks of conflicts with buses and students in the loading zone area.

## GUIDELINES FOR THE DESIGN AND OPERATION OF PARENT ZONES

The topic of design and operation of parent drop-off/pick-up zones at schools has not received considerable attention until recently. Researchers believe that while parent drop-off and pick-up zones are often overlooked in school design, they are very important. The provision of adequate zones minimizes illegal standing or parking near schools and helps prevent problems such as blocking bus driveways and flow on adjacent roadways (*46*). The research team did find some information for guidelines and recommended practices that is provided in Table 42. Several studies, performed in the states of North and South Carolina, have given significant consideration to design and operation of parent drop-off/pick-up zones.

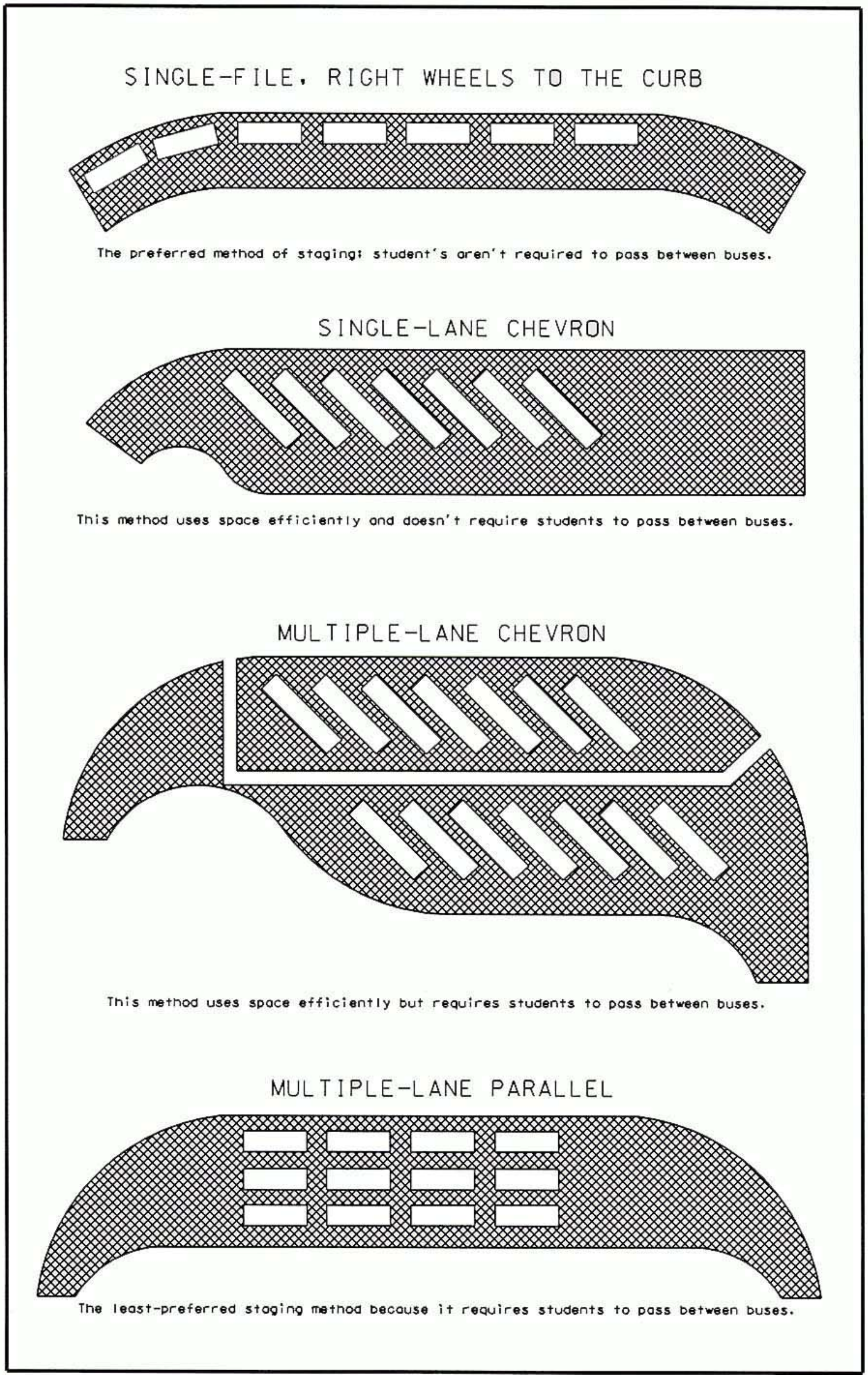


**Figure 19. Methods to Stage Buses at School Sites (35).**


**Figure 20. School Buses Staged in Preferred Method – Single-File Right Wheel to the Curb.**


**Figure 21. Buses Staged in Multiple Columns –
Avoid if Possible to Reduce Potential Conflicts.**

**Table 42. Guidelines for Design and Operation of Parent Drop-off/Pick-up Zones.**

| Guideline | Source(s) |
|---|---|
| Drop-off area design does not require backward movement by vehicles. | Katz, Okitsu, & Associates–California (*40*), Miami-Dade County–Florida (*41*), South Carolina DOE (*16*), Wake County–North Carolina (*33*), Arizona DOT (*24*), Douglas County–Colorado (*19*), North Carolina DOE (*12*), Missouri DOT (*38*), Minnesota DOT (*26*) |
| ★ Parent drop-off/pick-up zones should be one-way in a counterclockwise direction where students are loaded and unloaded directly to the curb/sidewalk. | Miami-Dade County–Florida (*41*), South Carolina DOE (*16*), Region of York–Canada (*18*), ITE Michigan Section (*20*), North Carolina DOE (*12*), California DOE (*13*), Missouri DOT (*38*), Minnesota DOT (*26*), Arizona DOT (*24*) |
| ★ Maximize fronting curb space as loading zone – provide an adequate driveway for lining up cars on site. | Katz, Okitsu, & Associates–California (*40*), North Carolina DOE (*12*), Safe School Design Guidelines (*47*), South Carolina DOT (*7*), 4286 Research (*6*) |
| ★ The length of the car pick-up zone can be determined by estimating the maximum number of cars likely to arrive at any one time. | New South Wales–Australia (*21*), Minnesota DOT (*26*), North Carolina DOT (*48*) |
| Prior to designing and laying out roads and parking, architects should consult with school administrators on: (1) number of cars dropping/picking up students; and (2) type of schedule (staggered or single opening time). | NSC (*27*), Arizona DOT (*24*) |
| Required drop-off and pick-up areas for schools (public or private) shall include at least: (1) 5 auto or (2) one auto space for every 50 students, whichever results in the greater number (no more than 12 spaces required). | City of Henderson–Nevada (*45*) |
| Drop-off areas should be at side entrances where site size/frontage permits so that the amount of pavement in front of schools at the street edge is reduced. | City of Mississauga–Canada (*15*) |
| ★ Do not load or unload students where they have to cross a vehicular path before entering the building. | North Carolina DOE (*12*) |
| ★ Short-term parking spaces should be identified past the student loading area and near the building entrance. | North Carolina State University (*49*) |
| ★ Parent loading should occur in designated zones to minimize pedestrian/vehicle conflicts. | 4286 Research (*6*) |
| ★ Student safety patrols and loading supervisors should be well trained and wear reflective safety vests. | 4286 Research (*6*), North Carolina State University (*49*) |
| ★ Traffic cones and other channelizing devices can be used to minimize pedestrian/vehicles conflicts. | 4286 Research (*6*) |

★ Guidelines with this star symbol also have a best practice section

### North Carolina Guidelines for Managing School Carpool Traffic

Some of the most comprehensive studies on the design and operation of drop-off/pick-up zones have occurred in the state of North Carolina. Researchers at the North Carolina State University (NCSU) collected data at 20 elementary schools on the loading process and associated queuing. Based on these studies, NCSU developed a *Best Practice for Managing School Carpool Traffic Schematic* (*49*). Figure 22 replicates this schematic and the corresponding guidelines. NCSU also produced a web-based school carpool decision support tool that provides procedural recommendations based on the common problems during school drop-off/pick-up times (*50*). For example, if the problem is that parents' vehicles are spilling back out of the site onto adjacent roads, implementation of a dual queue lane is recommended for the purpose of increasing storage capacity.

The North Carolina DOT also has the Municipal School and Transportation Assistance (MSTA) group dedicated to addressing safety concerns and traffic operations on school campuses and the surrounding state roadways (*8*). The MSTA, based on data collected at numerous schools throughout the state, has developed a design tool called the *School Traffic Calculator* (*48*). This tool estimates the morning and afternoon traffic loads and the corresponding maximum queue lengths that can be used to size the drop-off/pick-up zone.

### South Carolina Guidelines for On-Site Stacking Length

The South Carolina DOT also has a dedicated unit for handling school-related transportation issues. This unit recently published a document entitled *Guidelines for School Transportation Design* (*7*). This document contains information, provided in Table 43, regarding recommended on-site stacking lengths ranging from 800 to 1500 ft (244 to 458 m) depending on the school type and student population.

**Table 43. South Carolina DOT Recommendations for On-Site Stacking Length (*7*).**

| School Type | Student Population | Loop Drive Stacking Length (linear feet) (m) |
|---|---|---|
| Elementary | 200 – 600<br>600 – 1400 | 900 – 1200 (274.5 – 366)<br>1200 – 1500 (366 – 457.5) |
| Middle | 200 – 600<br>600 – 1200 | 900 – 1200 (274.5 – 366)<br>1200 – 1500 (366 – 457.5) |
| High | 400 – 800<br>800 – 2500 | 800 – 1200 (244 – 366)<br>1200 – 1500 (366 – 457.5) |
| Note: For high school populations greater than 2500 students, consider two separate student pick-up/drop-off loops. | | |

It should be noted that many of the school sites in South Carolina utilize a single two-way driveway (i.e., driveway serves as the entrance and exit) for the parent zone in order to increase the stacking length. This type of design is not as prominent in Texas schools where most sites have separate entrance and exit points, which can decrease the available stacking space.

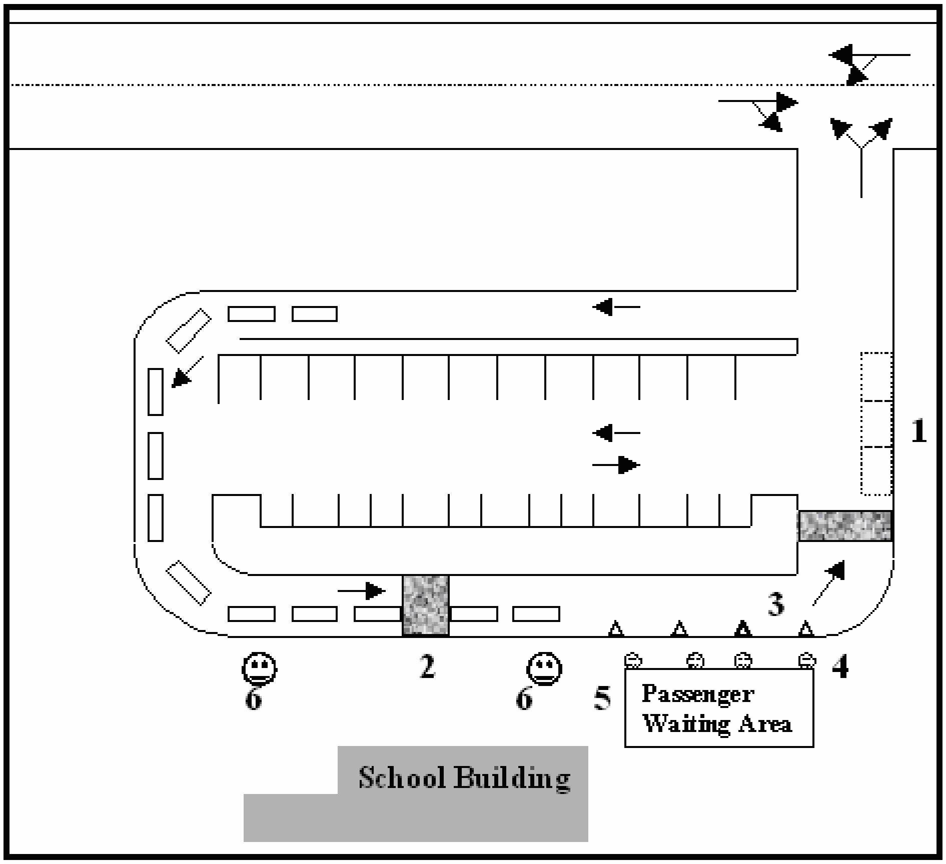


**Figure 22. Best Practice for Managing School Carpool Traffic Schematic (*49*).**

1. Short-term parking spaces should be identified past the student loading area and near the building entrance. These spaces can be identified by installing 'Visitor Parking' signs at the designated spaces and should be used for parents requiring an extended period of time to load or unload.
2. Crosswalks should be clearly marked with the first choice location being before the loading area and the second choice location after the loading area.
3. Make sure there is clear demarcation of the bays in the loading area.
   a. Paint the loading area into separate bays by installing 4-inch white solid pavement markings; each bay should be a minimum of 8 feet wide.
   b. The end bays should be at least a minimum length of 20 feet and the middle bays should be at least a minimum length of 30 feet. There should be a maximum of 4-5 bays.
4. Each bay should have its own safety assistant, trained by teachers at the beginning of every school year.
   a. One safety assistant should be present in each loading bay.
   b. This safety assistant is responsible for assisting the child(ren) into or out of their vehicle.
   c. Each safety assistant should wear an orange safety vest to provide visibility and to be easily identified by children and drivers.
5. At the end of the school day, have children wait in an organized fashion in the loading area or adjacent to it.
   a. Organization allows for children to pay attention and hear their name or number called.
   b. This helps to expedite the loading process by getting children to their vehicles quicker.
   c. It also helps the carpool time to be safe, as children will not be left to run around unsupervised.
6. Implement an Advanced Passenger Identification system using numbers or name cards placed in the windshield of the vehicle waiting in the carpool.
   a. This will require at least two people. The first person should stand five or six cars before the loading area and call out the names of the children over a walkie-talkie to the second person.
   b. The second staff member should be standing in the loading area itself relaying the names or numbers with a speaker system and directing students to the appropriate bay.

**Guideline 9: Provide an adequate driveway for stacking cars on site. (DESIGN)**

The research team found several examples of guidelines similar in nature to Guideline 9. Having adequate on-site stacking length to accommodate parent vehicles during the morning drop-off and afternoon pick-up operations is important. One of the primary focuses of the field studies during the 4286 project was to examine geometric design and operational practices in parent drop-off/pick-up zones. Researchers concentrated on collecting sufficient data at elementary schools in Texas to be able to validate the existing South Carolina (*7*) and North Carolina (*48*) guidelines for on-site stacking length.

The data collected during the 4286 field studies validated the *School Traffic Calculator* (*48*). It is good practice to use the afternoon pick-up data to predict the maximum queue of vehicles. The maximum queue length is then used to design and appropriately size the length needed in the parent driveway for lining up cars on site. The analysis of the average, maximum, and 95$^{th}$ percentile queue data at Texas schools did not produce any statistically significant models based on a regression analysis. The data did show that the observed maximum queue lengths were often well below the recommended on-site stacking lengths given in Table 43 and those predicted by the *School Traffic Calculator* (*48*).

It appears the South Carolina and North Carolina recommended on-site stacking lengths were more conservative compared to the Texas data. Based on this finding, the research team feels that the recommended on-site stacking lengths for Texas schools can be decreased and will still be able to meet the objective of Guideline 9 – providing an adequate driveway for stacking cars on site. Even though no statistically significant models were developed based on queue length, the research team had sufficient data to formulate recommended on-site stacking lengths for Texas elementary and middle schools. Based on the data from this project, researchers recommend the on-site stacking lengths for high schools contained in Table 43 for Texas because no new field data were collected at Texas high schools (*6*). Table 44 provides the recommended on-site stacking lengths for Texas schools.

**Table 44. Recommended Parent Drop-off/Pick-up Zone On-Site Stacking Length for Texas.**

| School Type | Student Population | Loop Drive Stacking Length (linear feet) (m) |
|---|---|---|
| Elementary | Less than 500<br>500 or more | 400 – 750 (122 – 229)<br>750 – 1500 (229 – 458) |
| Middle | Less than 600<br>600 or more | 500 – 800 (153 – 244)<br>800 – 1600 (244 – 488) |
| High (*7*) | 400 – 800<br>800 – 2500 | 800 – 1200 (244 – 366)<br>1200 – 1500 (366 – 458) |
| Note: For high school populations greater than 2500 students, consider two separate student pick-up/drop-off loops. | | |

***Best Practice for Application of Guideline 9***

Providing adequate on-site stacking length is important to the safety and operations of traffic within and around the school site.

*Examples to Avoid*

During the case studies and field studies, the research team observed many sites that did not provide adequate on-site stacking length. The inadequate on-site space to accommodate the queue led to spillback on adjacent roadways. Figure 23 shows an intermediate school site where both lanes of the northbound direction of the adjacent roadway were blocked by the queue of vehicles that backed up out of the parent drop-off/pick-up zone driveway. Figure 24 shows another example of queue spillback at an elementary school site.

**Figure 23. Example of Queue Spillback from the School Site.**

**Figure 24. Another Example of Queue Spillback from the School Site.**

**<u>Guideline 10</u>: Students should be loaded and unloaded on the right side directly to the curb/sidewalk. (DESIGN and OPERATIONS)**

***Best Practice for Application of Guideline 10***

The practice of loading and unloading students on the right side of vehicles directly to the curb/sidewalk is a prominent guideline found in numerous sources. If practiced, it is intuitive that pedestrian/vehicle conflicts in the parent drop-off/pick-up zone would be minimized because students would not be walking through driveways exposed to traffic.

*Examples of Good Practice*

Researchers observed several schools, particularly the elementary schools, with well-organized and efficient operations in the parent drop-off/pick-up zone. Figure 25 shows a good example of Guideline 10 where students were loaded directly from the vehicles to the curb/sidewalk.

**Figure 25. Good Examples of Students Loaded Directly from Vehicles to Curb/Sidewalk.**

*Examples to Avoid*

During the field studies, researchers encountered several examples where students were not loaded directly from vehicles to the curb/sidewalk in the parent drop-off/pick-up zone. Researchers observed most of these examples during the afternoon pick-up period when vehicles would park along the far curb of the loading zone, forcing students to cross the driveway to enter

**<u>Guideline 11</u>: Short-term parking spaces should be identified past the student loading area and near the building entrance. (DESIGN and OPERATIONS)**

the vehicles. This type of situation also violates the guideline that indicates that students should not have to cross a vehicle path before entering the building or after exiting the building. Figure 26 shows some pictures with examples of left-side loading, which increases the potential for pedestrian/vehicle conflicts.

**Figure 26. Examples to Avoid – Students Loaded on Left Side Away from Curb.**

***Best Practice for Application of Guideline 11***

The review of existing guidelines for the relative placement of short-term or visitor parking spaces at schools produced several different results. Several sources indicated that visitor parking should be combined with the parent drop-off driveway located near the main entrance and offices (*12*, *47*). The *Best Practice for Managing School Carpool Traffic Schematic* indicates that short-term parking spaces should be identified past the student loading area and near the building entrance (*49*). This source further recommends that these spaces can be identified by installing 'Visitor Parking' signs at the designated spaces and should be used for parents requiring an extended period of time to load or unload (see Figure 22). The findings from the 4286 field studies support Guideline 11 because placing the visitor spaces past the student loading area keeps the loading area clear of parked vehicles and results in safer and more efficient operations.

**<u>Guideline 12</u>: Parent loading should occur in designated zones to minimize pedestrian/vehicle conflicts. (OPERATIONS)**

***Best Practice for Application of Guideline 12***

One of the major aspects of the field studies was evaluation of pedestrian/vehicle conflicts in the parent drop-off/pick-up zones. The research team collected and classified pedestrian/vehicle conflicts that were observed during the morning and afternoon operations. Researchers analyzed these data and developed Guideline 12, which indicates that parent loading should occur in designated zones to minimize pedestrian/vehicle conflicts. Researchers also recommend supervision of morning drop-off and afternoon pick-up by school staff members, particularly at middle schools. The conflict data suggested that school type was a significant variable and that middle school sites had more conflicts than elementary sites. The majority of the elementary schools seemed to provide adequate supervision; however, several of the middle schools had little staff supervision of traffic and children, especially during the morning drop-off period.

*Examples to Avoid*

Researchers observed several violations of Guideline 12 at school sites. Several of the common scenarios for loading in non-designated areas are described in the list below:

- <u>Scenario 1</u>: loading occurs in a parking lot (typically occurs when the designated parent zone is congested and the parking layout is conducive to a parent cutting through and bypassing the queue) – see Figure 27. This type of loading is undesirable because children can be difficult to see when they emerge from rows of parked vehicles.
- <u>Scenario 2</u>: loading occurs across an adjacent street – see Figure 28. This type of loading is undesirable because parents and students often jaywalk across the street and the vehicles are often parked in no-parking zones.
- <u>Scenario 3</u>: loading occurs on the same side as the school on an adjacent street – see Figure 29. This type of loading is undesirable because the vehicles may block through traffic and are a potential safety hazard.

**Figure 27. Student Being Loaded in Parking Lot Instead of Designated Area.**

**Guideline 13: Student safety patrols and loading supervisors should be well trained and wear reflective safety vests. (PLANNING and OPERATIONS)**

**Figure 28. Student Being Loaded across the Adjacent Street Instead of Designated Area.**

**Figure 29. Students Being Loaded Off-Site along Right-of-Way of the Adjacent Street.**

***Best Practice for Application of Guideline 13***

Student safety patrols can be an effective tool for assisting children in and out of vehicles and helping the loading process in the parent drop-off/pick-up zone to be more efficient. The student safety patrols are more commonly utilized at elementary school campuses and often consist of children from the highest grade level at the school. Teachers, staff, and parent volunteers also often supervise loading operations, direct traffic, and assist children in and out of vehicles.

Researchers developed Guideline 13 based on the experience gained during the field studies. Members of the data collection team for each field study wore reflective safety vests to be visible to parents. Principals often commented that parents were on their best behavior during the field studies because of all the 'official' looking persons wearing the safety vests. It is important that members of student safety patrols and other adult loading supervisors are well trained and wear some type of reflective safety vests to enhance their visibility and give them an official look. Other equipment, besides vests, that can be helpful in creating a safe and efficient parent drop-off/pick-up zone are traffic control devices such as STOP paddles, whistles, and bullhorns.

*Examples of Good Practice*

During the field studies, researchers did not observe many of the student safety patrol and/or loading zone supervisor personnel wearing reflective safety vests. Figure 30 shows a picture of two appropriate reflective safety vests. Researchers observed more of the student safety patrol and loading zone supervisor personnel using other equipment such as STOP paddles to help direct traffic in the parent drop-off/pick-up zone. Figure 31 is a picture of a student safety patrol with a STOP sign mounted on the end of a pole (notice they are not wearing a reflective safety vest).

**Figure 30. Reflective Safety Vests Enhance Visibility.**


**Figure 31. Safety Patroller with STOP Pole Supervising Crosswalk in the Loading Zone.**

**<u>Guideline 14</u>: Traffic cones and other channelizing devices can be used to minimize pedestrian/vehicle conflicts. (DESIGN and OPERATIONS)**

*Examples to Avoid*

Researchers observed several sites where Guideline 13 was partially followed. Figure 32 shows a student patroller opening a door during the morning drop-off period. The list below provides an assessment of practices to avoid and those that were good for the type of situation in Figure 32:

- orange reflective safety vests were worn by each of the patrollers (GOOD),
- adult loading supervisor did not have a safety vest (AVOID), and
- patroller had to walk from the curb across a lane that was used for through traffic in order to open the vehicle door (AVOID).

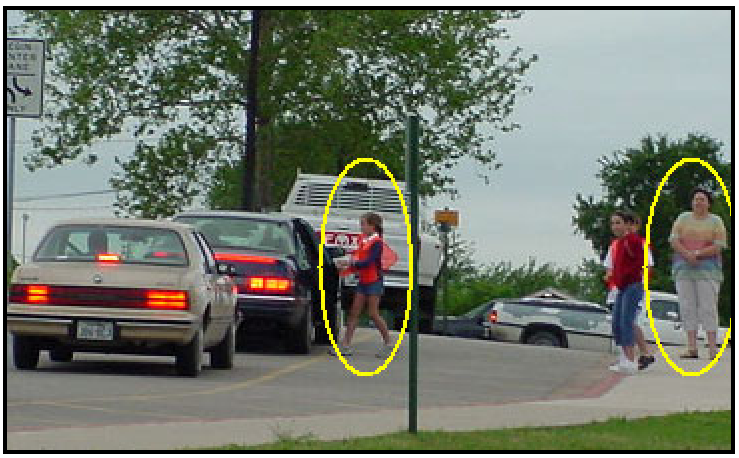

**Figure 32. Student Safety Patrol at Elementary School.**

***Best Practice for Application of Guideline 14***

The actual physical design of the school site plays a large role in dictating traffic circulation at the site. In addition to physical layout and geometric elements (e.g., driveway width – number of lanes) many schools utilize traffic cones and other channelizing devices to control on-site traffic patterns. Researchers observed several innovative practices, primarily placement of traffic cones, that schools used for traffic control and access restriction (*6*). The field conflict studies found that as the number of lanes in the parent zone increased, the pedestrian/vehicle conflicts also increased. This finding led to the development of Guideline 14, which indicates that traffic cones or other channelizing devices (e.g., gates, barrels, etc.) can be used to minimize pedestrian/vehicle conflicts in the parent zone and throughout the entire site.

*Examples of Good Practice*

Researchers observed several examples of good practices of Guideline 14 at school sites. Several of the common good practices are described in the list below:

- Channelizing practice 1: placement of cones to create a single-lane queue in the parent drop-off/pick-up zone (see Figure 33). This practice is desirable because it minimizes the potential for pedestrian/vehicle conflicts; however, it can only be used practically if there is enough capacity to process the queue efficiently using only one through lane.
- Channelizing practice 2: placement of cones in the middle lane (labeled as 2) of a three-lane loading zone to create a median area that acts like a second curb lane (see Figure 34). This practice is generally not favored because children have to cross an active driveway lane. The desirable part is that vehicles can unload students in two lines – one from the curb adjacent to the entrance (lane 1) and one from the far lane (lane 3), which creates additional on-site stacking space. However, this type of solution can improve operations and safety if well supervised (e.g., use a loading supervisor and have students unloaded in the far lane walk to the on-site crosswalk before crossing the curbside lane).
- Channelizing practice 3: placement of cones to restrict vehicles, typically parent vehicles, from accessing a zone designated for other uses (e.g., parking, bus loading, etc.). Figure 35 and Figure 36 show several examples of this practice. This practice is desirable because it is a relatively easy way to restrict traffic flow and circulation.

**Figure 33. Placement of Traffic Cones to Create a Single-Lane Queue.**


**Figure 34. Placement of Traffic Cones to Create a Dual-Lane Queue.**

**Figure 35. Traffic Cones Placed to Reinforce Turn Restrictions from Exit Driveway.**

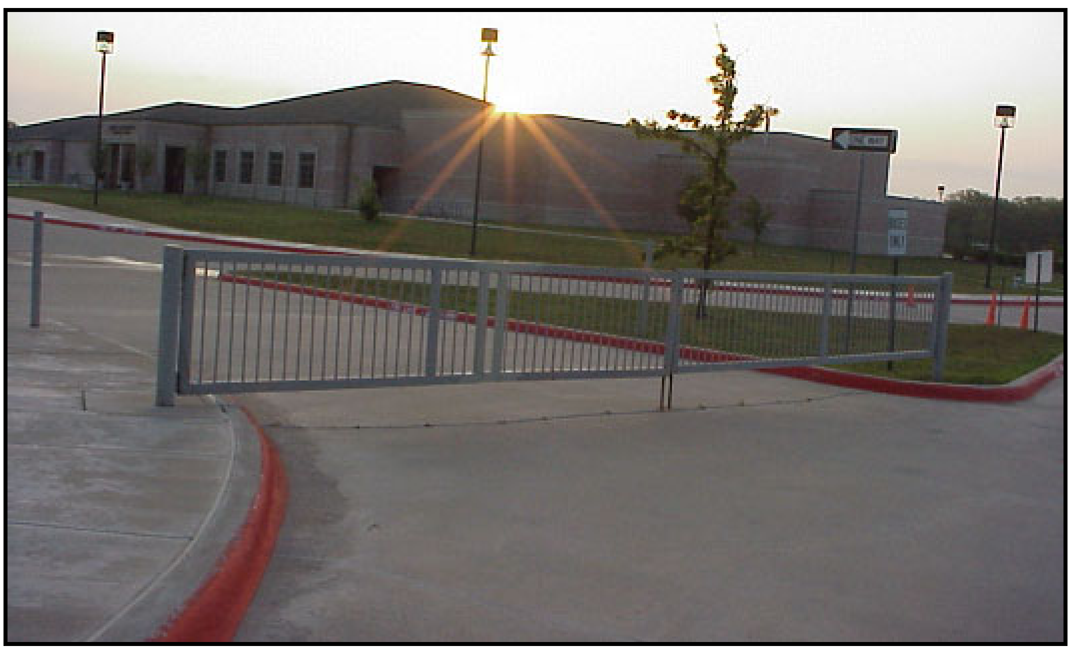

**Figure 36. Traffic Gate to Restrict Access from Parent Zone to a Pedestrian/Bicycle Zone.**

## BICYCLE AND PEDESTRIAN GUIDELINES FOR SCHOOLS

A number of comprehensive studies and programs have been dedicated to bicycle and pedestrian issues for schools. The Safe Routes to School is a program oriented toward pedestrian and cyclist safety that has grown internationally. Table 45 describes the most prominent bicycle and pedestrian guidelines reviewed by the research team.

**<u>Guideline 15</u>: Provide safe crosswalks with crossing guards. (OPERATIONS)**

**Table 45. Pedestrian and Bicycle Guidelines for School Sites.**

| Guideline | Source(s) |
|---|---|
| ★ Provide safe crosswalks with crossing guards (use adult crossing guard/safety officer at nearby intersections with sizable traffic volume). | Katz, Okitsu, & Associates–California (*40*), Miami-Dade County–Florida (*41*) |
| Pedestrian and vehicle conflicts should be minimized (do not mix them together). | Miami-Dade County–Florida (*41*), City of Mississauga–Canada (*15*), North Carolina DOE (*12*), Missouri DOT (*38*) |
| ★ There should be standard and well-maintained sidewalks and/or a designated safe path leading to the school. | Miami-Dade County–Florida (*41*), South Carolina DOE (*16*), Douglas County–Colorado (*19*), ITE Michigan Section (*20*), Arizona DOT (*24*) |
| Develop safe walk/bike routes/maps leading to school. | Too many to list |
| Pedestrians from student parking areas shall not be allowed to cross school drives to reach the school building. | South Carolina DOE (*16*), North Carolina DOE (*12*) |
| ★ Facilities should be provided for bicycle access and storage. | Wake County–North Carolina (*33*), City of Mississauga–Canada (*15*) |
| Except at pick-up locations, sidewalks shall be kept a minimum of 5 ft (1.525 m) away from roadways. | Seminole County–Florida (*39*) |
| Student pedestrian traffic should not be mixed with vehicle traffic. | School Bus Fleet (*35*) |
| No pedestrian crosswalks should cross through a loading area. | School Bus Fleet (*35*), NSC (*27*), California DOE (*13*), Missouri DOT (*38*) |
| Students approaching buildings on foot should not have to cross main traffic arteries. | North Carolina DOE (*12*) |
| Use two adult crossing guards at wide street crossings. | City of Phoenix–Arizona (*25*) |
| ★ Create wider paved student queuing areas at major crossings and paint sidewalk 'stand-back lines' to show where to stand while waiting. | City of Phoenix–Arizona (*25*) |

★ Guidelines with this star symbol also have a best practice section

The research team also found several other sources with valuable information on planning and designing student pedestrian facilities including:

- A Guidebook for Student Pedestrian Safety (*51*),
- Planning and Implementing Pedestrian Facilities in Suburban and Developing Rural Areas (*52*), and
- Recommendations to Reduce Pedestrian Collisions (*53*).

***Best Practice for Application of Guideline 15***

Many studies and programs, including Safe Routes to School, are currently geared to promoting safety for pedestrians, bicycles, and other non-motorized modes of getting to and from school. There are several key benefits typically cited by these studies and programs: (1) lowered vehicle demand and (2) exercise for the children. One of the good ways to encourage pedestrian and bicycle access is to provide safe crosswalks with crossing guards (Guideline 15). Some cities, notably the City of Phoenix, Arizona, have the guideline that two crossing guards be used at wide street crossings (see Figure 37).


**Figure 37. Two Adult Crossing Guards for Wide Streets.**

*Example to Avoid*

Researchers observed several practices that violated Guideline 15. Figure 38 shows an example of a situation where a crosswalk is not available to cross an adjacent street, which causes a parent and child to jaywalk across the roadway to their neighborhood across the street.

**Figure 38. Jaywalking across Street Adjacent to the School Site – No Marked Crosswalk.**

The need for adequate supervision of crosswalks is not reserved for those across streets adjacent to the site. It is also important to consider on-site crosswalks, particularly those across entrance driveways where vehicles may turn in conflict with pedestrians or bicyclists.

**<u>Guideline 16</u>: There should be well-maintained sidewalks leading to the school. (DESIGN, PLANNING, and OPERATIONS)**

***Best Practice for Application of Guideline 16***

Sidewalks and designated paths leading to schools promote safe access to non-motorized modes of travel. Many sources advocate that there should be well-maintained sidewalks and/or a designated safe path for students to use to get to and from school. Provision of pedestrian amenities such as sidewalks is especially important for access to elementary school sites.

The TxDOT *Roadway Design Manual* offers some guidance on design criteria for sidewalks (6 to 8 ft [1830 to 2440 mm], 5 ft [1525 mm] minimum) and borders (20 ft [6100 mm] for arterials and collectors, 15 ft [4575 mm] minimum) (*54*). The manual states that sidewalks are "applicable for commercial areas, <u>school routes</u>, or other areas with concentrated pedestrian traffic," which supports Guideline 16. The manual also discusses buffers in Section 2. It states:

> **Sidewalk Location.** For better pedestrian comfort, especially adjacent to high-speed traffic, it is desirable to provide a buffer space between the traveled way and the sidewalk. For curb and gutter sections, a buffer space of 3 ft [915 mm] or greater between the back of the curb and the sidewalk is desirable. For rural sections without curb and gutter, sidewalks should be placed between the ditch and right-of-way line if practical (*54*).
>
> **Sidewalk Width.** Sidewalks should be wide enough to accommodate the volume and type of pedestrian traffic expected in the area. The minimum clear sidewalk width is 5 ft [1525 mm]. Where a sidewalk is placed immediately adjacent to the curb, a sidewalk width of 6 ft [1830 mm] is desirable to allow additional space for street and highway hardware and allow for the proximity of moving traffic. Sidewalk widths of 8 ft [2440 mm] or more may be appropriate in commercial areas, along <u>school routes</u>, and other areas with concentrated pedestrian traffic (*54*).

*Example of Good Practice*

Figure 39 is a picture of well-maintained sidewalks on both sides of a street near a school site. These sidewalks were designed with the recommended 3-ft buffer from the adjacent roadway.

*Example to Avoid*

Researchers performed studies at several campuses that were located on two-lane high-speed roadways. These sites typically did not have sidewalks, and less than 1 percent of their total enrollment walked or biked to and from school. Figure 40 shows a picture of an elementary school site located along a farm to market (FM) roadway with a typical posted speed limit of 55 miles per hour (mph) – 35 mph during school hours. There are no sidewalks at this site and virtually all of the access to the site by students is by parent vehicles or school buses.

**Guideline 17: Create wider paved student queuing areas at major crossings and paint sidewalk "stand-back lines" to show where to stand while waiting. (DESIGN)**

**Figure 39. Roadway near School with Well-Maintained Sidewalks on Both Sides of Street.**

**Figure 40. School Site Located on Two-Lane High-Speed Roadway – No Sidewalks.**

***Best Practice for Application of Guideline 17***

In 2001, the City of Phoenix Transportation Department formed a School Safety Task Force. This group developed approximately 20 recommended actions based on their review of safety and operations issues around schools. One of the recommended actions was to create wider student queuing areas at major crossings and paint sidewalk "stand-back lines" (Figure 41) to delineate where students should stand while waiting at crosswalks. Figure 42 shows a picture taken at a crossing in Phoenix before a student queuing area was installed. Figure 43 shows the same crossing after the wider student queuing area was installed. The benefit of having the students farther from the adjacent roadway is evident based on the before and after pictures.

Figure 41. Stand-Back Line at Major Crossing.

Figure 42. Students on Sidewalk at Crossing before Installation of Paved Queuing Area.

Figure 43. Students Waiting in New Queuing Area Away from Crossing.

**Guideline 18: Facilities should be provided for bicycle access and storage. (DESIGN)**

***Best Practice for Application of Guideline 18***

Guideline 18 relates to the provision of facilities for bicycle access and storage at school sites. Bicycle access facilities include bicycle lanes (Figure 44), shared lanes (produced by providing a wider lane for the inside travel lane), and in some cases trails on separate right-of-way (ROW). In addition, access needs to be provided between the roadway or trail and the bike storage facility. For most schools, bicyclists are required to walk their bike once on the school site. Bike storage facilities range from bicycle racks (Figure 45) to concrete pads with fencing (Figure 46).


**Figure 44. Bicycle Lane in Front of Middle School Site.**

**Figure 45. Example of Typical Rack for Bicycle Storage.**

**Figure 46. Fenced Concrete Pad Adjacent to School Building for Bicycle Storage.**

## GUIDELINES FOR SCHOOL ACCESS DRIVEWAYS

Researchers examined guidelines related to school access driveways. The guidelines fell into one of the following topic areas: (1) number, (2) spacing, (3) location, or (4) layout and design.

### Guidelines for Number of School Access Driveways

The research team gathered information on existing guidelines related to the number of driveways to adequately service the school. Researchers found most of the guidelines in local and state access management manuals. Several of the guidelines were not specific to the number of school driveways, just the number of driveways to serve general land uses. Table 46 provides information on the guidelines specific to school sites for the number of school access driveways.

### Spacing Guidelines for School Access Driveways

Researchers collected information on existing guidelines for the spacing of school driveways. Most were found in local and state manuals. Almost all the guidelines treated schools the same as other land uses for driveway spacing. Table 46 gives information on guidelines for driveway spacing for schools. Six hundred feet was cited by two sources as the ideal spacing to allow for adequate left-turn lane development (Figure 47). TxDOT has a draft Access Management Manual that addresses intersection/driveway spacing (*55*). The manual refers to spacing between driveways as connection spacing. The draft manual is online at the TxDOT website (*55*).

### Location Guidelines for School Access Driveways

Researchers found several existing design guidelines for how far school access driveways must be offset from the nearest intersection. As with driveway frequency and spacing, researchers collected most of the existing guidelines from local and state access manuals. Secondary sources were the AASHTO *Policy on Geometric Design* (*56*), DOT design manuals, and the *Manual on Uniform Traffic Control Devices* (MUTCD) (*57*). The following list gives a range of guidelines for the minimum offset distance for school access driveways from adjacent intersections:

**<u>Guideline 19</u>: School driveways should conform to TxDOT design and access management guidelines for number, spacing, location, and layout. (DESIGN)**

- New Hampshire DOT – 100 ft (30.5 m),
- South Carolina DOT – 75 to 100 ft (22.875 to 30.5 m), and
- New York DOT – 2W + 15 ft (4.575 m); where W is the width of the nearby intersection.

Some agencies indicated that queuing and operational analyses are performed on a case-by-case basis to determine the necessary offset distance for a driveway from the nearest intersection.

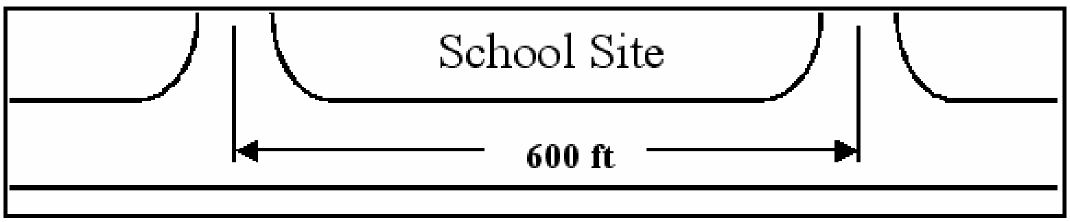


**Figure 47. Ideal Spacing of School Driveways for Adequate Left-Turn Lane Development.**

**Guidelines for the Layout and Design of School Access Driveways**

Researchers uncovered existing guidelines for the layout and design of school access driveways. These guidelines included recommended values for minimum turning radius and lane widths for driveways. Survey respondents cited several sources including access management/driveway manuals, AASHTO *Policy on Geometric Design* (*56*), and DOT design manuals. Table 46 provides four specific values for driveway designs. The South Carolina DOT has guidelines for layout and design for two-way car (Figure 48) and two-way bus (Figure 49) school driveways.

One source had a guideline that driveway intersection angles should be between 75 and 90 degrees because skewed driveway and street intersections can cause problems (*36*). Furthermore, several sources advocated that it is often desirable for exit driveways to have two outbound lanes (Figure 50), one for left-turning vehicles and one for right turners (*36*, *26*). This helps reduce congestion, because the right-turning cars and/or buses can proceed while the left turners are waiting for the traffic from the right to clear. Several agencies also had recommended practices for the relative placement of school access driveways. Table 46 also provides the guidelines for relative placement of driveways at school sites and their corresponding source.

As previously mentioned, TxDOT has a draft Access Management Manual that addresses driveway-related issues (*55*). Guideline 19 indicates that school driveways, particularly those with access to state-maintained roadways, should conform to TxDOT design and access management guidelines for number, spacing, location, and layout. The draft manual is online at the TxDOT website (*55*).

**Table 46. Driveway-Related Guidelines for School Sites.**

<table>
<tr><th colspan="2">Guidelines for the Number of Driveways</th><th>Source</th></tr>
<tr><td colspan="2">No more than three for any parcel (assuming minimum spacing is met).</td><td>New Hampshire DOT–Survey Response</td></tr>
<tr><td colspan="2">Typically allow for two entrances – one for bus traffic and the other for student, teacher, and parent drop-off/parking.</td><td>Delaware DOT–Survey Response</td></tr>
<tr><td colspan="2">Minimum of two – one for buses and one for parent drop off.</td><td>Maryland DOT–Survey Response</td></tr>
<tr><td colspan="2">Discourage all direct access for schools but the Colorado State Highway Access Code controls if there are driveways permitted.</td><td>Colorado DOT–Survey Response</td></tr>
<tr><td colspan="2">• Elementary – two or three depending on if there is all-day kindergarten<br>• Middle – two<br>• High – three or four depending on student population</td><td>South Carolina DOT (*7*)</td></tr>
<tr><th colspan="2">Guidelines for the Spacing of Driveways</th><th>Source</th></tr>
<tr><td colspan="2">Use rule of thumb of 10 times operating speed as a minimum spacing.</td><td>Virginia DOT–Survey Response</td></tr>
<tr><td colspan="2">300 to 400 ft (91.5 to 122 m) is desirable.</td><td>Delaware DOT–Survey Response</td></tr>
<tr><td colspan="2">600 ft (183 m) – distance required to accommodate the installation of a properly designed left-turn lane.</td><td>Minnesota DOT (*26*)<br>South Carolina DOT (*7*)</td></tr>
<tr><th colspan="2">Guidelines for the Layout and Design of Driveways</th><th rowspan="2">Source</th></tr>
<tr><th>Minimum Radius (ft)</th><th>Recommended Lane Width (ft)</th></tr>
<tr><td>50 (15.25 m)</td><td>12 (3.66 m)</td><td>Mississippi DOT–Survey Response</td></tr>
<tr><td>50 (15.25 m)</td><td>12 (3.66 m)</td><td>Maryland DOT–Survey Response</td></tr>
<tr><td>35 (10.675 m)</td><td>16 (4.88 m)</td><td>Delaware DOT–Survey Response</td></tr>
<tr><td>25 car / 40 bus</td><td>12 with 18 throat entrance</td><td>South Carolina DOT (*7*)</td></tr>
<tr><td>30 car / 50 bus</td><td>12 + increased on curves</td><td>Missouri DOT (*38*)</td></tr>
<tr><th colspan="2">Guidelines for the Relative Placement of Driveways</th><th>Source</th></tr>
<tr><td colspan="2">Locate the bus area so that buses exit upstream of automobiles and gain priority, thereby reducing delay.</td><td>Douglas County–Colorado (*19*)</td></tr>
<tr><td colspan="2">The one-way driveway into the school should be located at the far left side from the direction where the majority of traffic is coming from such as a city. In addition, the through roadway serving the one-way into the school should have a left- and right-turn lane. In this situation, the left-turn traffic only has to yield to the opposing through traffic lane and the right-turn lane. The majority of those exiting the school area will be turning right, creating only one vehicle conflict.</td><td>Minnesota DOT (*26*)</td></tr>
<tr><td colspan="2">Driveways should not be located too close to nearby intersections. Doing so will create offset or dogleg intersections with other streets or high-volume driveways. Offset intersections can create erratic patterns and detract from drivers' abilities to look out for pedestrians.</td><td>School Bus Fleet (*36*)</td></tr>
</table>

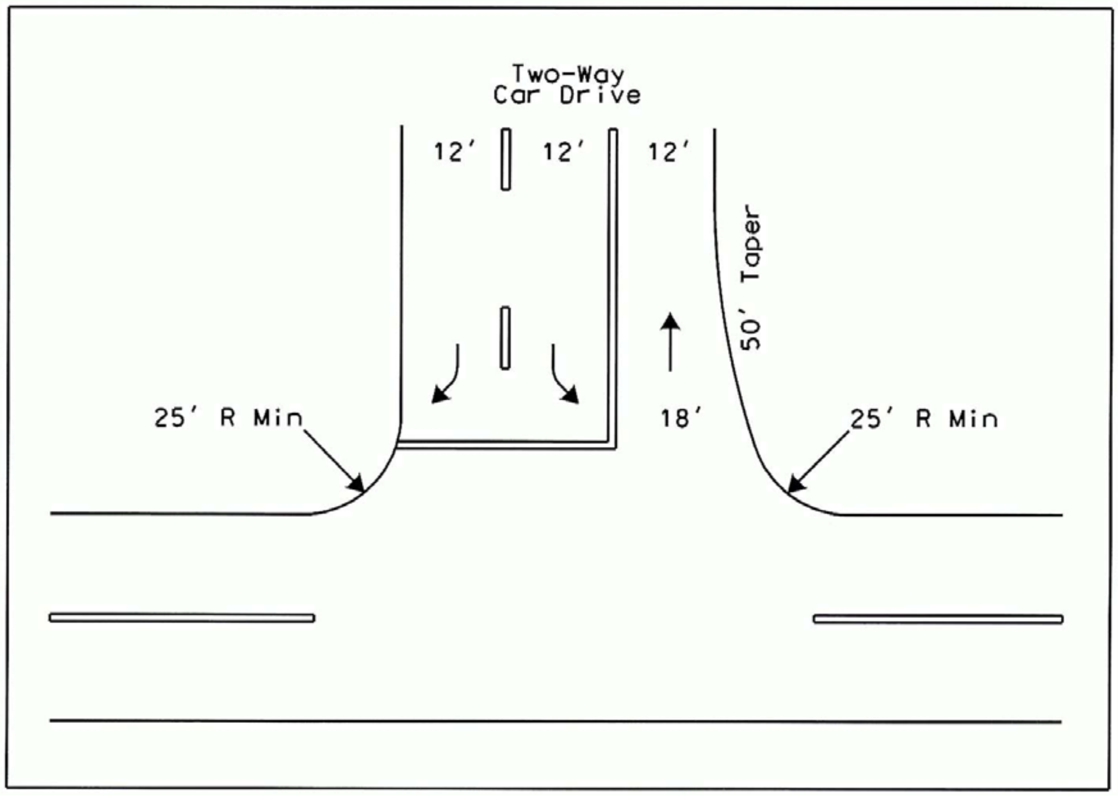


**Figure 48. South Carolina DOT Layout and Design for Two-Way Car Driveway (7).**

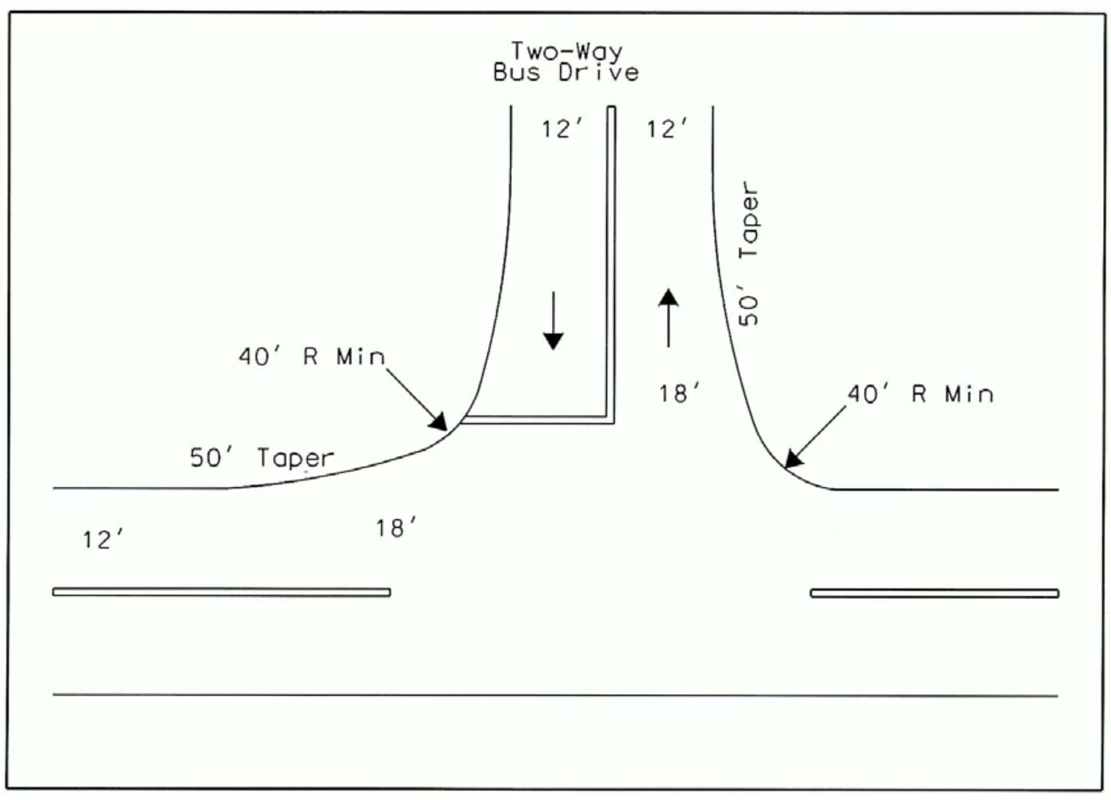


**Figure 49. South Carolina DOT Layout and Design for Two-Way Bus Driveway (7).**

**<u>Guideline 20</u>: Utilize the existing Texas Department of Transportation design guidelines for left- and right-turn lanes and apply these to school sites. (DESIGN)**

**Figure 50. School Exit Driveway with Two Lanes for Left and Right Turn Movements.**

## GUIDELINES FOR TURNING LANES FOR SCHOOL SITES

Many agencies have existing guidelines for the installation and design of turn lanes for access to adjacent sites. The research team gathered information on existing design criteria or guidelines for the installation of turn lanes/bays at new and/or existing school sites. The majority of those with guidelines cited a state manual (access management, design, and/or driveway) as a primary source for their turning lane criteria. One state customarily installs turn lanes with a minimum length of 300 ft (91.5 m) at all school driveways, and another recommends construction of turn lanes at most new school sites statewide.

Another group of DOT representatives cited the AASHTO *Policy on Geometric Design of Streets and Highways* (*56*) – also known as the Green Book – as a primary source for their turning lane criteria. One agency indicated that they use the AASHTO turn lane criteria in Table 9-75 of the Green Book; however, they reduce the advancing volume by 50 percent when dealing with school site issues. Another agency routinely installs turn lanes at all school driveways and uses the AASHTO design criteria.

Three agencies with existing guidelines indicated that they require a traffic impact study, which dictates when turn lanes are installed. One of these agencies also requires the school district to fund and construct the turn lane(s) if they are warranted. In summary, many of the guidelines for required length and taper of left-turn lanes converged on 500 to 600 ft (152.5 to 183 m) as the distance needed to develop an adequate left-turn lane. Most of the warrants for turn lanes were based primarily on volume and speed as criteria.

### *Best Practice for Application of Guideline 20*

The guidelines contained in the TxDOT *Roadway Design Manual* should be used for the design of left- and right-turn lanes to school sites (*54*). Installation of turn lanes is particularly important to consider when school sites are located on high-speed roadways where separation of turning movements from through traffic provides operational and safety benefits. School sites generate fairly substantial peaks of traffic during relatively short time periods – average of 30 minutes in the morning and 30 minutes in the afternoon. These peaks must be considered in the design and layout of turn lanes to school sites.

The research team observed several common problems related to turn lanes at school sites. The first problem was that no turn lanes were present and the associated queuing caused safety and operational problems. Figure 51 shows a situation where right-turn traffic into the school driveway is using an unpaved shoulder as the de facto right-turn lane so that through traffic is not blocked on the adjacent roadway. The second problem was that turn lanes did not have adequate length to accommodate the vehicles arriving to turn into the school site. Figure 52 shows an example of the second problem where the left-turn lane is experiencing spillback onto the through lane because of the high traffic demand and the inadequate length. Figure 53 shows a newly installed two-way left-turn lane in front of an elementary school.

**Figure 51. Traffic Queue on Unpaved Shoulder – Right-Turn Lane Might Be Warranted.**

**Figure 52. Queue in Left-Turn Lane Starting to Spillback and Block Through Lane.**

**Guideline 21: All site and regulatory signage and markings within school sites shall comply with the Texas Manual on Uniform Traffic Control Devices. (DESIGN)**

**Figure 53. Newly Installed Left-Turn Lane in Front of an Elementary School.**

## TRAFFIC CONTROL, MARKING, AND SIGNING GUIDELINES

In the review of existing guidelines for traffic control, markings, and signing for school sites, the research team concentrated on guidelines and recommended practices dealing with on-site issues at schools. As noted in the case studies, the research team observed a wide variety of traffic control, markings, and signing at the school sites in Texas.

Table 47 lists the on-site guidelines for traffic control, markings, and signing for school sites. The majority of the existing guidelines related to signing issues. Two sources have a guideline that all school site and regulatory signage comply with the MUTCD (*57*). Another agency requires the installation of truck exclusion signs around the school area.

### *Best Practice for Application of Guideline 21*

The MUTCD is thought of in the traffic engineering profession as the definitive source for guidance on signing, pavement marking, and traffic control. Guideline 21 advocates that all site and regulatory signage and markings within school sites shall comply with the Texas MUTCD (*58*). If traffic control devices, signs, and pavement markings with school sites comply with the Texas MUTCD, it is more likely that drivers, pedestrians, and bicyclists will operate in a uniform manner consistent with off-site operations.

**Table 47. Traffic Control, Markings, and Signing Guidelines for School Sites.**

| Guideline | Source(s) |
|---|---|
| Restrict turning movements during school beginning/ending periods to reduce congestion/conflicts. | Miami-Dade County–Florida (*41*) |
| Install truck exclusion signs around the school area. | Miami-Dade County–Florida (*41*) |
| ★ All site and regulatory signage and markings shall comply with the Texas Manual on Uniform Traffic Control Devices (TMUTCD). | Seminole County–Florida (*39*), ITE Michigan Section (*20*), School Bus Fleet (*36*) |
| Curbs (flush ribbon or raised) at bus and vehicle drop-off/pick-up locations shall be painted yellow. | Seminole County–Florida (*39*) |
| Sign height from the ground is a minimum of 7 ft (2.135 m) for a single sign and 5 ft (1.525 m) for a double sign. | School Bus Fleet (*35*) |
| Justify a traffic signal (where vehicle volumes warrant) during the peak periods at secondary school access to or from an arterial. | Douglas County–Colorado (*19*) |
| All curbside parking should be prohibited in advance of school pedestrian crossings, at driveways, and at school building entrances. | New South Wales–Australia (*21*), ITE Michigan Section (*20*) |
| Where necessary, traffic control devices should be provided to assist school traffic in entering the regular traffic flow. | NSC (*27*) |
| It is recommended that all roadways, with the exception of loading and unloading zones, on school properties be signed 'No Parking or Standing, Fire Lane'. | ITE Michigan Section (*20*) |
| Provide 'Buses Only' and 'No Entry' signage at ends of the bus loop. | Kentucky DOE (*37*) |
| Paint SCHOOL pavement stencil on each high-speed crossing approach. | City of Phoenix–Arizona (*25*) |

★ Guidelines with this star symbol also have a best practice section

*Example to Avoid*

The research team observed several common violations of Texas MUTCD guidelines related to signs and pavement markings at school sites. Some of the common violations included:

- Use of yellow paint for pavement markings and directional arrows – Figure 54 provides an example of yellow crosswalk pavement markings at an elementary school.
- Signs mounted below standard levels – Figure 55 shows a sign mounted below the 5-ft minimum (person next to sign is approximately 6 ft tall).
- Signs with inconsistent text color – Figure 56 shows a 'School Buses Only' sign that uses green paint for the text instead of the black.
- Non-standard signs – Figure 57 shows a picture of a standard 'Do Not Enter' sign on one side and a non-standard 'Do Not Enter' sign on the other.


**Figure 54. Example of Yellow Markings for On-Site Crosswalk at Elementary School.**


**Figure 55. Sign on Elementary Site Mounted Several Feet below the Standard Height.**


**Figure 56. Sign at Elementary Site with Non-Standard Font Color and Message.**

**Figure 57. Example of Non-Standard Sign at Elementary School Site.**

## GUIDELINES FOR PARKING DESIGN AND LAYOUT AT SCHOOL SITES

The research team identified only a few sources with existing guidelines for school parking facilities. Table 48 lists the guidelines and associated sources for parking requirements and design at school sites. The most prominent guideline from the identified sources was that parking areas for students, staff, and visitors should be separated from loading zones. There were several guidelines that seemed to conflict with each other. The most obvious conflict was that one guideline suggested that all parking areas be separate and not part of any on-site driveway, whereas another advocated that visitor parking be combined with the parent drop-off driveway.

The research team also found several guidelines for parking requirements (i.e., size and/or number of spaces) at schools. One guideline was general and suggested that there should be one parking stall for each staff member and an additional 10 percent of that total for visitor parking (*19*). A similar guideline indicated that 2.25 spaces should be provided for each teacher station (this includes spaces for staff and visitors) (*13*). One agency has a guideline for parking at high schools that suggests that a parking capacity for student lots be calculated based on a minimum of 50 percent of the student enrollment (*13*).

As indicated in the interviews conducted with school district personnel and architects, many utilize local requirements, typically from a municipality, for the parking requirements at schools. The local requirements for total number of spaces often vary based on school type (i.e., high vs. middle vs. elementary schools). Most school architects also use standard graphics software packages for the actual design of parking spaces (angled, parallel, or conventional) and lots.

**Table 48. Parking Requirements and Design Guidelines for School Sites.**

| Guideline | Source(s) |
|---|---|
| Separate parking areas (student, staff, visitors, and buses) from student loading/unloading areas. | South Carolina DOE (*16*), Miami-Dade County–Florida (*41*), Douglas County–Colorado (*19*), New South Wales–Australia (*21*), ITE Michigan Section (*20*), North Carolina DOE (*12*) |
| Peninsula and detached islands in parking areas shall have 6 inch (15.2 cm) raised curbing. | Seminole County–Florida (*39*) |
| When the island area exceeds 1000 $ft^2$ (93 $m^2$), the curb shall taper down to a flush ribbon curb for 6 ft (1.83 m) in length at a location that is inaccessible to vehicles yet allows for mower access to the island. | Seminole County–Florida (*39*) |
| Staff parking areas can be located with less concern for accessibility than other areas because staff members generally arrive before and leave after students and are generally more experienced in traffic. | School Bus Fleet (*35*) |
| In the construction of parking areas, it might be advantageous if only the visitor parking spaces were close to the school. Care should be exercised in the placement of these areas to preclude the visitor from crossing the school bus traffic pattern. | NSC (*27*), North Carolina DOE (*12*) |
| Short-term parking spaces should be identified past the student loading area and near the building entrance. Installing 'Visitor Parking' signs can identify these spaces. | North Carolina State University (*49*) |
| Prior to designing and laying out parking lots, architects should consult with school administration on the total number of pupils and staff. | NSC (*27*) |
| There should be one stall for each staff member and an additional 10% of that for visitor parking. | ITE Michigan Section (*20*) |
| Buildings should be parallel to the street and have parking located at the side or rear of the property. | City of Mississauga–Canada (*15*) |
| Avoid parking cars parallel to curbs. This can cause traffic congestion and create a serious safety problem if students should step into traffic. | North Carolina DOE (*12*) |
| Provide an adequate turning radius (45 ft [13.725 m] minimum outside and 26 ft [7.93 m] minimum inside) within parking lots. | North Carolina DOE (*12*) |
| Combine visitor parking with the parent drop-off driveway located near the main entrance and administrative office. | North Carolina DOE (*12*) |
| Avoid driveways that allow parents to take shortcuts through parking lots to drop off or pick up students. This type of parking layout encourages students to cross vehicular paths. | North Carolina DOE (*12*) |
| Provide 2.25 parking spaces for each teacher station (this includes space for staff members and visitors). | California DOE (*13*) |
| Many school districts provide student lots with a minimum parking capacity calculated on 50 percent of the school enrollment. | California DOE (*13*) |
| Locate kitchen/custodial staff parking at service/kitchen area. | Kentucky DOE (*37*) |

# CHAPTER 6. SCHOOL SITE PLAN REVIEW CHECKLIST

This chapter presents a checklist tool that TxDOT engineers and other interested stakeholders can use to review school site plans based on the guidelines contained in Chapter 5. Researchers intend for this checklist to facilitate greater use of the existing Precious Cargo Program, which encourages early cooperation and planning between TxDOT, school districts, architects, and other stakeholders.

## TYPES OF SITE PLAN REVIEW

There are two basic types of site plan review performed as part of the TxDOT Precious Cargo Program:

1. existing school campus with traffic flow problems or other safety issues within or around the school site, or
2. new school campus.

The research team developed questionnaires to facilitate planning between TxDOT and school district representatives for both types of site plan review. Appendix A provides the questionnaire to use when the review is of an existing school campus. The questionnaire to use for a new school campus is in Appendix B.

## SITE PLAN REVIEW CHECKLIST

Table 49 provides the site plan review checklist. The research team based this checklist on the 21 guidelines in Chapter 5 contained in text boxes. TxDOT engineers and other interested stakeholders can use this checklist and other guidelines contained in Chapter 5 to review site plans for existing or new school sites.

**Table 49. Site Plan Review Checklist.**

| Guideline # | Review Question | Answer | | Comments |
|---|---|---|---|---|
| | | Yes | No | |
| 1 | Is the building setback a sufficient distance to provide adequate site storage? | | | |
| 2 | Is the school site located on a high-speed roadway? (if yes, please comment) | | | |
| 3 | Is access provided from more than one direction to the immediate vicinity of the site (i.e., from at least two adjacent streets)? | | | |
| 4 | Is the school site situated where the road alignment provides good visibility? | | | |
| 5 | Are the physical routes provided for the basic modes (buses, cars, pedestrians, and bicycles) separated from each other on the site? | | | |
| 6 | Does overhead cover or soffit protect all primary building entrances for students? | | | |
| 7 | Has the school site and proposed plans been reviewed by the proper road agency? | | | |
| 8 | Are school buses going to be staged single-file right wheel to the curb in the loading zone? | | | |
| 9 | Is there adequate driveway stacking length for lining up cars on site – see Table 44? | | | |
| 10 | Are students loaded and unloaded on the right side directly to the curb/sidewalk in the bus and parent loading zones? | | | |
| 11 | Are the short-term parking spaces located past the student loading area and near the building entrance? | | | |
| 12 | Is parent loading occurring only in designated zones? (if not, please note non-designated zones in comments section) | | | |
| 13 | Are the student safety patrols and loading supervisors well trained and outfitted with reflective safety vests? | | | |
| 14 | Are traffic cones or other channelizing devices used within the site to minimize pedestrian/vehicle conflicts? | | | |
| 15 | Are safe crosswalks with crossing guards provided on site and off site to minimize pedestrian/vehicle conflicts? | | | |
| 16 | Are there standard and well-maintained sidewalks and/or a designated safe path leading to the school? | | | |
| 17 | Are there wider paved student queuing areas at major crossings and "stand-back lines" to show where to stand while waiting? | | | |
| 18 | Are facilities for bicycle access and storage provided at this campus? | | | |
| 19 | Do the school driveways conform to TxDOT design and access management guidelines for number, spacing, location, and layout? | | | |
| 20 | Does this school site have existing or planned left- or right-turn lanes? Do they meet existing TxDOT design guidelines? | | | |
| 21 | Do all site and regulatory signs and markings within the site comply with the Manual on Uniform Traffic Control Devices? | | | |

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# APPENDIX A
# EXISTING SCHOOL CAMPUS QUESTIONNAIRE

## EXISTING SCHOOL CAMPUS SITE PLAN REVIEW COORDINATION FORM

**School Name**: ________________________________________

**School District**: ______________________________ **County**: __________________________

**Provide a current site plan or aerial photograph of the campus with all driveways, parking lots and student loading zones clearly labeled.**

School Type (check one): ☐ Elementary ☐ Intermediate ☐ Middle ☐ High

School hours: _______ AM to _______ PM

Student Population: _______ Existing _______ Maximum

Number of faculty/staff: _______ Is parking a concern?........................................ ☐ Yes ☐ No

Does faculty/staff arrive at the same time as students?............................................ ☐ Yes ☐ No

How many buses serve the school? _______ Estimated number of passengers? _______

Do students walk or bike to and from school? ☐ Yes ☐ No – If yes, estimate how many? _____

How many parent vehicles access the school site? _______ AM drop-off _______ PM pick-up

Describe the existing traffic pattern for the parent/student-loading zone: (attach diagram if necessary)

___________________________________________________________________________

___________________________________________________________________________

___________________________________________________________________________

Please check the box of each problem that needs to be specifically addressed during this review:

| Problem Description | Yes | No |
|---|---|---|
| May need a reduced speed school zone | | |
| May need a marked crosswalk | | |
| May need a traffic signal | | |
| May need left or right turn lanes into the site from adjacent roadway(s) | | |
| The unloading of students from parent's cars is slow & disorganized during morning drop-off | | |
| The loading of students to parent's cars is slow & disorganized during afternoon pick-up | | |
| Vehicles are spilling out of the school site onto adjacent roadway(s) during morning drop-off | | |
| Vehicles are spilling out of the school site onto adjacent roadway(s) during afternoon pick-up | | |
| Pedestrians are walking thru active traffic lanes during drop-off or pick-up times | | |
| Other (please describe): | | |

# APPENDIX B
# NEW SCHOOL CAMPUS QUESTIONNAIRE

# NEW SCHOOL CAMPUS SITE PLAN REVIEW COORDINATION FORM

**School Name**: ________________________________________

**School District**: ______________________________ **County**: __________________________

**Site plan prepared by**: _______________________ **Dated**: ___________________________

**Provide a copy of the proposed site plan of the new campus.**

School Type (check one): ☐ Elementary ☐ Intermediate ☐ Middle ☐ High

Proposed school hours: _______ AM to _______ PM

Student Population: _______ Expected _______ Design capacity of school

Number of faculty/staff: _______ Will they arrive at the same time as students? .. ☐ Yes ☐ No

How many buses will serve the school? _______ Estimated number of passengers? _______

Do you expect students walk or bike to and from school? ☐ Yes ☐ No – If yes, estimate how many? _______

Estimated number of students arriving by personal automobile? _______

Describe the traffic pattern for the parent/student-loading zone: (attach diagram if necessary)

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

**On the site plan identify the following:**

_____ The number of levels, or stories, of each building.

_____ Main entrances including handicapped entrances and parking spaces.

_____ Parking lots, providing as much detail as possible (number of parking spaces, islands, handicapped spaces, visitor, faculty and staff, bus spaces, and delivery points).

_____ Student loading zone(s) (parents and buses) including their proposed traffic pattern.

_____ All main driveway connections to adjacent roadways – initial and proposed.