INTER-AMERICAN DEVELOPMENT BANK

TRAFFIC SAFETY

Using Engineering to Reduce Accidents

Philip Anthony Gold

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The opinions expressed herein are the author's and do not necessarily represent those of the Inter-American Development Bank.

Traffic Safety
Using Engineering to Reduce Accidents

Printed in the United States of America

This book is dedicated to Helena, Carolina and Thomas, companions on this long journey, and to all the victims of accidents that could have been avoided with better traffic engineering.

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PREFACE

The Inter-American Development Bank (IDB) is pleased to publish in English a book that has proven useful in reducing traffic accidents, one of the main causes of death in Latin America and the Caribbean. The author, Philip A. Gold, is a consultant to the IDB for traffic safety.

The book gives traffic engineers, planners, and managers a methodology to identify, analyze, and correct factors that cause traffic accidents. The procedures and materials required are of low cost and simple installation, accessible to most entities that administer traffic systems. The book focuses on critical spots on urban roads. The methods and solutions are equally useful for reducing accidents elsewhere on urban roads and on interurban highways and rural roads.

This book is based on work contracted in 1987 by the Institute for Applied Economic Research (IPEA) of Brazil. During the last 12 years, the author has used the material in numerous traffic safety training courses and has used this unique opportunity to test, revise, and update the contents, resulting in the current volume.

The manual has both practical and didactic characteristics. It presents the elements of road design, signs, signals, and markings (or their absence) and the behaviour of drivers and pedestrians that, separately or in combination, cause accidents. This diagnosis is followed by an examination of corrective traffic engineering to reduce accidents, along with ways to monitor the results. The book complements existing norms by showing how traffic engineering techniques may be more widely and correctly utilised.

A previous version of the book was awarded the Volvo Traffic Safety Prize in 1993 (for Region 2 of Brazil, composed of the States of São Paulo and Rio de Janeiro). The book was published by the IDB in Spanish and Portuguese in 1998.

Charles L. Wright
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(for the original work, 1987)

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Several IPLAN/IPEA staff members deserve special mention. Ricardo Luis Santiago, President of IPEA, and Flávio Rabelo Versiani, Superintendent of IPLAN approved the project and secured its financing; Charles L. Wright, Coordinator of Transport and Communications, carried out the supervision and technical editing; and José Alex Sant'Anna provided technical revision and useful comments.

Airton Perez Mergulhão and Fernando Antônio Garcia collaborated as co-authors, draftsmen and photographers for Chapters 10 and 11. The original work was carried out at VETEC Engenharia S/C Ltda., with the support of Victor Abel Grostein, Roberto Araújo Pereira, and other staff members. René José Micheletti made the artistic drawings.

Many of the ideas and examples, tables and figures contained in this book are results of the work of Philip Gold at the Traffic Engineering Company (CET) of the City of São Paulo, between 1982 and 1986, in the Department of Traffic Safety and Technical Standards. Special thanks go to the President of the CET during that time, Gilberto Monteiro Lehfeld, for stimulating the interest of technical staff of the CET and of other Brazilian entities in the utilisation of engineering measures to prevent accidents.

(for the English version)

Charles L. Wright, Coordinator and Editor

This book was translated from the Portuguese by the author, Philip A. Gold; Dharm Gurusuamy, Peter Zoll, Jennifer Cody and I reviewed the manuscript prior to publication, and Gloria Vetter did the desktop publishing.

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The Brazilian Institute of Applied Economic Research (Instituto de Pesquisa Econômica Aplicada – IPEA) financed the original study from which this volume evolved. IPEA generously ceded the rights to the study to the IDB, allowing the Bank to make this volume widely available to the three largest linguistic groups in Latin America and the Caribbean.

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ABBREVIATIONS

AASHT	American Association of State Highway and Transportation Officials
ADT	Average Daily Traffic
B/C	Benefit/Cost Ratio
BIAT	Computerized Traffic Accident Data Bank (INST/Brazil)
CTB	Brazilian Traffic Code, in effect since January 1998
CET	Traffic Engineering Company (São Paulo, Brazil)
CONTRAN	National Traffic Council (Brazil)
DENATRAN	National Traffic Department (Brazil)
DER	State Highway Department (Brazil)
DEST	Traffic Engineering and Safety Division (of DNER, Brazil)
DETRAN	State Traffic Department (Brazil)
DNER	National Highway Department (Brazil)
DO	Accident Resulting in Property Damage Only (without personal injury)
DSV	Traffic Operations Department (São Paulo, Brazil)
EBTU	*Brazilian Urban Transport Company*
EPUSP	Polytechnic School of the University of São Paulo, Brazil
FEPASA	São Paulo State Railway Authority
FHWA	Federal Highway Administration (United States of America)
GEIPOT	Brazilian Transport Planning Company
GIS	Geographical Information System
HMSO	Her Majesty's Stationery Offce (United Kingdom)
IBRD	International Bank for Reconstruction and Development (World Bank)
IDB	Inter-American Development Bank
IML	Medical Legal Institute (Coroner's Office)
INST	National Traffic Safety Institute (Brazil)
IPEA	Institute for Applied Economics Research (Brazil)
IPLAN	Institute of Planning (Brazil)
IPPUC	Urban Research and Planning Institute of Curitiba
IPR/DNER	Highway Research Institute/DNER (Brazil)
IPT	Technological Research Institute (São Paulo, Brazil)
IRR	Internal Rate of Return
MAAP	Microcomputer Accident Analysis Package (TRL, United Kingdom)
MSU	Manual of Urban Signs, Signals and Road Markings (CET, Brazil)
NPV	Net Present Value
ODA	*Overseas Development Administration (United Kingdom)*
OECD	Organization for Economic Co-operation and Development
PE	Pedestrian Accident
PI	Personal Injury Accident (without pedestrian involvement)
PMSP	São Paulo City Government
RCNT	National Traffic Code Regulations (Brazil)
ROSPA	Royal Society for the Prevention of Accidents (United Kingdom)
SAT	Traffic Accident System (of CET)
SEADE	State Statistical Data Analysis System (São Paulo, Brazil)
SMT	Municipal Transport Secretariat (São Paulo, Brazil)
TIC	Total Implementation Cost
TRL	Transport Research Laboratory (formerly TRRL, United Kingdom)
TRRL	Transport and Road Research Laboratory, now Transport Research Laboratory (United Kingdom)

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CHAPTER 1

TRAFFIC ACCIDENTS

1.1 Overview of Traffic Accident Costs

Traffic accidents are a serious public health problem throughout Latin America and the Caribbean (LAC). Brazil has roughly one-third of the people and vehicles in LAC and one-third of the accident fatalities, based on a recent study by the Danish Road Directorate (1999), so the Brazilian data are illustrative of a common problem in the region. In Brazil in 1995, there were 25,513 deaths and 321,110 injuries resulting from 255,537 accidents, 83,082 (33%) being in rural areas and 172,455 (67%) in urban areas (Table 1.1). These figures are from the National Traffic Department (DENATRAN), which does not publish data on accidents with no deaths or injuries (property damage only), since many states do not require registration of these accidents.

Brazil's National Highway Department (DNER) registered 63,063 non-injury accidents in 1995 on federal roads covered by the highway patrol. Since federal highways carry under 40% of all highway traffic, non-injury accidents on all highways can be conservatively estimated as twice this number, or 126,126 (Table 1.1). In urban areas, non-injury accidents can be estimated as at least 4 times the 172,455 accidents with injuries, since such accidents were 2-3 times greater than those of injury accidents when the city of São Paulo required their registration and, despite the obligation, most were not registered.

DNER estimated the average cost of injury accidents on its highways at US$ 51,500, including loss of future income, vehicle damage, medical and hospital costs, and damage to cargo. These are the country's most violent accidents, as many involve trucks and most occur at relatively high speeds. DNER also estimates the average cost of non-injury highway accidents at US$ 15,600, considering only vehicle and cargo loss and damage.

For urban areas, the weighted average of fatal and non-fatal injury accidents (including pedestrian deaths and injuries) is US$ 13,580; for accidents without injuries, US$ 1,410 (Table 1.1).[1]

The total annual cost of accidents in Brazil reaches the extraordinary value of US$ 9.6 billion, consisting of US$ 6.2 billion for those with injuries and deaths and US$ 3.3 billion for accidents in which no-one was injured (Table 1.1).

TABLE 1.1
THE COSTS OF ROAD TRAFFIC ACCIDENTS IN BRAZIL, 1995

Type	Rural	Urban	Total
	Number of Accidents		
Personal injury	83,082[1]	172,455[1]	255,537[1]
Property damage only	126,116[2]	689,820[3]	815,936
	Average Cost (US$)		
Personal injury	51,500[4]	13,580[5]	
Property damage only	15,600[4]	1,410[5]	
	Total Cost (US$ millions, 1997)		
Personal injury	4,279	2,342	6,621
Property damage only	1,967	973	2,940
Total	6,246	3,315	9,561

Sources: (1) DENATRAN; (2) Double the 63,063 property damage only accidents registered by DNER on police controlled federal highways; (3) 4 times urban personal injury accidents; (4) DNER data; and (5) calculation based on CET data.

1.2 Traffic Accidents as a Public Health Problem

The dead and injured in traffic accidents are concentrated in the 15 to 55 years age group and, within this group, these accidents are one of the main causes of death in most countries that have a significant level of motorisation. Using again the Brazilian example, the Ministry of Health data shows that, in 1995, the average age of fatal traffic accident victims was only 33 years, compared with 61 for cancer victims and 65 for victims of heart and circulatory disease. In relation to life expectancy at birth, presently 71 years in Brazil, an average of 38 years of life are lost per fatal accident victim, compared with 10 years for cancer and a mere 6 years for heart and circulatory diseases.[2] Thus, 964,940 expected years of life were lost with the 96,494 cancer deaths in 1995; 1,283,394 years with the 213,899 deaths due to heart and circulatory disease; and 1,259,890 years with the 33,155 traffic deaths.

The number of traffic accident deaths registered by the Ministry of Health in 1995, 33,155, is 30% superior to the 25,513 deaths registered by DENATRAN for the same year (cited on p. 1). The DENATRAN data come mainly from police accident reports. The police reports register deaths at the scene of the accident, but normally do not include deaths that occur while the injured are being taken to the hospital or after admission. The police report form may not even be filled out if the police are not informed of the accident or if the accident occurred in one of the roads not covered by the highway patrol.

The precision of Ministry of Health data depends on establishing a link between accidents and deaths, given that a patient may die from one of the consequences of the accident, such as pneumonia or heart failure and the latter "cause" may appear in the death certificate.

An unpublished study by the CET, which manages traffic in São Paulo, Brazil, found that a significant number of people injured in traffic accidents died within three months of their accidents, but the accidents were not registered as the cause of death. This information was obtained by comparing data from three sources:

- people injured in traffic accidents within the São Paulo city limits, according to police reports;
- deaths due to traffic accidents within the São Paulo city limits, according to death certificates issued by the Coroner's Office (IML), through which all the corpses of fatalities due to violent deaths should pass; and
- deaths from any cause in the State of São Paulo, according to the archives of the State Data Analysis System (SEADE).

The CET found that the number of traffic accident deaths registered at the IML would have to be increased by 74% to obtain the true number of traffic fatalities.

If these data are indicative of the degree of under-registration of deaths, traffic accidents could be the worst public health problem, excepting only the illnesses associated with malnutrition amongst children during the first year of life.

Traffic accidents have serious economic and social impacts, as the victims, with the average age of 33, are already educated, are at the peak of their productive capacities, and have dependents that are neither economically nor emotionally prepared for the loss of their loved one.

Survivors of traffic accidents frequently suffer physical and/or psychological damage that remains with them for the rest of their lives, including paralysis, loss of members, and blindness. Sixty three percent of Brazilian orthopaedic and trauma hospital beds are occupied by traffic accident victims (GEIPOT, 1987, p.15).

1.3 The Potential Contribution of Traffic Engineering

It is often said that 90% of traffic accidents are caused by "human error," so the only solutions are education, enforcement of traffic regulations, and punishment of drivers and pedestrians that disobey traffic laws. These factors are important and there is an urgent need to improve education and enforcement. However, studies in Brazil and in other countries indicate that inadequate conditions of vehicles, signs and signals, and of construction and maintenance of the roads and sidewalks are also contributing factors in many accidents. The number and severity of accidents can thus be reduced by improved traffic engineering, generating great social benefits, with or without improved behaviour of people in traffic.

Investments in traffic engineering have two strong points: (i) the results are immediate and can be traced to the measures implemented; and (ii) the results are usually long-lasting and do not require continued presence of human resources. Other traffic safety actions, such as public awareness campaigns and traffic education programs, seldom offer these advantages.

The following chapters show how engineering improvements in critical spots of the road network (those with high accident rates) substantially reduce or even eliminate accidents at these places. Experience with the implementation of many engineering improvements in Brazil and other countries yields an average reduction of 30% in the frequency of accidents at treated spots. This reduction usually provides very high economic returns for the resources invested, when one compares the modest cost of the changes with the benefits of fewer accidents.

When traffic engineering measures are broader and include small scale improvements in the built environment, the results can be even better (GEIPOT, 1987, p. 33-34). For example, in Belo Horizonte, Brazil, the official number of traffic deaths decreased from 1,071 in 1976 to 371 in 1981, as a result of the implementation of the Central Area Project. Deaths per 10,000 vehicles fell from 45 to 12 in the city as a whole, as accidents were reduced to very low levels in the Central Area, which had by far the greatest concentration of pedestrians and accidents. In Recife, Brazil, due to traffic engineering programs, the index of pedestrian accidents per 10,000 vehicles diminished from 427 in 1970 to 93 in 1985. In Curitiba, Brazil, traffic deaths fell from 203 in 1980 to 145 in 1983, despite growth of both the population and the motor vehicle fleet.

Lastly, it should be noted that the traffic engineering interventions, of the types under discussion, may present extremely high benefit-cost ratios. Often the social cost of the investments is paid back within a few weeks of the project's implementation (see Chapter 12).

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[1] Both estimates are from the São Paulo Traffic Engineering Company (CET) for the Municipality of São Paulo and have been updated by the author to 1997 US dollars.

[2] The following calculations are illustrative without being demographically precise, because the life expectancy today of people 33 or older would be slightly more than 71 years, as they have survived at least 33 years.

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CHAPTER 2

HOW ACCIDENTS OCCUR AND HOW TO AVOID THEM

2.1 An Accident (Figure 2.1)

It is raining. A car enters a curve at 60km/h, skids, leaves the road and collides with a concrete post. Result: one passenger dead; the driver and the other passenger very seriously injured.

2.2 The Story of the Accident

The following hypothetical story summarises some of the typical causes of traffic accidents.

The Driver

An executive with a large company, under strong professional pressure. After a day at work, he met two old friends who took him to the bar on the corner, where he relaxed, talked about old times, and drank more than normal. When they left the bar, it was dark and raining. The executive decided to drive his friends home. He was unfamiliar with the route his friends indicated, and the curve where the accident occurred. He braked too late.

The Car

The driver had just got his car back from the repair shop after a tune-up and service. He was unaware that the brakes had not been adjusted properly.

The Road and its Signs and Signals

The superelevation of the curve was less than recommended in project design standards. The road surface was worn smooth and there was an unprotected concrete post less than one metre from the edge of the road. The speed limit of 30 km/h was posted just before the curve, but the sign was partially hidden by overgrown vegetation.

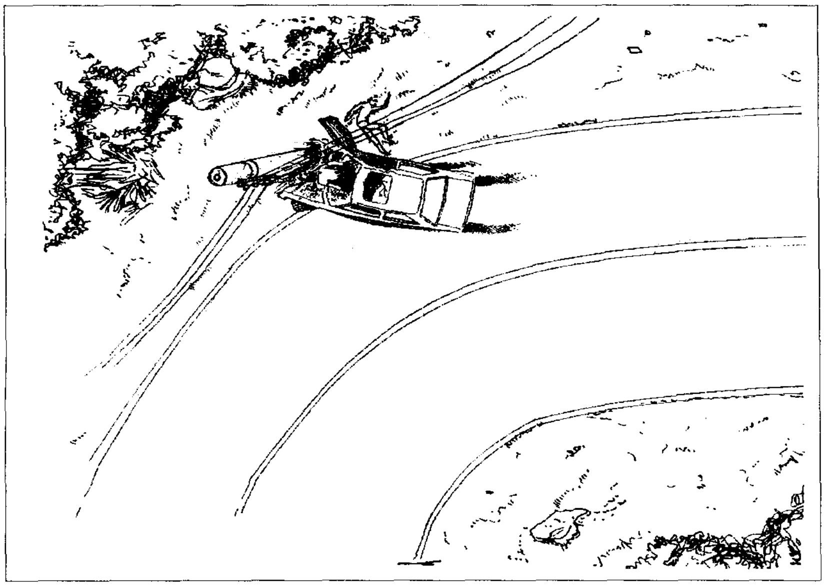
The Regulations and the Police

Prior to the curve, there were speed limit signs of 40km/h. There were no police in the area at the time of the accident.

2.3 What Caused the Accident?

For witnesses, the probable cause might be excess speed. For doctors, the influence of alcohol on the driver's judgement and reflexes. For a psychologist, the inadequate performance of the driver, due to his abnormal level of tension. For the automotive expert, the poor performance of the brakes. The driver's family might blame his friends for encouraging him to drive under the influence of alcohol.

FIGURE 2.1
ONE ACCIDENT, SEVERAL CAUSES



Drawing: Renê José Micheletti

For the traffic engineer, the hidden sign failed to warn the driver of the dangerous curve ahead, the superelevation was inadequate, and the road surface was excessively slippery, due to wear and the rain.

All these interpretations could be correct. The accident occurred because of several simultaneous contributing factors. It caused death and serious injuries because the post was too near the road, with no provision for deflecting the vehicle or softening its impact. The elimination of any causal factor would have significantly reduced the probability of the accident. In other circumstances, the driver, less tense and nervous, might drink less, have better reflexes, see the signs, and reduce his speed. He could control the vehicle more skilfully, avoiding the collision with the post, despite the badly adjusted brakes, the insufficient superelevation, the dangerous position of the post, and the rain.

If the brakes were well adjusted, the car might not collide with the post, despite the drunk driver and the other adverse factors. With adequate superelevation, the car might not leave the road.

With visible police presence along the highway, the driver would have obeyed the speed limit; with sobriety checks, he would have been taken off the road.

2.4 The Contributing Factors

The factors contributing to this accident belong to four interrelated groups:

- the human factor
- vehicles
- the road, prevailing conditions and built environment
- institutional and social factors

The *human factor* refers to behavioural aspects of the people involved in the accident. In the example, they were identified as:

- nervous tension, due to problems at work
- consumption of alcohol prior to driving
- unfamiliarity with the route
- distraction, due to chatting with friends

All these factors contributed to diminishing the executive's driving performance, resulting in his braking too late. Perhaps the only one of these factors appearing in the police report would be the suspicion that the driver had been drinking. Depending on the local legislation and police procedures, even that might be omitted. The other factors could only be discovered by interviewing the driver, his co-workers, family, or the surviving passenger.

The *vehicle factor* refers to an inadequate operational condition, in this case, poor brake adjustment. Other accidents present worn tyres and shock absorbers, steering defects, broken windscreen wipers, and other defects.

The *road, prevailing conditions, and the built environment.* These factors cover the characteristics of the road, the signs and signals, and the surrounding area at the moment of the accident. In this accident, they were: the inadequate superelevation of the curve; the excessively smooth road surface; the unprotected concrete post too near the road; the vegetation covering the sign; and the rain.

Three groups of factors should be considered to correct these problems:

- *Characteristics of the road's construction, its geometric design, and the surrounding area.* This includes the inadequate superelevation and the nearness of the post to the road.
- *Maintenance of the road system:* the wear of the road surface and the poor visibility of the traffic signs. Such characteristics are symptoms of deficiencies in the road maintenance system. The road surface can be rehabilitated or grooved to improve the adherence of tyres to the asphalt.
- *Factors related to nature:* In the example, the vegetation camouflaged the speed limit sign, while the rain made the smooth road surface extremely slippery. Vegetation is easily controlled by regular trimming. The effects of the rain can be reduced by good drainage systems. The driver's visibility can be aided by better car windscreen wipers and, at night, by improved street lighting. The consequences of fog may be diminished by the use of warning lights, signs, and messages transmitted to drivers via their car radios.

Institutional and social factors include traffic regulations (such as speed limits) and law enforcement. Normally, deficiencies in these factors are not considered as causes in the analysis of accidents and critical spots, but they are important in determining overall accident rates and they influence the number of accidents in specific locations.

A national traffic code is a collection of norms that define the desired behaviour of road users (drivers, pedestrians, and others) in all possible situations, based on the idea that an accident implies a fault on the part of at least one road user. However, situations arise in which signs and signals in accord with the national traffic code still leave gaps in the information transmitted to the road users, resulting in deficiencies that should be considered contributing factors.

In Brazil, inadequate training of the majority of drivers is also a contributing factor. Many drivers are unskilled in basic techniques and few exhibit defensive driving attitudes.

The main safety function of traffic police is to ensure that road users comply with the norms set out in the national traffic code, including those transmitted through signs and signals. The absence of police does not free road users of their obligations and, for this reason, the absence of police in a particular location is not normally considered a contributing factor in the accidents that occur there.

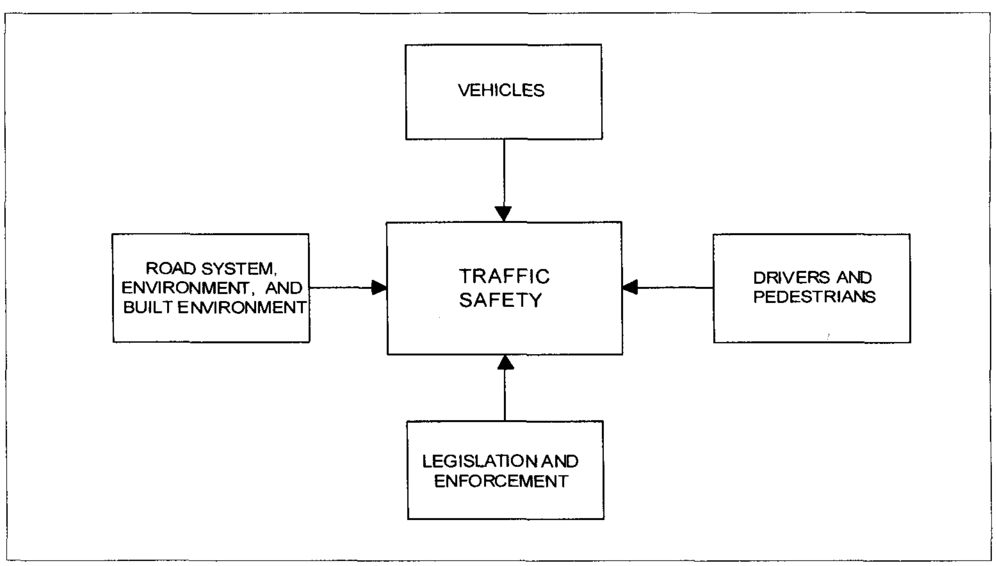
However, some signs, signals and road markings designed to control the behaviour of drivers and pedestrians, work well only with the presence of police or of automatic enforcement equipment (for example, radar or other speed detectors coupled to photographic or digital cameras), or when drivers think the police may be nearby. One obvious example is highway speed limits. No country has managed to control vehicle speeds on highways without resorting to permanent enforcement or frequent controls. The absence of police and automatic enforcement equipment contributes to increasing accident rates.

Impunity may also be considered a contributing factor if drivers face a low probability of paying heavy fines or losing their licenses, despite the presence of police.

2.5 The Role of Engineering

Figure 2.2 shows four fundamental elements for traffic safety. In general, an improvement in any one of these elements will lead to an improvement in traffic safety. The possibilities include: better education and training of road

FIGURE 2.2
FACTORS WHICH AFFECT TRAFFIC SAFETY



users (drivers, pedestrians, cyclists, and motorcyclists); better vehicle maintenance; better geometric road design, signs, and signals and associated factors in the surrounding built environment; and more rigorous police enforcement of traffic norms and regulations.

However, a traffic engineer's[1] work is usually restricted to direct interventions in the road network. For critical spots, this involves identifying signs, signals, and other devices that will reduce the frequency of accidents at these locations. This in turn requires study of the available accident information, a site visit, and discovery of patterns and common factors among the accidents. Once the problems are identified, modification of the road system is required to correct inadequate traffic engineering and compensate for problems not controllable by the engineers. These include: driver and pedestrian behaviour; vehicle characteristics; traffic norms and regulations, and the intensity and rigour of their enforcement.

Once the corrections have been identified, the traffic engineer should also participate in the process of convincing the authorities to implement them, informing the public of the benefits of these measures, and indicating to authorities and the public the desirable behaviour in the new situation.

The traffic engineer should maintain a correct professional attitude. During site inspections, he or she will often observe driver and pedestrian behaviour that is incompatible with traffic safety. The engineer will also discover inadequacies and errors in the design of the roads and of the signs and signals, and failures in their maintenance. The traffic engineer should avoid the tendency to assign blame, or to judge drivers, pedestrians, or fellow traffic engineers. He or she should be objective and design the best traffic interventions to eliminate, or minimize the effects of, each contributing factor.

If traffic law enforcement is weak, the traffic engineer should give preference to measures that depend less on the presence of enforcement. As a citizen, he or she may also collaborate in efforts to improve the other associated areas mentioned.

Finally, traffic safety engineering can be an intensely satisfying occupation, but the engineer must be prepared to recognize and deal with frustrating circumstances that appear almost daily. He or she must maintain the awareness, concentration, and energy essential for successful work.

The author has trained many traffic engineers in accident prevention and reduction. At the beginning of the courses they typically express great interest in the subjects studied, but strong pessimism about the possibility of applying the knowledge in practice. They cite many obstacles: supervisors that are not interested in traffic safety; their salaries are low; there is no money to implement the projects; the measures will not be effective due to non-enforcement of traffic laws; drivers and pedestrians are so uneducated that nothing will work, etc. Fortunately, during and after the course many of these engineers discover ways to overcome some of these obstacles. Persistent, optimistic traffic safety engineers often achieve surprisingly positive results.

The author has found two books to be especially helpful in encouraging correct professional attitudes and a positive outlook on work in general: *Skillful Means (1978)*; and *Skillful Means 'Wake Up': Mastering Successful Work* (1994), both by Tarthang Tulku.

[1] This book uses the term "traffic engineer" to refer to any technical person in charge of design, operation, or modification of the street and road network and/or its signs and signals. Traffic engineering is often a required or elective subject of civil engineering courses. However, in some countries many professionals in traffic engineering come from areas other than civil engineering, such as other fields of engineering, architecture, physics, and mathematics. Some countries permit only certified engineers to legally practice this profession.

CHAPTER 3

CHARACTERIZING TRAFFIC ACCIDENTS

The traffic engineer must know the causes of traffic accidents to design measures to reduce them. This requires obtaining and analysing information about the accidents, and site inspections. This process normally starts with an examination of data extracted from police accident reports.

3.1 Basic Definitions

Traffic Accident

A traffic accident is an unintentional traffic event that results in personal injury and/or damage to property (usually vehicles and their cargo, and occasionally roadside objects or buildings).

A traffic accident involves at least one motor vehicle or non-motorised vehicle, in movement in a road designated for the use of vehicular traffic.

Events not covered by this definition are not usually considered as traffic accidents, but perhaps should be. They include pedestrians that injure themselves falling on defective sidewalks.

Traffic Accident with Property Damage Only

An accident that produces only damage to vehicles and other inanimate objects, without any of the people involved being injured. Many accidents registered by the police as *property damage only accidents* are really personal injury accidents due to internal injuries unnoticed when the police fill out their report. These injuries appear later and sometimes result in death. Reliable data collection requires information from hospitals, the coroner's office, or other institutions that register violent deaths (GEIPOT, 1987).

Personal Injury Accident

An accident that results in injuries to at least one person involved, whether or not the victim(s) is (are) treated in hospital. Each victim's injuries may be classified as *minor* or *serious*, for example. The traffic engineer should remember that these terms are not well defined, especially when the police report is filled out without benefit of a professional medical diagnosis.

Injuries classified as minor may be serious, just as *personal injury* accidents may be incorrectly classified as *property damage only* accidents. On the other hand, an injury described as serious might be a minor injury. For example, considerable bleeding of the head may be caused by superficial scalp injuries.

This book separates the analysis of pedestrian accidents (personal injury accidents with pedestrians as the injured victims) from other personal injury accidents (those in which drivers and passengers are the injured victims).[1] The term *personal injury accident* is used exclusively for accidents that do not involve pedestrians. This convention classifies traffic accidents in one, and only one, of the following basic types:

- pedestrian
- personal injury
- property damage only

The only exceptions will be those accidents in which both pedestrians and vehicle occupants are injured. These should be classified according to the first impact sustained, due to its importance in identifying the causes of the accident. For example, when a pedestrian is hit by a vehicle, which then crashes into a post off the road, this is a pedestrian accident (with additional victims).

Fatal Accident

A traffic accident that results in the death of at least one of the victims. Some accidents registered in police reports as non-fatal accidents are in fact fatal accidents: the death of one or more victims occurs some time after the report has been written up. Death may even occur months after the accident (see section 4.2).

3.2 Geographical Distribution

Inside/Outside the Central Business District

In general, cities have a concentration of accidents in the central business districts where most commercial activities and services are located. This concentration does not mean that traffic in the central areas is more dangerous than in other parts of the city, it merely reflects the central area's relatively high flows of vehicles and pedestrians. For example, the central business district of the Municipality of São Paulo, which occupies less than 1% of the municipal land area, had 17% of its pedestrian accidents according to the Traffic Engineering Company (CET). This was due mainly to the high number of vehicles and pedestrians found in the central area.

At Intersections/Between Intersections

Conflicting movements of vehicles, and of vehicles and pedestrians, constantly occur at the intersection of two or more roads and naturally result in high frequencies of accidents. Accidents also occur in the road sections between intersections, but tend to be distributed along the length of the road, rather than concentrated as in intersections.

In both cases, the probability of accidents occurring increases with increasing pedestrian and/or vehicle flows.

Traffic Generators

Some types of urban activities generate unusually large volumes of vehicle and/or pedestrian traffic, such as supermarkets, commercial centres, public transport terminals and stations, bus stops, and schools. These traffic generators tend to be significant accident locations, unless specific measures are adopted to minimise risks.

Critical Spots

A *critical spot* is a location with an exceptionally high traffic accident frequency. There is no absolute definition, such as "a location with more than *x* accidents per year." However, definitions of this type may be adopted temporarily to aid in the formulation and design of accident reduction policies and programs.

For example, a policy of treating critical points with frequencies higher than 50 accidents per year makes sense for the capital cities of the Brazilian states, although it would be difficult to find a location with such a high frequency in any of Brazil's smaller and medium size cities. However, each city has its critical spots.

The highest accident frequencies are often registered in intersections where there are conflicting flows of vehicles and pedestrians. There are exceptions, however, as on road sections where many pedestrians cross at various points, distributed along the road, and sections with below-standard traffic engineering. Two examples of the last type are curves with negative superelevation and short road sections with defective paving.

Different types of critical spots may defined, depending on the aspect chosen for analysis, such as:

- general critical spots, considering all accidents;
- critical spots of personal injury accidents (excluding pedestrians);
- critical spots of fatal accidents;
- critical spots of pedestrian accidents;
- critical spots of accidents involving motorcycles;
- critical spots of accidents with injured children.

These definitions lead to critical spots that often do not coincide. Maps of each type of critical spot may highlight different locations and the most appropriate corrective measures may differ in each case.

Since urban traffic accidents often concentrate in the central business district, the general critical spots (considering all accidents) are also often concentrated in this area. The frequency of personal injury accidents (excluding pedestrians), however, is relatively less than occurs along avenues outside the city centre. This is due to the relatively low speeds of the traffic in the centre, caused by traffic congestion and/or traffic lights.

Similarly, the geographical distribution of critical spots of pedestrian accidents may be different from that of accidents in general and from that of non-pedestrian personal injury accidents. Pedestrian accidents are obviously concentrated at points where pedestrians cross the road. Consequently, a pedestrian accident critical spot could appear in front of an intercity bus terminal, where there are few (non-pedestrian) personal injury accidents. For example, a road section of less than 100 metres, in front of the Tietê interurban bus terminal in São Paulo was once the worst critical spot of the city with 40 pedestrian accidents in one year, although few other types of accidents occurred there.

Critical spots are not the whole story, as traffic accidents are distributed through the entire road network. The *critical spot* concept may create the opposite impression if the press, radio and television repeatedly mention a few critical spots as synonymous with the traffic accident problem. The City of São Paulo illustrates this well. In the 100 intersections with the highest frequencies of registered traffic accidents (all types):

- only 5% of all registered accidents occur;
- only 3% of all personal injury and pedestrian accidents occur;
- only 1% of accidents with fatal victims occur.

On the other hand, there are many other critical spots with smaller, but still above average, frequencies among the locations of the remaining 95% of accidents. The majority of these critical spots have similar situations and contributing factors, which would permit the standardisation of improvements and, consequently, economies of scale during their design and implementation, while those critical spots most mentioned by the media present non-typical situations that require individual solutions.

Critical Sections

Critical sections are sections of urban roads or rural highways where accidents occur with relatively high frequencies, but without the existence of significant concentrations in particular spots along the section.

Critical Areas

Whole areas of the road network sometimes have extraordinarily high accident frequencies due to problems such as conflicting flows, inadequate signs and signals, or poorly maintained road surfaces.

Temporary Interferences

Any temporary interference in the road network may suddenly generate many accidents in locations where few accidents normally occur. The most obvious examples are locations with public works in progress, where traffic is rerouted. These situations require care in signing and signalling and in the design of the diversion, to avoid creating *temporary critical spots*.

3.3 The Temporal Distribution of Accidents

Data for the São Paulo Municipal area, distributing accidents by day of the week and by time of day, highlight important differences between pedestrian accidents, (non-pedestrian) personal injury accidents, and property damage only accidents.

Pedestrian Accidents

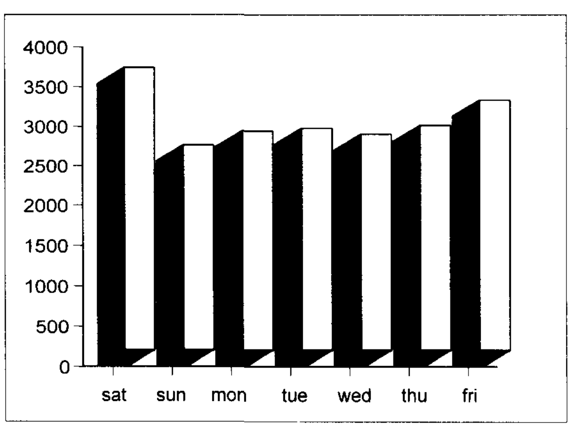
Figure 3.1[2] shows that Saturdays have the highest incidence of pedestrian accidents in São Paulo, 17% of the total, despite afternoon vehicle flows that are lower than on weekdays. The second highest frequency occurs on Fridays, with 15% of the total.

On Sundays, when both vehicle and pedestrian flows are notably less than on other days, the average frequency of pedestrian accidents (13%) remains near the weekday level, except for Fridays.

The traffic engineer that programs site inspections should note that 30% of all pedestrian accidents occur on Saturdays and Sundays, when the characteristics of traffic are different from weekdays.

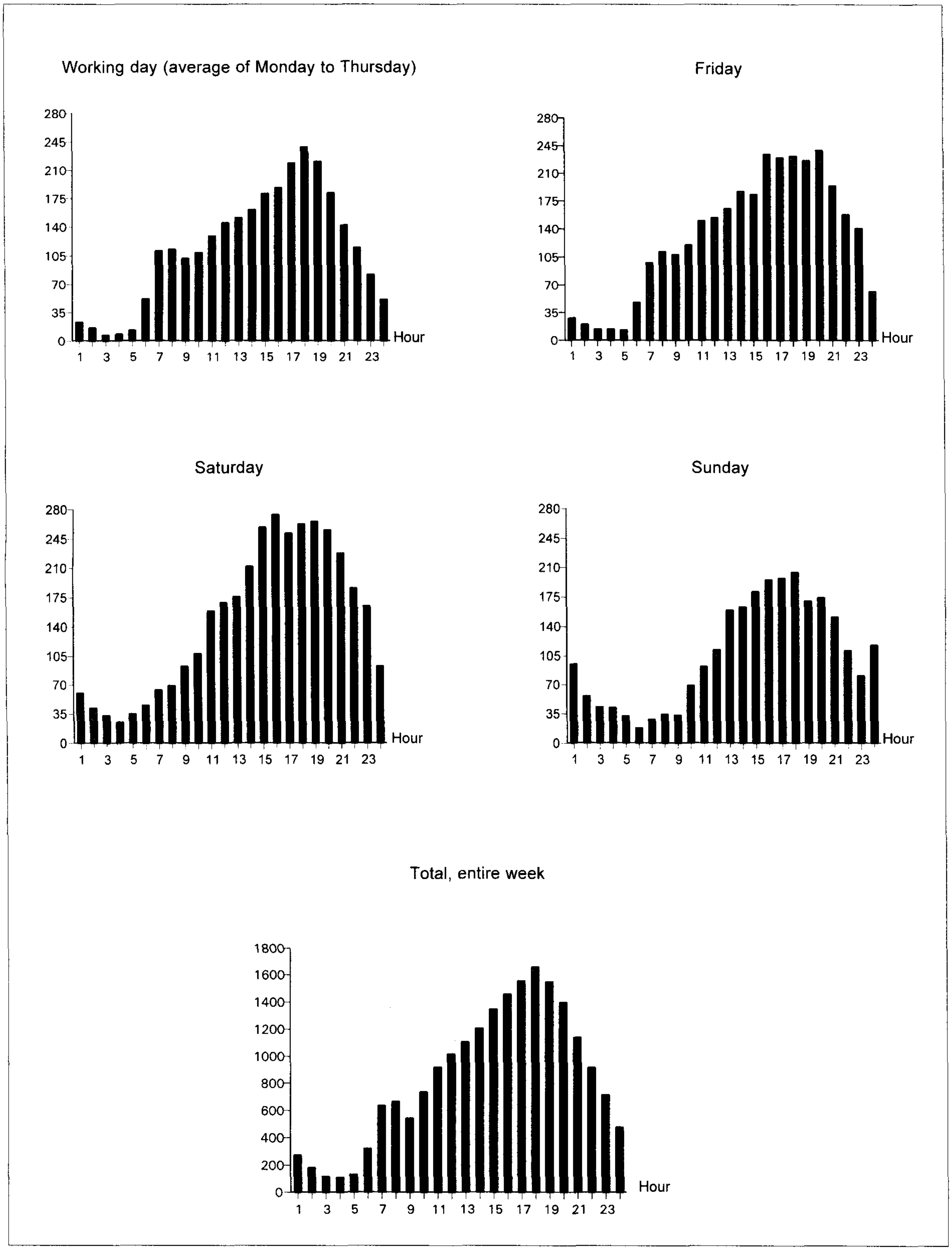
Figure 3.2 presents the frequency of pedestrian accidents distributed by time of day. The profile for total pedestrian accidents, with a peak hour from 18h00 to 19h00, is very similar to the profile for Monday through Thursday.

FIGURE 3.1
DISTRIBUTION OF PEDESTRIAN ACCIDENTS BY DAY OF WEEK, SÃO PAULO, 1985



Source of original data: CET.

FIGURE 3.2
DISTRIBUTION OF PEDESTRIAN ACCIDENTS BY TIME OF DAY AND DAY OF WEEK, SÃO PAULO, 1985



Source of original data: CET.

On Fridays, the peak period extends from 16h00 to 21h00, with a pedestrian accident hourly frequency equal to that of the peak hour of the other weekdays.

On Saturdays, the peak period is even longer, from 15h00 to 21h00, with a pedestrian accident frequency slightly greater than weekdays, despite lower vehicle and pedestrian flows. The pedestrian accident frequency between midnight Friday/Saturday and 6h00 Saturday, is much greater than on weekdays for those hours.

Sunday has the lowest pedestrian accident frequency, but the number between midnight Saturday/Sunday and 6h00 Sunday exceeds that of any other day of the week.

Among the factors that may explain these characteristics are:

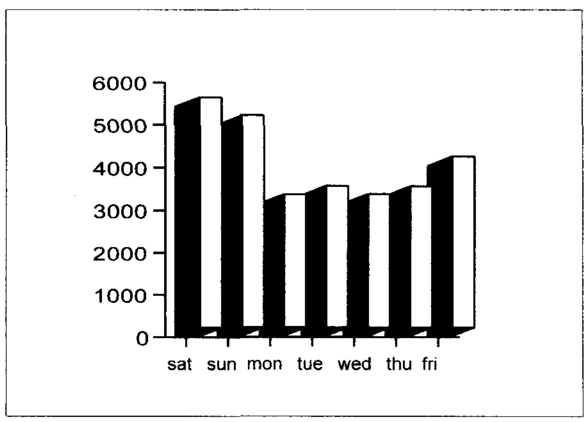
- many pedestrian accidents coincide with the highest vehicle and pedestrian flows;
- vehicle speeds tend to be higher at times of low vehicle flow, which increases the risk of pedestrian accidents and the severity of pedestrian injuries;
- on Friday, Saturday and Sunday nights, drivers and pedestrians consume more alcohol than on other days;
- many Friday and Saturday night leisure activities leave drivers and pedestrians very tired the next day; and
- during weekends, there are more less-experienced drivers on the roads.

Personal Injury Accidents (non-pedestrian)

Figures 3.3 and 3.4 show that non-pedestrian personal injury accidents have characteristics that differ from those of pedestrian accidents.

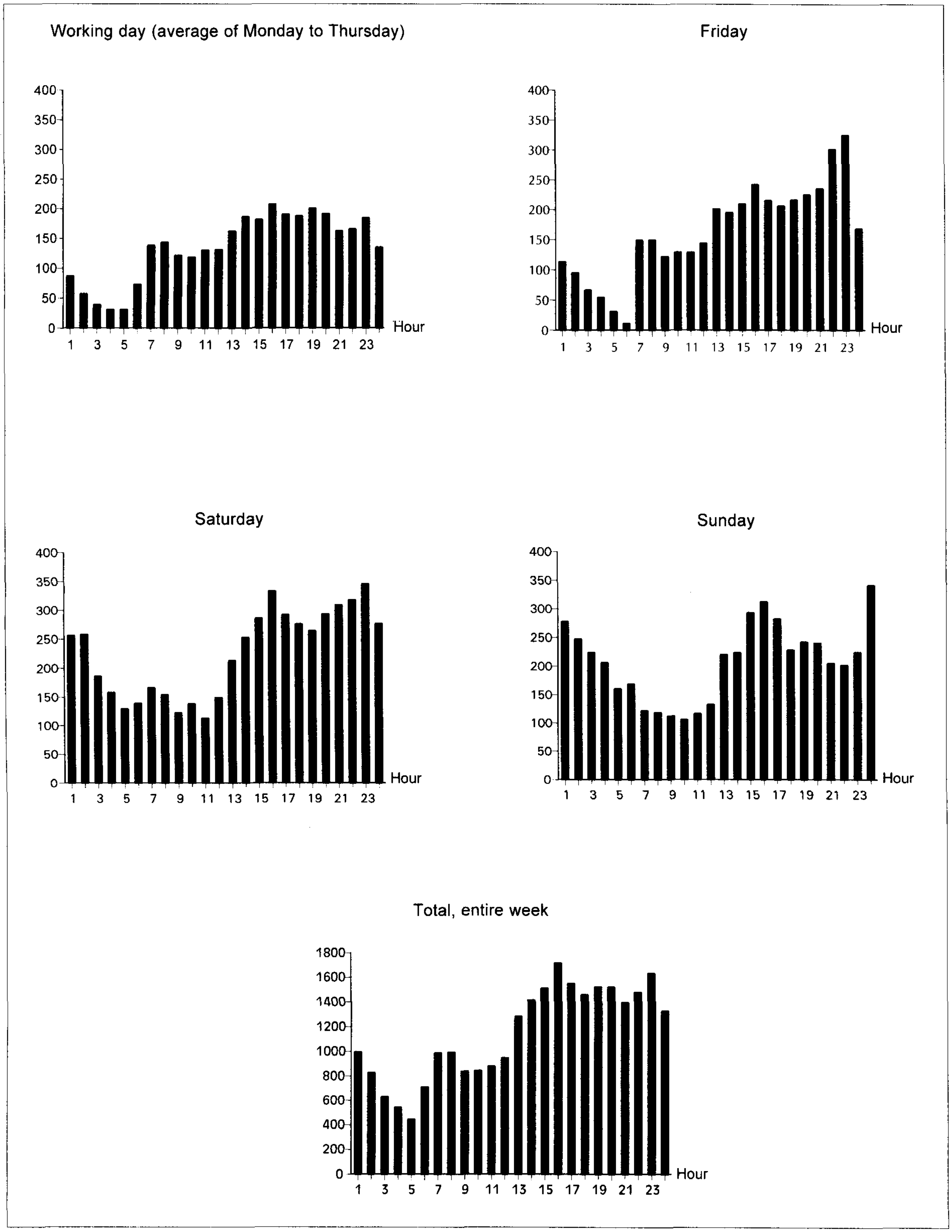
Saturday has the highest frequency for both types, with 20% of the total of non-pedestrian personal injury accidents, compared with 17% of pedestrian accidents. Sunday is second for the non-pedestrian accidents, with 18%, whereas Friday is second for pedestrian accidents with 15%. The Saturday frequency is almost double the weekday frequency from Monday through Thursday.

FIGURE 3.3
DISTRIBUTION OF PERSONAL INJURY ACCIDENTS (EXCLUDING PEDESTRIAN ACCIDENTS) BY DAY OF WEEK, SÃO PAULO, 1985



Source of original data: CET.

FIGURE 3.4
DISTRIBUTION OF PERSONAL INJURY ACCIDENTS (EXCLUDING PEDESTRIAN ACCIDENTS)
BY TIME OF DAY AND DAY OF WEEK, SÃO PAULO, 1985



Source of original data: CET.

Thirty eight percent of non-pedestrian personal injury accidents occur on Saturdays and Sundays, exceeding the 30% for pedestrian accidents. Monday through Thursday presents no well-defined peak hour. From Friday to Saturday there is a marked peak period: from 22h00 to 3h00. After this, there is constant high frequency extending from 13h00 Saturday to 3h00 Sunday, with fairly high frequency continuing until 7h00 Sunday. Later on Sundays there is a peak period from 15h00 to 18h00.

Factors that may explain these characteristics are the same as those mentioned for pedestrian accidents, plus the traditional alcohol-assisted Sunday lunch and the consequent drunken drivers during the afternoon.

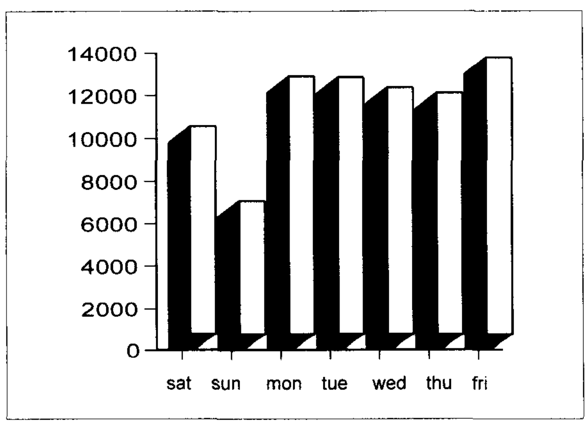
Accidents with Property Damage Only

Figures 3.5 and 3.6 present the distributions for property damage only accidents registered by the police. In Brazil and many other countries, the majority of these accidents are not registered. Registration is not required in many states; agreements may be made by the parties involved; and the police tend to register them only when requested to do so by those involved. Consequently, these data are less reliable than data from pedestrian and non-pedestrian injury accidents.[3]

The following characteristics are noteworthy:

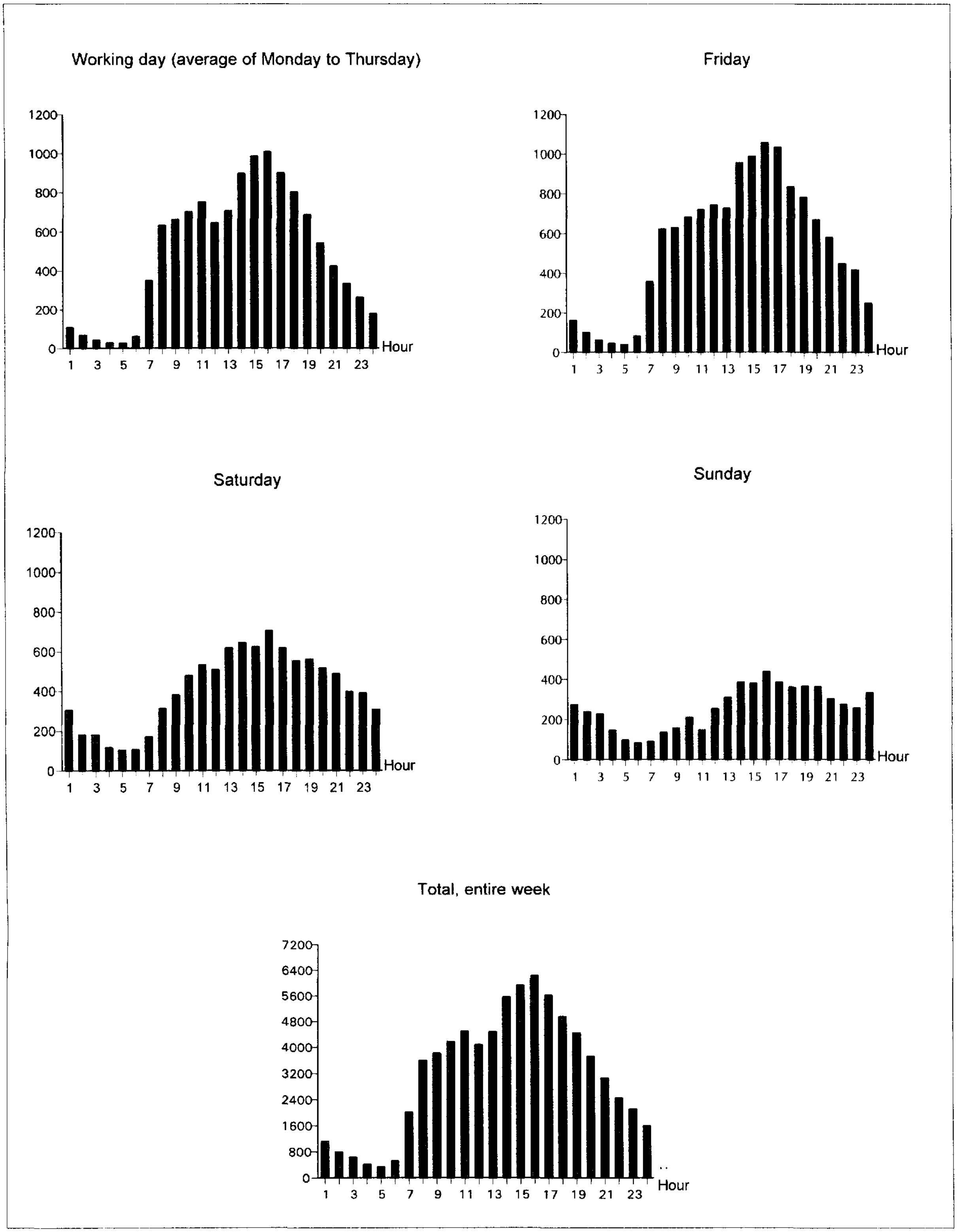
- the lowest registered frequencies occur on Saturdays and Sundays;
- the highest frequencies are registered on Fridays;
- the weekday peak period is from 15h00 to 17h00, although the hourly frequency remains high during all business hours;
- on Fridays the peak period extends from 14h00 to 18h00;
- during weekends, both Saturdays and Sundays have long critical periods from 13h00/14h00 to 21h00/22h00.

FIGURE 3.5
DISTRIBUTION OF ACCIDENTS WITH PROPERTY DAMAGE ONLY
BY DAY OF WEEK, SÃO PAULO, 1985



Source of original data: CET.

FIGURE 3.6
DISTRIBUTION OF ACCIDENTS WITH PROPERTY DAMAGE ONLY
BY TIME OF DAY AND DAY OF WEEK, SÃO PAULO, 1985



Source of original data: CET.

Total Accidents

Total accidents equal the sum of pedestrian accidents, non-pedestrian injury accidents and property damage only accidents, and do not require a separate characteristics analysis. Figures 3.7 and 3.8 present the distributions as in the previous subitems.

The Importance of the Temporal Distribution of Accidents

The data on the hour and the day of the week (or date) when the accidents occur normally is given in police reports. This information is extremely important for accurate analysis of accident causes and, consequently, for the choice of the most appropriate preventive measures, as illustrated by the following examples.

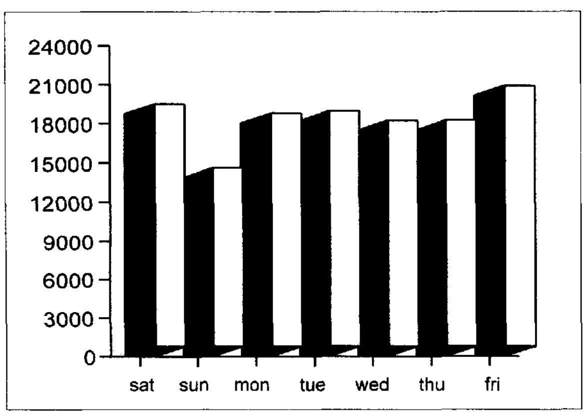
Consider three locations with equal frequencies of 20 pedestrian accidents per year, among other accidents. Analysis of the police reports reveals the following characteristics.

- Location 1: pedestrian accidents concentrated in weekdays, 11h00 to 12h30
- Location 2: pedestrian accidents concentrated on Saturdays, 9h30 to 13h30
- Location 3: pedestrian accidents with no notable concentrations on specific days or times of day

Site inspections, made during the times and days of maximum frequency, for locations 1 and 2, and at any time for location 3, might lead us to the following diagnoses.

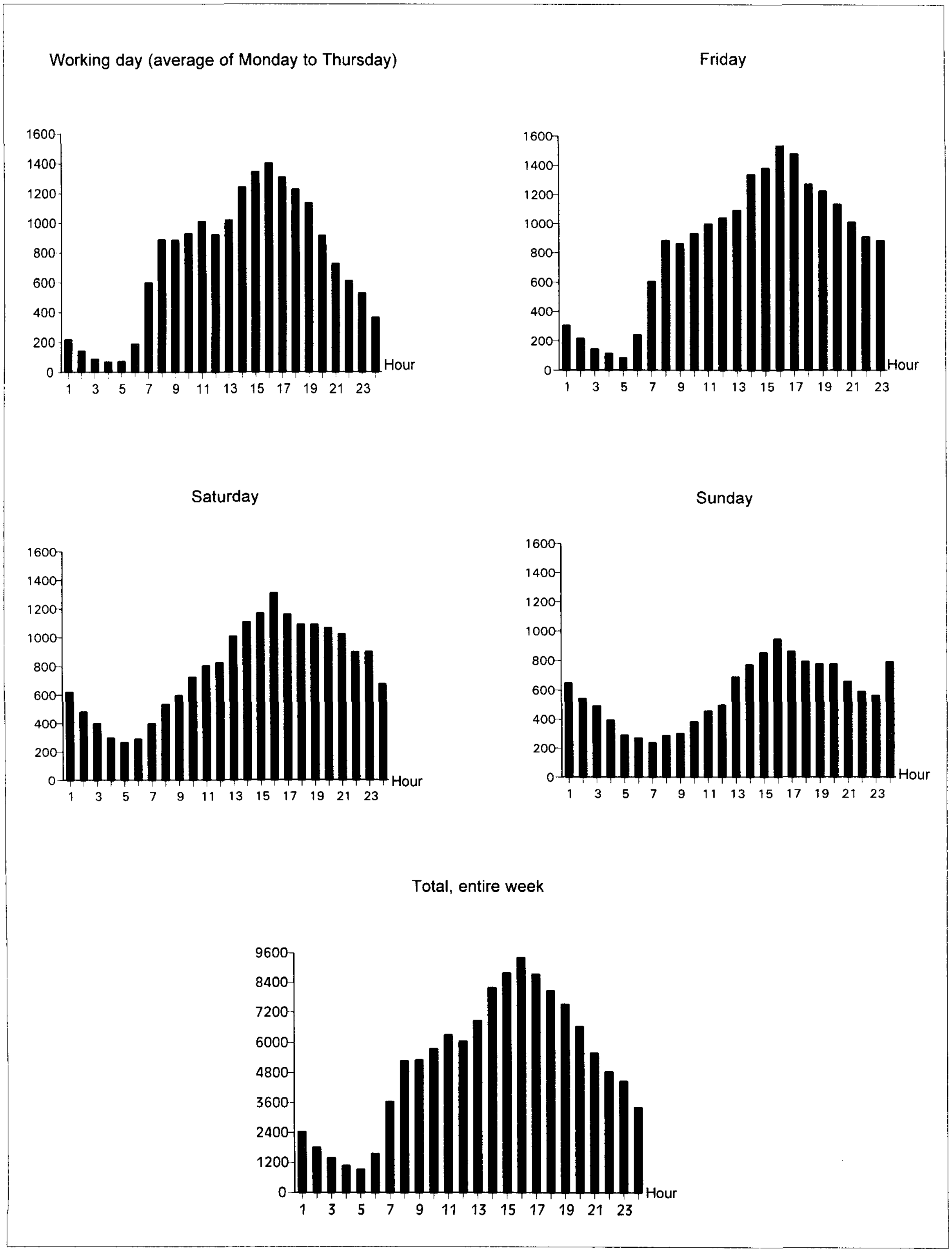
- At location 1, the problem concerns schoolchildren leaving three area schools at the end of classes. They have to cross the road under unsafe conditions, with no specific signs or signals, no traffic police, and no crossing guards. Traffic passes at high speeds with virtually uninterrupted flow. One solution is to use portable signs and crossing supervisors (possibly teachers or other school personnel), limited to the brief periods when students arrive and leave (see section 10.8).
- At location 2, the problem is a large shopping centre with a Saturday morning peak and many pedestrians crossing a main two-way road at an intersection with traffic lights, but with no pedestrian phase. One solution is to program a pedestrian phase in the traffic light cycle, complemented by pedestrian traffic lights

FIGURE 3.7
DISTRIBUTION OF ALL ACCIDENTS
BY DAY OF WEEK, SÃO PAULO, 1985



Source of original data: CET.

FIGURE 3.8
DISTRIBUTION OF ALL ACCIDENTS BY TIME OF DAY AND DAY OF WEEK, SÃO PAULO, 1985



Source of original data: CET.

and refuges for pedestrians in the middle of the road section.

- At location 3, the problem is poor visibility between drivers and pedestrians, caused by flower boxes, newsstands, and parked vehicles. One solution is to remove the fixed objects that interfere with visibility and extend the sidewalk to remove parked cars from the corner area.

Without knowing that the pedestrian accidents at the first two locations are concentrated in different days of the week and different times of day, the traffic engineer might send a team to carry out site inspections during weekday afternoons, and would not detect the school children's problem nor that of the shopping center. The team would be unlikely to design the most appropriate solutions for these cases.

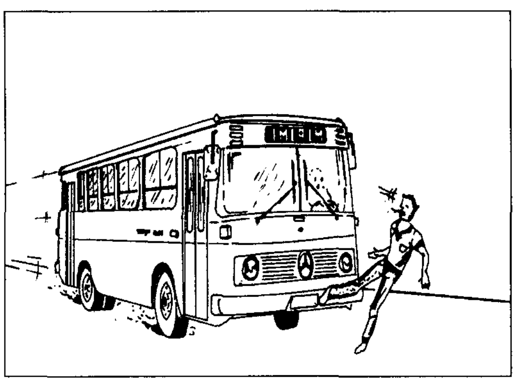
The team could probably identify the problem of impaired visibility at the third location at any time of a weekday.

3.4 Types of Accidents

The definitions used throughout this book are given below and are based on those used in São Paulo, Brazil, when it was written. Some other definitions may be equally valid.

Pedestrian Accident

An accident in which a pedestrian is hit by a vehicle (motorised or non-motorised). It may occur in the roadway or on the sidewalk. At the moment of the accident the pedestrian may be crossing the street, walking on the sidewalk or along the street, or be standing still, in the roadway or on the sidewalk.



A multiple pedestrian accident is one in which two or more pedestrians are hit by a vehicle.

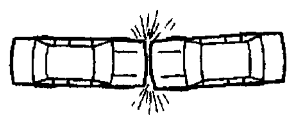
In Iberian America, the same word ("atropelamento" in Portuguese and "atropellamiento" in Spanish), is used for a pedestrian accident and accidents that involve bicycles or animals and motor vehicles. When traffic police and engineers follow this practice, pedestrian accidents are mixed with accidents involving pedal cyclists and even animals. Such accidents should be considered separately from pedestrian accidents, especially since bicycles behave in traffic more like motorised vehicles than pedestrians.

Collision

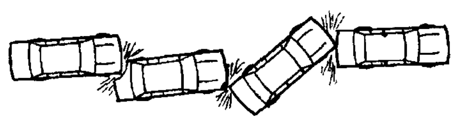
An accident between two or more moving vehicles (motorised or non-motorised) travelling in the same traffic lane, in the same direction or in opposite directions.

Rear-end Collision is a collision between two vehicles moving in the same direction, in the same lane.

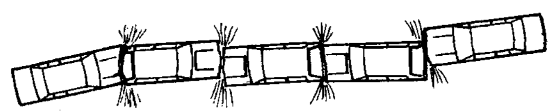
Head-on Collision is a collision between two vehicles moving in opposite directions.



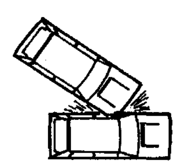
Pile-up is a collision between three or more vehicles, one behind the other. It may be composed of only rear-end collisions,



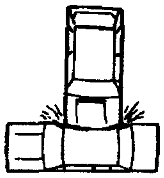
or it may include a head-on collision.



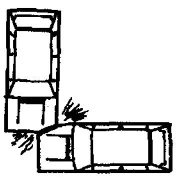
Sideswipe is an accident between moving vehicles travelling in different lanes, but in the same direction, usually when one of them begins a left or right turn, or a change of lane, at the wrong moment.



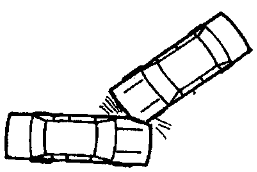
Right-angle Accident involves vehicles travelling in different directions at an angle of 90°, normally in intersections, parking lot exits, etc.



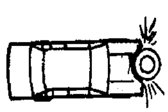
Frontal Right-angle Accident is a right-angle accident when the impact point of both vehicles is the front.



Sideswipe in Opposite Directions is an accident between vehicles travelling in opposite directions and in different lanes. Generally, one of the vehicles is starting a left or right turn.



Collision with Fixed/stopped Object is an accident in which a moving vehicle hits a non-moving vehicle or a fixed object.



Non-moving vehicles may be parked or stopped at a traffic light. Fixed objects are normally located outside the carriageway and may include street lighting posts, signposts, trees, newsstands, telephone boxes, letter boxes, safety barriers, and guardrails. When in the carriageway, they include signposts (rarely), road maintenance equipment, and public works materials.

Complete Vehicle Overturn is an accident in which the roof of a vehicle comes into contact with the ground at least once during the accident.

Partial Vehicle Overturn is any accident in which one side of the vehicle rests on the ground at the end of the accident.

Combination

Accidents may combine two or more of the aforementioned types, for example, a pedestrian accident that causes a pile-up and a complete vehicle overturn.

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[1] In this book, the term pedestrian accident is applied exclusively to impacts of vehicles on pedestrians. This convention is recommended to avoid confusing or improper categories. To maintain coherence, vehicle-cyclist and vehicle-animal accidents should be classified as (vehicular) accidents involving, in the first case, a bicycle and a motorised vehicle, and in the second case, an animal and a motorised vehicle.

[2] Figures like those of this chapter may be made from statistical data, using a personal computer and a spreadsheet such as Excel, Lotus, or Quattro Pro.

[3] In some cities, some personal injury accidents may also be omitted, despite a legal obligation to register all of them.

CHAPTER 4

COLLECTING DATA ON ACCIDENTS

4.1 The Importance of Information on Accidents

Accident data are vital for effective design of traffic engineering measures to reduce accidents. To identify critical spots (locations with abnormally high accident rates), the traffic engineer needs a register with at least the dates and locations of accidents that occurred during a period of one year. This register must be updated regularly to evaluate the results of the measures that are implemented.

The time accidents occur is also important. A site investigation of traffic engineering conditions during normal working hours will not be very useful if the worst accidents occur at night. The principal cause might be inadequate street lighting or some other factor that can only be observed at night.

Similarly, a high concentration of accidents at a specific location, just before lunch on weekdays may be associated with the arrival and departure of children at schools or of workers at a factory. A high incidence at dawn may be due to excess speed while the vehicle flow is still low.

These different situations normally require different measures to reduce accidents.

Distinctions such as "pedestrian accident or non-pedestrian accident?" are also relevant, as the solutions may differ. The same holds for the different types of vehicle-only accidents: rear-end, head-on, sideswipe, right angle, pile-up, hitting a fixed object, overturn, and partial overturn. The contributing factors and the most appropriate solutions may be quite different.

Data on accident severity are necessary for assigning the correct priority to critical spots. If the main objective is to reduce deaths and injuries, the engineer must know which accidents resulted in death and which produced injuries.

A layperson might consider the latter information superfluous, since a high incidence of accidents at a location must correspond to a high incidence of dead and injured. However, this is often not the case. Frequently, locations with the highest numbers of accidents are major intersections in the city centre, where traffic congestion and traffic lights result in relatively low vehicle speeds. Thus, property damage-only accidents prevail in these zones, while many of the most serious accidents occur in more isolated locations, with less dense vehicle flows and, consequently, higher speeds and more severe accidents.

4.2 Available Data

In most cities, traffic accidents are registered at police stations. In Brazil and some other countries, the military traffic police also register accidents. Data registered at the scene of the accident are generally richer in information than those registered later at the police station.

The reports for serious accidents are usually filled out at the accident location by a traffic policeman. They provide very useful information for traffic engineers who later analyse the accident, revealing contributory factors that allow them to correctly diagnose the causes and design corrective measures. Recent editions of local newspapers also provide other useful information, including brief descriptions of the accidents and the names of the people involved. This often makes it possible to obtain additional information, when needed.

Personal Injury Accidents (including pedestrian accidents)

Pedestrian accidents almost always cause personal injury, as the human body has low limits of tolerance to impacts from vehicles, even small vehicles travelling at low speeds. The characteristics of these accidents are very different from those of vehicle-only accidents and, consequently, they should be classified separately. The basic traffic accident classification, used in this book, arises from this difference: *(property) damage-only accidents* (DO), *vehicle-only accidents with personal injury* (PI), *and pedestrian accidents* (PE).

Despite the usefulness of this classification for analysing the causes of accidents, police reports often are structured differently. This requires the engineer to verify if an accident classified by the police as *personal injury* (PI) is actually a *pedestrian accident* (PE). This in turn requires reading the police report, with its description of the accident and the information about the victim(s).

The death of a victim at the site of the accident is usually registered in police reports. In many countries, however, the death of a victim after the accident, on the way to hospital, during medical treatment, or after leaving the hospital, is not registered in the police report. This results in systematic underreporting of fatal accidents, so that the country tends to underestimate the seriousness of the problem and to underinvest in measures to reduce accidents. The underreporting also reduces the information available to the traffic engineer, making it more difficult to locate critical spots and understand the causes and potential corrective measures.

There are two ways to avoid this loss of information about fatal victims: (i) monitor the progress of victims with serious injuries by contacting hospitals; and (ii) register the names of all non-fatal victims and compare these with the names of all deaths occurring after the accident (e.g., within 30 days).

As mentioned in Chapter 1, the CET carried out such a pilot survey. It drew up a list of the names of people injured in traffic accidents in the Municipality of São Paulo during one month, and then made a second list of those who died within three months. The fatalities were identified from death certificates registered in the State Data Analysis System (SEADE).

The list of fatalities was compared with the list of names of fatal traffic accident victims registered at the Coroner's Office (Instituto Médico Legal – IML), also within a period of three months after the accidents. By law, the corpses of **all** fatal traffic accident victims should be examined by the IML. However, approximately 43% of the names on the fatal victims list did not appear in the IML list in the three month period after the accidents. Omission was more noticeable as the number of days or weeks increased between the accident and the resulting death.

Consequently, to obtain the correct total, it would be necessary to increase the registered total at the IML by about 74%. Other surveys show similar increases in the numbers of deaths when such a follow-up study is undertaken. For example, Pereira and Ribeiro (1988) found a 55% increase in Curitiba, Brazil, and DNER (1987) found an increase of 66% for Federal highways in the State of Rio de Janeiro.

This problem is not confined to Brazil. Traffic engineers in other countries should investigate how the data are generated, registered, and treated. Doctors may register as the cause of death something that is a result of the accident (internal injuries, pneumonia, heart failure).

Traffic authorities should define the number of days after the event in which a victim's death should be attributed to the accident. Countries vary in respect to this definition. For example, France limits the period to six days after the accident, while Japan extends traffic deaths to one year. Thirty days is a reasonable limit, since the vast majority of deaths occur within 30 days of the accidents.

The author found the following characteristics of the accident reports of Brazilian traffic police, which are common in other countries:

- absence of standardisation among reports from different cities and states, making it difficult to compare results on a regional or national scale;
- large variations in the quantity and quality of registered accident data; the worst have almost no information, while the best feature detailed descriptions of accidents with well elaborated complementary sketches and diagrams; and
- diversity of report sources: State Traffic Departments (DETRANs), Military Police, and Civil Police, depending on the city or state.

4.3 Supplementing the Available Data on Accidents

There are frequently gaps in the information obtained from the aforementioned sources of data on accidents. Some examples and the typical reasons for the gaps are given below.

- When people are injured, the police officer concentrates on the urgent task of administering first aid and organizing the transport of the victims to a hospital. Filling out the accident form is a secondary task.
- With property damage-only and pedestrian accidents, the first police officer to arrive at the scene often finds few or no signs of the accident, even when arriving only a few minutes after the event. The parties involved in a property damage-only accident may agree on payment for damages and leave the scene without waiting for the police.
- In many pedestrian accidents in Brazil and other countries, the driver of the vehicle involved immediately takes the victim to a hospital, even though it may medically be more advisable to wait for an ambulance.
- Some gaps in police reports are due to the procedures used to fill out the forms. When there is only property damage, the parties involved and the witnesses often remove the vehicles from the road to avoid additional accidents or traffic jams, making it difficult or impossible for police to reconstruct the scene of the accident. Procedures may require the police to write "scene altered after accident" on their report form, and to omit a description of the accident, even if witnesses describe the occurrence clearly. However, some officers in Brazil and elsewhere obtain descriptions of the accident from those involved and witnesses, jotting them down on separate forms and obtaining the signatures of the authors of the statements. Other police authorities identify traffic engineering conditions and failures, and include these in the police report or on separate forms.

The traffic engineer may need to supplement the available accident data to design corrective or preventive measures. Interviews with people familiar with the scene, such as local residents and workers, are often the best source of information. A police officer that has been called to the scene repeatedly may be able to explain the details of the accidents and probable causes. The people directly involved in the accidents are often available to explain what occurred.[1]

The CET carried out a two-year pilot study of supplementary data collection in 1984-1985. It collected information about fatal pedestrian accidents as soon as possible after the accidents. A trainee was sent to the accident location to fill out the form shown in Figures 4.1 to 4.3, registering all the technical data about the location and any additional information that could be obtained from interviews.

The best results were obtained when the investigation was carried out within 24 hours after the accident occurred. The forms were of great value in identifying the four basic groups of contributory factors that often did not appear in the police reports: human factors; vehicle factors; road/environment and built environment factors; and institutional/social factors.

The use of such forms is recommended for all critical spot analysis (the names of the people involved in the accidents described in Figures 4.1 to 4.3 were modified to respect their privacy).

[1] Legal requirements and access to information vary greatly from country to country. The traffic engineer should investigate these requirements and avoid procedures that might lead to complaints or litigation against the city or the traffic department.

FIGURE 4.1

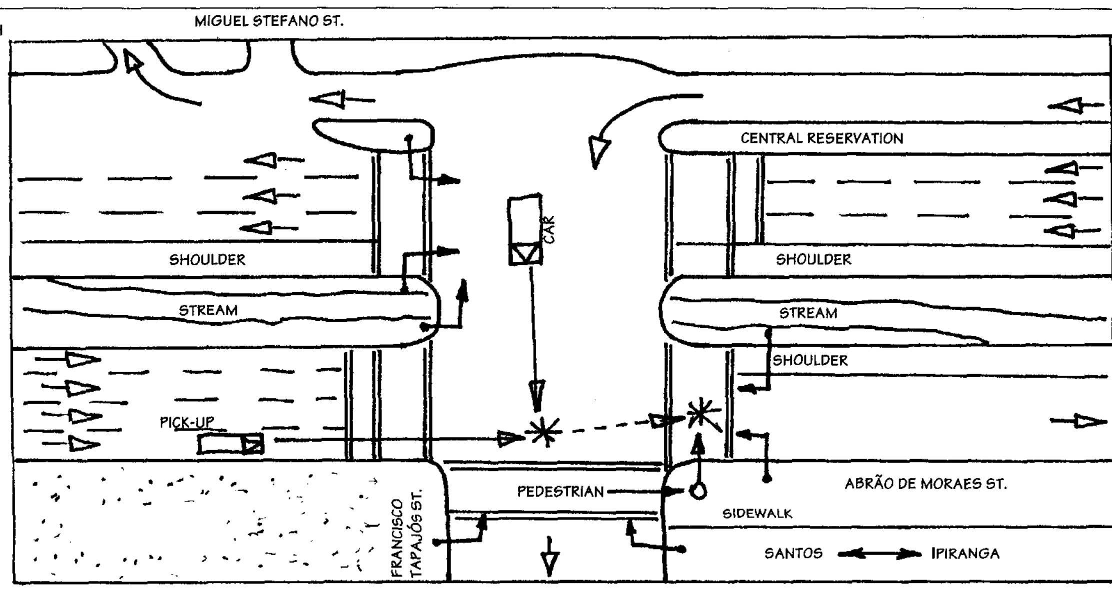
TRAFFIC ACCIDENT DATA SHEET

LOCATION Prof. Abrão de Moraes St. x Francisco Tapajós St.	DATE 06/04/84	TIME 02:50 pm
ZONE/BOROUGH Água Funda	DAY OF WEEK Mon	HOLIDAY No
REFERENCE/EMERGENCY SERVICES/HOSPITAL Saúde	SECTOR 250	AREA 4
OBSERVATIONS	ACCIDENT CODE NUMBER 04	

NAME OF VICTIM	SEX		INJURIES			AGE	FAMILIARITY WITH LOCATION				DIST.	VEHICLES MH 5830 FX 3456
	M	F	FATAL	SERIOUS	MINOR		HOME	STUDY	WORK	OTHER	m	
Geni da Silva		X	X									PARTICIPATION

DESCRIPTION Volkswagen pick-up crossed a red light in Abrão de Moraes St., collided with a Volks Beetle coming from Francisco Tapajós St. and ran over a woman crossing the avenue to catch a bus in Miguel Stefano St.

SKETCH



OBSERVATIONS/SOURCES: Medium/high vehicle flow. Constant/medium pedestrian flow.

– High speed, especially vehicles on Abrão de Moraes St.

– During the inspection most pedestrians preferred to cross the avenue where the victim was run over.

– Due to vehicles turning left into Abrão de Moraes St. there is no time for pedestrians to cross where the victim was hit.

– Suggestion by local workers/residents: install pedestrian traffic lights or increase the green time for Francisco Tapajós St.

INSPECTED BY: IRENE/ALFREDO	DATE	DAY OF WEEK	TIME	NUMBER
	08/05/84	MON	10:00 am	145

Source: CET

FIGURE 4.2

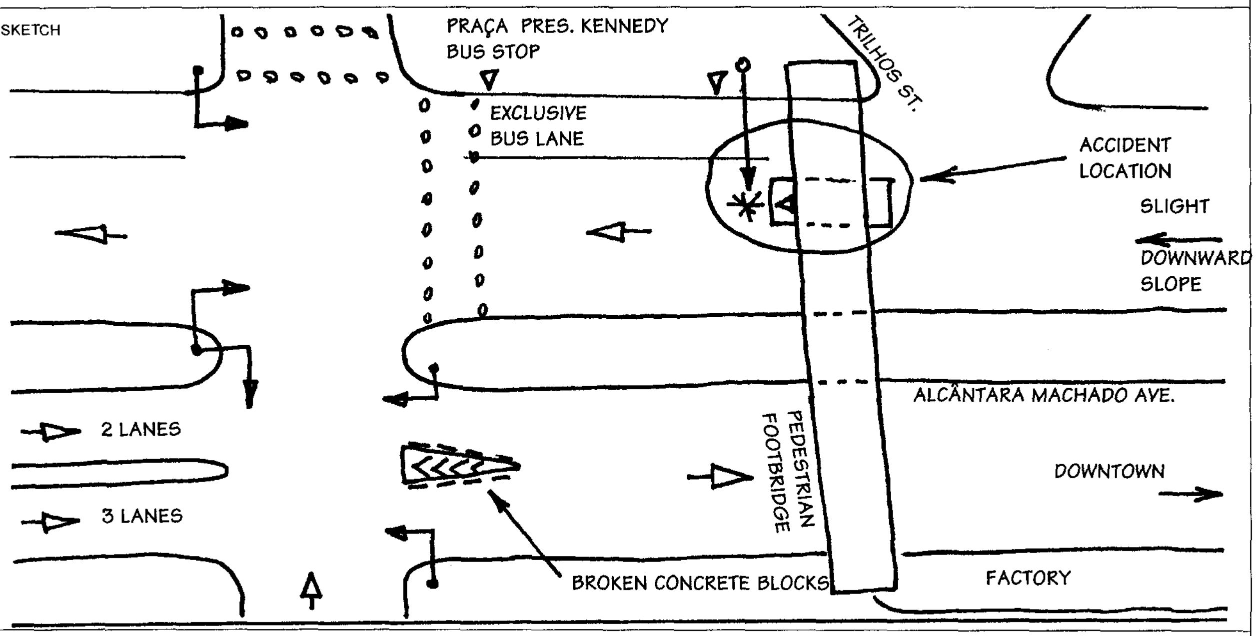
TRAFFIC ACCIDENT DATA SHEET

LOCATION Alcântara Machado Ave. under the pedestrian footbridge	DATE 04/11/84	TIME 09:20 pm
ZONA/BAIRRO Brás Near the factory Alpargatas	DAY OF WEEK Mon	HOLIDAY No
REFERENCE/EMERGENCY SERVICES/HOSPITAL	SECTOR 430	AREA 4
OBSERVATIONS	ACCIDENT CODE NUMBER 04	

NAME OF VICTIM	SEX		INJURIES			AGE	FAMILIARITY WITH LOCATION?				DIST.	VEHICLES
	M	F	FATAL	SERIOUS	MINOR		HOME	STUDY	WORK	OTHER	m	
José da Silva	X		X			49						PARTICIPATION Fled

DESCRIPTION A drunken man tried to cross the avenue and was run over by a vehicle.

SKETCH



OBSERVATIONS/SOURCES: Constant flow of vehicles and pedestrians.
– High speed.
– After 11:00 pm pedestrians do not use the footbridge because of muggings.
– One month ago an ambulance ran a red light and killed a woman who was crossing the avenue.

INSPECTED BY: IRENE	DATE 06/20/84	DAY OF WEEK WED	TIME 03:50 pm	NUMBER 149

Source: CET

FIGURE 4.3

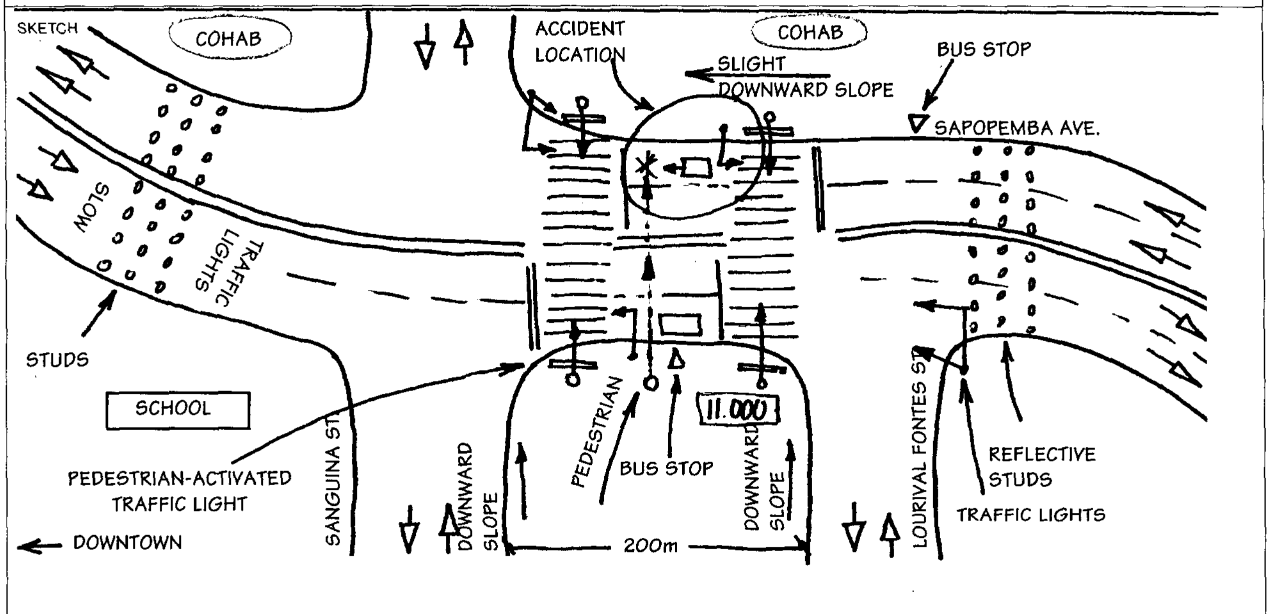
TRAFFIC ACCIDENT DATA SHEET

LOCATION SAPOPEMBA AVE. 11,000	DATE 05/25/84	TIME 08:55 pm
ZONE/BOROUGH	DAY OF WEEK Fri	HOLIDAY No
REFERENCE/EMERGENCY SERVICES/HOSPITAL SÃO MATEUS	SECTOR 430	AREA 4
OBSERVATIONS	ACCIDENT CODE NUMBER 04	

NAME OF VICTIM	SEX		INJURIES			AGE	FAMILIARITY WITH LOCATION?				DIST.	VEHICLES HY 1569 Bus
	M	F	FATAL	SERIOUS	MINOR		HOME	STUDY	WORK	OTHER	m	
João da Silva	x		X			26						PARTICIPATION

DESCRIPTION A 26-year-old man exited from the rear door of a bus and, when crossing the avenue, was hit by a bus of the AVOU company (see sketch), travelling in the opposite direction.

SKETCH



OBSERVATIONS/SOURCES: Local residents/workers had already protested because a boy had died there, run over by a car.

– Medium/high vehicle flow – high speed.

– Constant pedestrian flow.

– According to local residents/workers, many pedestrian accidents occur on this stretch.

– The inspection showed that many people, especially children, crossed the intersection of Sapopemba Ave. x Lourival Fontes Ave. because of the bus stop and the low-income housing area COHAB, withouth making use of the pedestrian traffic light and away from the pedestrian crossing area.

Pending: Return at night to examine public lighting.

INSPECTED BY: IRENE/TAVARES	DATE	DAY OF WEEK	TIME	NUMBER
	06/04/84	FRI	11:50 am	180

Fonte: CET

CHAPTER 5

INSTALLING AN ACCIDENT DATA BANK

The first step in using traffic engineering to reduce accidents is to create a data bank with basic information such as the locations of the accidents and the severity of personal injuries. This chapter shows how to organise an accident data bank from police reports. The next section describes the different types of information and how to assure priority for the most useful data in the analysis and diagnosis of critical spots.

Subsequent sections provide an outline of a manual data bank, a description of the use of personal computers, and typical reports produced by computer programs.

5.1 Types of Data and Priorities

Data from police accident reports include:

- date, time and location;
- basic data about the vehicles involved;
- data about the people involved;
- identification of witnesses;
- some description of the accident (text and/or sketch);
- physical/mental state of driver(s) involved;
- mechanical state of the vehicles involved;
- auxiliary data about weather conditions, the road(s), signs, signals and road markings, at the time of the accident; and
- preliminary evaluation of the seriousness of injuries sustained by victims.

Minimum Data

To identify critical spots requires the following minimum data for all accidents that have occurred during a given period in the study area (borough, city, specific highway, etc.):

- date and time; and
- location (road name and kilometre, or number of nearest building or some other point of reference; for intersections, the names of some or all streets that meet or cross at the intersection).

This information will allow the traffic engineer to locate the spots with the highest general accident frequencies. However, personal injury accidents should receive priority, so data is needed on deaths, injuries, and the severity of non-fatal injuries (if these appear in the police report). The usual classification is:

- minor injury
- serious injury
- death

For each accident, the information should include the number of people with minor and serious injuries and the number of dead.

To separate pedestrian and vehicle-only accidents, each accident should be classified as:

- property damage only (DO) or
- non-pedestrian personal injury (PI) or
- pedestrian accident (PE)

This basic data is sufficient to identify and plot on maps the locations with the highest frequencies of accidents:

- in general
- with death(s)
- with minor and serious injuries
- with pedestrian(s)

The engineer can monitor the trends of the frequencies of accidents and their severity.

The grouping of accidents by:

- *months of the year* facilitates the identification of seasonal variation or cycles of accident concentration, along with the existence of special factors, such as bank holidays, summer holiday period, and local cultural or touristic events;
- *days of the week* allows the identification of the critical days of the week (those with the highest frequency of accidents and/or injuries);
- *days of the month* permits the identification of any special event that increases the frequency of accidents;
- *times or periods of the day* permits the identification of hours or periods of the day/night when the accident and/or injury frequency increases, along with periods of low frequency that should be avoided when planning site inspections.

In sum, these data allow the engineer to identify: (i) the locations with high accident frequencies (giving priority to injury severity); (ii) the most critical days of the week; and (iii) the most critical times of day. He or she can then optimise the programming of site inspections and even identify some probable causal factors.

Basic Characterisation of Accidents

For critical spot studies, the identification of traffic engineering failures or needed improvement requires data that describe how the accidents occurred, the movements of the vehicles and pedestrians involved immediately before the accident, the points of impact, and the mistakes made by drivers and pedestrians.

The police report usually contains three types of data:

- a descriptive report of the accident;
- a sketch showing the final positions of the involved vehicles; and
- the damage to the vehicles (also as a sketch).

If sufficient data are available, the traffic engineer can reconstruct the moment of the accident and the type of collision (rear-end, sideswipe, etc.) or pedestrian accident. The approach paths of the vehicles and pedestrians involved may also be described.

The type of vehicle provides information on visibility, speed, manoeuverability and braking characteristics, which differ widely between vehicle types (automobile, truck, bus, or motorcycle). The police report normally contains this information.

The information about the drivers and pedestrians involved in the accidents is also very useful. The most pertinent factor in pedestrian accidents is age, since walking behaviour differs significantly among age groups. Many elderly persons walk slowly and have auditory and visual deficiencies; children are apt to behave in sudden, unexpected ways. The age of drivers is a fair indicator of the number of years of driving experience, and may be useful in identifying accidents that involve inexperienced drivers. Motorcyclists have disproportionately high participation in accidents, especially during their first thousand kilometres of motorcycling.

Environmental Factors

Other data recorded in police reports include road conditions, weather conditions, and the quality of street lighting, signs, signals, and road markings and other factors in the surrounding built environment. These data have priority as the basis for corrective traffic engineering measures: treatment of the road surface may reduce skidding during rainy weather; street lighting may be intensified in poorly lit locations; and signs, signals, and road markings may be implemented, redesigned, or supplemented.

5.2 Manual (Non-computerised) Data Bank

A manual data bank may be used as a stand-alone procedure when the number of accidents is small, as a temporary step in setting up a computerised data bank, or as a supplement or backup to a computerised data bank.

Setting up a manual data bank is a simple task that involves noting data from police reports and organizing these notes to facilitate the analysis and diagnosis of the causes of accidents. A photocopy of each police report is usually sufficient for this purpose, although it is often useful to use a summary form and a complementary sketch to register essential data, such as those shown in Figures 5.1 and 5.2.

Practical examples of the use of such documents are presented in item 7.4 and in Chapter 9. The recommended size of the forms is 5 cm x 17 cm to facilitate:

- filling the form out by hand;
- reading and manipulating up to 20 accident forms on a normal office desk; and
- mounting these forms on A4 size sheets to insert them directly into technical reports.

Card is the ideal material for the forms, since it is durable and easy to handle. The forms may be filed by street and by intersection, ready for use at any moment for analysis of accidents, by time of day, day of the week or month, type of vehicle, etc., followed by easy return to the file. The sketch may be drawn, or glued, on the back of the form or, in more complex cases, drawn on a separate sheet, which may be folded and clipped to the form.

FIGURE 5.1
SUPPLEMENTARY REFERENCE DIAGRAM

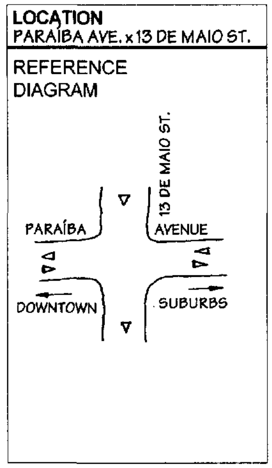
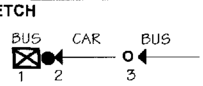
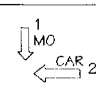


FIGURE 5.2
ACCIDENT DATA SHEETS
PARAÍBA AVENUE x 13 DE MAIO ST.

LOCATION PARAÍBA AVE. x 13 DE MAIO ST.	**LOCATION** PARAÍBA AVE. x 13 DE MAIO ST.
CODE NUMBER Accident 15/97	**CODE NUMBER** Accident 16/97
POLICE REPORT NUMBER 74	**POLICE REPORT NUMBER** 77
DATE 10-23-87	**DATE** 12-14-87
DAY OF THE WEEK Friday	**DAY OF THE WEEK** Monday
TIME 6:50 am	**TIME** 9:05 pm
DAY/NIGHT O	**DAY/NIGHT** ●
WEATHER Good	**WEATHER** Raining
ROAD CONDITIONS Dry	**ROAD CONDITIONS** Wet
ACCIDENT TYPE Pile-up: injury	**ACCIDENT TYPE** Right-angle: injury
VEHICLES INVOLVED CAR x BUS x BUS	**VEHICLES INVOLVED** CAR x MO
SKETCH 	**SKETCH** 
DESCRIPTION AND OBSERVATIONS Vehicle 1 waiting for green light.	**DESCRIPTION AND OBSERVATIONS** Vehicle 1 entered the intersection despite a red light. Underaged driver: age 14.

5.3 Computerised Data Bank

The analysis of large numbers of accidents is facilitated by transferring the data to an electronic computer file. Personal computers now have sufficient capacity for storing and accessing all pertinent accident data for a period of several years. There are also software packages that allow the traffic engineer to include the sketch of an accident in the data file. Document scanners have simplified this task even further. This information may be extracted directly from the police reports for specific studies, or the computer files may used in combination with the accident summary forms. Each accident must have the same identification number for both sources. In this way the computer may provide the identification numbers of all the accidents that have occurred at the intersection of street X with street Y, for example. Access will be quick and simple if the accident summary forms are filed in order of the accident identification numbers.

Various systems and programs for data bank administration are available. These systems are being constantly updated and innovations appear periodically in the market, so it is advisable to consult a specialist before making a decision.

5.4 Examples of Computerised Systems

This section discusses five computerised traffic accident data bank systems with which the author is familiar, without comparing them to other systems. Each one of them has some interesting aspects.

São Paulo Traffic Engineering Company - CET

Since the late 1970s, the CET has maintained a computerised data bank on traffic accidents in the Municipality of São Paulo, where it is responsible for the planning and operation of traffic systems. In 1995 the CET received data on an average of 538 accidents per day, including 43 pedestrian accidents, 76 (non-pedestrian) personal injury accidents, and 419 property damage only accidents. The last category is vastly underreported, since in 1995 police were not required to register accidents that involved only property damage.

The CET system, known as the Traffic Accident System (SAT), was created using Dbase. Some subsystems, constructed for specific purposes, also use FoxPro. SAT contains all the key data registered in the police reports and is accessible to all CET employees, via a network of microcomputers installed in the regional offices.

The users may obtain, on line, accident data tables, selected in accordance with their individual needs, such as giving priority to accidents with fatal victims, with severe injuries, or injuries to children. Specific zones, streets, or intersections may be selected, along with specific dates, types of accident, and types of vehicles. The system also emits and distributes periodic management reports, via the computer network, independently of *ad hoc* queries by individual users.

An example of SAT output is given in Table 5.1, which presents data on accidents during the first six months of 1993 at the junction of Guararapes Street and Nova Independência Street.

CADA and CADB are the codes of the two intersecting streets.

CODE — is the code of the basic accident type
- 02 – vehicular, with personal injury
- 03 – vehicular, property damage only
- 04 – pedestrian accident

S — is the information source:
- C = (military) traffic police
- D = (civil) police station

PV — identifies the police vehicle that was sent to the accident

PS — identifies the civil police station

PR — is the identification number of the police report, from which all information is taken

VEHS — informs the types and number of each vehicle type involved.

Each column represents a type of vehicle. For example, the first refers to automobiles, the second to trucks, then buses, motorcycles, and bicycles.

TABLE 5.1
TRAFFIC ACCIDENTS: JAN-JUN 1993

GUARARAPES x NOVA INDEPENDÊNCIA											
CADA	CADB	DATE	TIME	CODE	S	PV	PS	PR	VEHS	VICTIMS	DAY
14780	08377	01/18/93	905	03	C	320		11	1 1		2
14789	08377	02/20/93	845	02	C	2312		7	1001	000001	0
08377	14780	02/20/93	930	02	D		096	659	2	01	0
14780	08377	04/15/93	1550	03	C	BAND		57	1 1		5
14780	08377	05/12/93	815	03	C	BAND		15	2		4
08377	14780	06/09/93	2130	02	D		096	1946	11	01	4

Source: CET

VICTIMS informs the number of victims and the severity of their injuries. The two first columns refer to victims with minor injuries, columns three and four to victims with serious injuries, and columns five and six to fatal victims.

DAY indicates the day of the week: 0 = Saturday, 1 = Sunday, 2 = Monday, etc.

The data show that 6 accidents occurred, 3 with victims and 3 without. The majority of the vehicles involved were automobiles. One victim suffered minor injuries and, apparently, two died. "Apparently," because double counting may have occurred. One fatal victim was registered by the traffic police in police vehicle 2312, on 20 February 1993 at 8h45 and the second was registered on the same day, 45 minutes later, at Police Station No. 96. This small interval between accidents warrants a check to see if there was double counting of a single fatal accident. Doubt may be eliminated by obtaining the police reports and comparing the name(s) of the fatal victim(s).

Table 5.2 presents all accidents registered in 1993 on Dr. Alceu de Campos Rodrigues Street, at intersections and between intersections.

N° indicates the numbers of the buildings or the kilometre mark closest to the locations of accidents that occurred between intersections.

NA (not available) indicates the police report does not have the N° information.

AMARO, etc. are the names of the other streets at intersections with Dr. Alceu de Campos Rodrigues Street.

DIR indicates the direction of vehicle flow: city centre to suburbs, etc. (not used in the example).

The data show that 8 pedestrian accidents occurred (code 04). Once again there may be double counting in the case of the two pedestrian accidents registered on 7 December 1993 at 13h30 and 13h59. All the pedestrian accidents occurred during daylight.

Table 5.3 presents the distribution, by day of the week and time of day, of accidents registered in 1994 on Antônio Batuira Avenue, distinguishing accidents with non-pedestrian personal injury, property damage only, and pedestri-

TABLE 5.2
TRAFFIC ACCIDENTS – 1993
DR. ALCEU DE CAMPOS RODRIGUES STREET

STREET/AVENUE	N°.	REF.		DATE	DAY	TIME	CODE	VEHICLES	VICTIMS	DIR	S	PV	PS	PR
		NA		07/11/93	1	1600	03	10010	000000		C	210		103
		NA		10/07/93	5	1630	03	20000	000000		C	300		60
		NA		12/03/93	6	1320	03	20000	000000		C	BAND		20
		NA		01/30/93	0	1430	03	20000	000000		C	260		69
		NA		02/15/93	2	1500	03	20000	000000		C	220		160
		NA		06/10/93	5	2000	03	20000	000000		C	300		66
		NA		06/17/93	5	900	03	20000	000000		C	220		80
	75			08/18/93	4	1420	04	00010	000000		C	2215		09
	237			03/08/93	2	1505	03	20000	010000		C	220		132
	247			04/20/93	3	1130	03	20000	000000		C	220		58
	295			09/01/93	0	1200	04	10000	000000		D			0086
	540			02/15/93	2	1835	03	00000	000001		C	2235	097	14
	560			04/05/93	2	1315	03	20000	000000		C	BAND		40
	722			12/07/93	3	1359	04	10000	000000		D		015	12887
AMARO				12/07/93	3	1330	04	10000	010000		C	2233		14
AMARO				12/16/93	5	1500	04	10000	010000		C	2705		08
AMARO				02/02/93	3	1400	03	10000	010000		C	200		35
AMARO				03/11/93	5	5	02	20000	000000		C	2312		04
AMARO				03/23/93	3	645	04	10000	040000		D		015	2691
AMARO				04/12/93	2	1700	04	10000	010000		D		015	3366
AMARO				05/26/93	4	1405	04	00000	010000		C	2704		09
AMARO				05/16/93	1	1805	02	20000	010000		D		015	4672
CLODOMIRO AMAZONAS				*09/26/93*	*1*	*130*	*03*	*20000*	*000000*		C	BAND		01
CLODOMIRO AMAZONAS				10/19/93	3	1400	03	20000	000000		C	230		55
CLODOMIRO AMAZONAS				12/20/93	2	1645	02	11000	000000		C	2207		15
CLODOMIRO AMAZONAS				03/25/93	5	2100	03	20000	010000		C	BAND		04
JOAO CACHOEIRA				12/14/93	3	1745	03	10100	000000		C	BAND		67
JOAO CACHOEIRA				12/14/93	3	930	03	10000	000000		D		015	13584
JOAO CLIMACO PEREIRA				09/30/93	3	1845	03	20000	000000		C	BAND		40
JOAO CLIMACO PEREIRA				10/22/93	6	1305	03	20000	000000		C	230		117
JOAO CLIMACO PEREIRA				04/19/93	2	1100	03	20000	000000		C	210		90
JOAO CLIMACO PEREIRA				06/07/93	2	1720	03	20000	000000		C	100		24

Source: CET

TABLE 5.3
TRAFFIC ACCIDENTS CLASSIFIED BY
TIME OF DAY AND DAY OF WEEK – 1994
ANTONIO BATUIRA AVENUE

TIME		INJURY ACCIDENTS (EXCLUDING PEDESTRIANS)								PROPERTY DAMAGE ONLY ACCIDENTS								PEDESTRIAN ACCIDENTS							
FROM –	TO	SAT	SUN	MON	TUE	WED	THU	FRI	TOTAL	SAT	SUN	MON	TUE	WED	THU	FRI	TOTAL	SAT	SUN	MON	TUE	WED	THU	FRI	TOTAL
0	59	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	159	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
200	259	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
300	359	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
400	459	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
500	559	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
600	659	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
700	759	0	1	0	0	0	0	0	1	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0
800	859	0	0	0	0	0	0	0	0	0	0	2	0	1	1	0	4	0	0	0	0	0	0	0	0
900	959	0	0	0	1	0	0	0	1	0	1	0	0	0	0	2	3	0	0	0	0	0	0	0	0
1000	1059	0	0	0	0	0	0	0	0	0	0	1	2	0	0	1	4	0	0	0	0	0	0	0	0
1100	1159	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1200	1259	0	0	0	0	1	0	0	1	0	0	1	0	0	1	2	4	0	0	0	0	0	0	0	0
1300	1359	0	0	0	0	1	0	1	2	0	0	1	0	1	0	1	2	0	0	0	0	0	0	0	0
1400	1459	0	0	0	0	0	0	0	0	0	0	2	0	1	1	1	5	0	0	0	0	0	0	0	0
1500	1559	1	0	0	0	0	0	0	1	1	0	0	1	0	0	1	3	0	0	0	0	0	0	0	0
1600	1659	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	3	0	0	0	0	0	0	0	0
1700	1759	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
1800	1859	0	0	0	0	0	0	0	0	1	1	1	0	1	1	0	5	0	0	0	0	0	0	0	0
1900	1959	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	2	0	0	0	0	0	0	0	0
2000	2059	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	4	0	0	0	0	0	0	0	0
2100	2159	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0
2200	2259	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
2300	2359	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2	0	0	0	0	0	0	0	0
TOTAL		1	1	0	1	3	0	2	8	5	5	10	7	5	7	10	49	0	0	0	0	0	0	0	0

Source: CET

ans. No pedestrian accidents occurred, almost all personal injury accidents occurred during the day, and property damage only accidents occurred at all times of the day except dawn, with higher frequencies during weekdays than on weekends.

For fatal accidents, SAT includes a subsystem containing more detailed information, accepting data in addition to that from police reports, obtained through supplementary investigations by CET staff.

SAT does not include accident diagrams (sketches) from the sketches and descriptions contained in the police reports. These are produced manually, by consulting copies of the police reports, obtained only for specific studies. The system does not permit automatic mapping of accidents.

Computerised Traffic Accident Data Bank – BIAT

BIAT was developed by consultants in São Paulo for use by the technical staff of traffic departments of small and medium cities. The BIAT system received the technical approval of the Brazilian National Traffic Safety Institute (INST), a non-profit organisation. As with the CET system, police accident reports are the main source of data. The data are entered directly by using interactive standardised forms on the computer screen, requesting and recording information. The system immediately checks the validity of each item of information introduced, requesting corrections when necessary.

There are several options for standard managerial reports and the user can create a wide variety of tables to analyse the different types of data.

The BIAT system uses the C++ language and includes a graphics program that can incorporate accident diagrams, based on sketches and descriptions contained in the police reports. Like the CET's SAT system, the BIAT does not include automatic mapping.

The system has been working in several Brazilian cities since March 1997 and is now being updated and expanded.

Brazilian National Highways Department – DNER

DNER's Engineering and Traffic Safety Division (DEST) has a data bank containing information on all accidents registered on all federal highways where police patrols are assigned. In 1995, the system received data on 95,514 accidents (262 per day), distributed over 37,000 km of highways.

The system uses the Cobol language and emits periodic managerial reports. The system was not developed to be directly accessible to DNER staff or other interested users; non-standardised reports must be requested from DEST.

The DNER uses *ForPrint for Windows* software to print individual reports, resulting in self-explanatory output that is easy to read and interpret, as seen in Table 5.4. This table shows a page from a report for a study of construction of a second carriageway on 700 km of the highway linking São Paulo to Florianópolis, a project that received IDB financing.

The example in Table 5.4 contains all the accidents registered on a stretch of the highway during one year by location. The information can be read rapidly: the date, the day of the week, the time of day, the type of accident (pedestrian accident, rear-end collision, etc.), and the severity of injuries sustained by the victims. The report allows the users to immediately identify and examine locations with high frequencies of serious accidents and, for each location, the most common types of accidents and the days of the week and times of day when they occur. This analysis identifies some probable causes of accidents even before site inspections are carried out. For example, the existence of many accidents with vehicles leaving the roadway, in short stretches, indicates a high probability that there are curves with inadequate geometry.

Table 5.4 shows that:

- there is probably a dangerous curve between km 28 and km 29, with posts near the road or with some other dangerous object(s) that transform accidents with vehicles leaving the roadway into serious or fatal accidents;
- there is a need to physically separate vehicles that travel in opposite directions, especially between km 29 and km 30, where there are many head-on collisions and sideswipe collisions with vehicles travelling in opposite directions during all weekdays and all hours of the day and night; and
- there is probably a significant flow of pedestrians crossing the road between km 32 and km 33, especially during weekends, as indicated by the pedestrian accidents.

The system does not include the automatic creation of accident sketches or diagrams, nor the mapping of accidents. However, DNER is presently studying a way to link the system with a Geographical Information System (GIS) that is being set up to integrate all types of DNER technical data. Such a system would permit automatic mapping.

Microcomputer Accident Analysis Package – MAAP

The MAAP system was developed in the United Kingdom by the Transport Research Laboratory (TRL), a leading government research entity that was recently privatised. The work was performed for the Overseas Development Administration (ODA), a government entity. The system was designed to help solve problems often found in developing countries, including the lack of available accident data, non-systematic treatment of existing data, and a shortage of qualified technical staff.

The MAAP system registers data directly on the computer and emits standardised managerial reports and *ad hoc* reports requested by users. It is designed to be user friendly.

The MAAP system differs from the systems described previously by permitting the mapping of accidents, in many different forms, using as bases schematic maps of the road network and coloured pages, captured by scanner from normal city guide books.

The MAAP system does not accept accident sketches. It does permit the user to include all other data from the accident reports or from groups of summary forms (see section 5.2), facilitating the identification of contributing factors common to different accidents.

This description of the MAAP system is based on version v5.

Traffic Accident Observatory – OAT

The city of Curitiba, Brazil, has recently set up a traffic accident data bank known by its Portuguese acronym OAT as part of an IDB-financed Urban Transport Project. OAT integrates information from all available sources, such as police reports, hospital files, emergency medical services, and registers of the Coroner's Office. The system also accepts data from new or non-standard sources, such as interviews with witnesses or people involved in the accidents. The systematic monitoring of data from hospitals and the Coroner's Office will register deaths of injured victims that occur en route to the hospital, or days, weeks, or months after the accident.

The OAT system will receive data on traffic flows of vehicles and pedestrians, obtained from manual and automatic counts. This permits the automatic calculation of indices of accidents and victims in relation to traffic volumes. The system has complete flexibility for data analysis, is very user friendly, and includes the automatic mapping of accidents by coupling of the data bank with the city's Geographical Information System. The system does not accept or create accident diagrams.

5.5 Additional Observations

An accident data bank is useful in many other situations aside from the identification, analysis, and comparative evaluation of corrective measures for critical spots. It can be used to avoid misinformation. For example, if the mayor receives a complaint that many accidents are occurring on the corner of streets X and Y, he can find out quickly that only one accident occurred there during the last three years. Further, the accident occurred at 2 am. on a Sunday, when an automobile crashed into a wall 2 metres from the edge of the road, and involved a drunk driver. On another occasion, the mayor could respond to a worried councillor that an engineering project, awaiting approval, should significantly reduce the number of accidents occurring on the corner of Avenues S and T, where 21 personal injury accidents were registered during the previous year.

An up-to-date data bank is vital for monitoring and evaluating a traffic safety program, in addition to substantiating requests for resources to start, maintain, or expand such a program.

TABLE 5.4
EXTRACT OF HIGHWAY ACCIDENTS BETWEEN SÃO PAULO AND FLORIANÓPOLIS (1994) - LINK: BR-116/PR Km 0 TO Km 96

		Date	Day of the week	Time		Severity	Type of accident
		26/07/94	Tuesday	11	5	2-Injury	12-Vehicle leaves road
Km	28	Number of accidents = 7					
		08/24/94	Wednesday	9	10	2-Injury	01-Collision with fixed object
		11/12/94	Saturday	6	20	2-Injury	11-Partial overturn
		11/22/94	Tuesday	14	0	1-Damage only	12-Vehicle leaves road
		07/12/94	Tuesday	8	30	1-Damage only	12-Vehicle leaves road
		03/19/94	Saturday	1	30	2-Injury	12-Vehicle leaves road
		10/17/94	Monday	16	30	3-Fatal	12-Vehicle leaves road
		01/03/94	Monday	11	30	3-Fatal	12-Vehicle leaves road
Km	29	Number of accidents = 15					
		12/26/94	Monday	2	40	2-Injury	02-Full overturn
		06/04/94	Saturday	18	0	1-Damage only	08-Head-on collision
		04/01/94	Friday	8	30	2-Injury	08-Head-on collision
		02/19/94	Saturday	14	10	2-Injury	08-Head-on collision
		04/29/94	Friday	10	40	2-Injury	08-Head-on collision
		12/22/94	Thursday	15	30	1-Damage only	09-Collision-opposite direction
		02/18/94	Friday	19	30	2-Injury	09-Collision-opposite direction
		11/15/94	Tuesday	4	10	2-Injury	09-Collision-opposite direction
		08/17/94	Wednesday	16	30	2-Injury	09-Collision-opposite direction
		08/24/94	Wednesday	2	30	3-Fatal	09-Collision-opposite direction
		04/12/94	Tuesday	5	30	2-Injury	10-Right-angle collision
		02/16/94	Wednesday	17	30	2-Injury	12-Vehicle leaves road
		12/17/94	Saturday	15	10	2-Injury	12-Vehicle leaves road
		09/02/94	Friday	22	40	1-Damage only	13-Other types
		05/10/94	Tuesday	1	30	2-Injury	13-Other types
Km	30	Number of accidents = 6					
		10/27/94	Thursday	20	30	2-Injury	08-Head-on collision
		09/26/94	Monday	17	0	2-Injury	08-Head-on collision
		10/29/94	Saturday	10	0	1-Damage only	11-Partial overturn
		07/21/94	Thursday	16	5	1-Damage only	12-Vehicle leaves road
		03/06/94	Sunday	9	30	1-Damage only	12-Vehicle leaves road
		09/08/94	Thursday	11	30	3-Fatal	14-Pedestrian hit-and-run
Km	31	Number of accidents = 2					
		11/06/94	Sunday	19	0	2-Injury	08-Head-on collision
		12/24/94	Saturday	10	0	2-Injury	11-Partial overturn
Km	32	Number of accidents = 8					
		12/04/94	Sunday	10	30	2-Injury	03-Pedestrian hit
		01/17/94	Monday	13	15	2-Injury	03-Pedestrian hit
		10/07/94	Friday	22	30	3-Fatal	03-Pedestrian hit
		04/09/94	Saturday	7	10	2-Injury	08-Head-on collision
		04/05/94	Tuesday	21	40	3-Fatal	09-Collision-opposite direction
		11/06/94	Sunday	9	10	2-Injury	11-Partial overturn
		08/06/94	Saturday	9	0	2-Injury	12-Vehicle leaves road

Source: Departamento Nacional de Estradas de Rodagem (DNER).

CHAPTER 6

IDENTIFYING CRITICAL SPOTS

6.1 Who Identifies the Critical Spots and How?

An architect, who works in traffic engineering, returns from vacation in mid January and finds the following items on her desk at the municipal traffic department.

- A message from the manager (who is on vacation): "This year we will begin a project to reduce accidents at critical spots. You will coordinate the project. I want to receive a critical spot study each week, with proposals for corrective and preventive measures. For the moment, proposals should be limited to low cost measures because the budget for this type of project has not been fixed."
- A message from the technical director requesting urgent traffic safety studies for two intersections: Itaipá Street x Andrade Street; and Paraná Avenue x Rio Grande do Sul Avenue, with no further explanations.
- A newspaper article with a letter, signed by members of several community associations, demanding immediate action to reduce the danger to pedestrians at the intersection of Bairro Street and Central Avenue.
- Copies of up-to-date accident lists prepared from information obtained from police reports.

What should she do? How will the architect identify the critical spots? How will she select one or more to be studied? How should the director's request and the community associations' petition be treated?

This chapter presents some proposals to help the traffic engineer structure a program for the treatment of critical spots.

6.2 Types of Critical Spots

Locations with Highest Accident Frequencies

These are the locations with the highest total accident frequencies, obtained by summing the frequencies of property damage only accidents, non-pedestrian personal injury accidents, and pedestrian accidents.

Locations with Highest Accident Risks

The locations with the highest accident frequencies are not necessarily the most dangerous, since danger is measured by the probability of each vehicle/pedestrian being involved in an accident when passing through the locale.

TABLE 6.1
RELATIVE DANGER LEVELS OF ACCIDENT LOCATIONS

Location Number	Frequency (Accidents/year)	Flow (Vehicles/year)	Danger Index (Accidents/10^5 vehicles)	Decreasing Order	
				Frequency	Danger (risk)
1	2	10.000	20	3	1
2	50	500.000	10	2	2
3	100	2.000.000	5	1	3

Although accident frequency and danger are associated, a high accident frequency may result from a high volume of vehicles/pedestrians. This means that the locale is not very dangerous in relation to its volume of traffic. Conversely, a low accident frequency yields a high-risk of accidents if the locale has a low volume of vehicles/pedestrians.

Thus, vehicle/pedestrian traffic counts are needed to apply the concept of accident risk to the comparative analysis of critical spots. Table 6.1 shows how this concept may reorder the priority of critical spots, when compared with accident frequency alone.

Locations with the Largest Increase in Accident Frequency

Some locations with relatively low frequencies of accidents may exhibit extremely fast growth of accidents. Table 6.2 provides a hypothetical count of one year's accidents at the intersection of Andrade Street and Itaipá Street (the study requested by the technical director). Some change that provokes accidents is probably happening at this locale.

TABLE 6.2
MONTHLY DISTRIBUTION OF ACCIDENTS

Month	1	2	3	4	5	6	7	8	9	10	11	12
Accident total	0	0	0	1	1	2	3	4	4	6	6	6

Complaints from the Public/Press

Letters sent to traffic authorities or published in newspapers may classify some locations in the road network as very dangerous. These allegations are often correct, but the locales cited may not show up in the statistics with high accident frequency, high accident risk, or high accident growth rates.

Suppose this is the case for the intersections of Paraná Avenue and Rio Grande do Sul Avenue (the technical director's request for a study) and of Bairro Street and Central Avenue (newspaper cutting). The following typical results might be found during the technical site inspections:

- Paraná Avenue and Rio Grande do Sul Avenue

  There is a high level of vehicle movement with many conflictive situations; drivers brake suddenly and frequently to avoid collisions. People interviewed at the location affirm that many minor collisions occur, but that no one has been injured and nobody calls the police when they happen. No one remembers any serious accidents.

- Bairro Street and Central Avenue

  Very many pedestrians cross the roads under adverse traffic conditions, during the peak periods. This is due to high traffic volumes and high vehicle speeds, with almost no effective control by signs, signals, or traffic police. Very few pedestrian accidents have been registered, although people interviewed at the site affirm that many have occurred.

6.3 Selection for Analysis

What criteria should be used to select critical spots for analysis and improvement?

- reduction of total accidents?
- reduction of accidents with personal injuries?
- reduction of pedestrian accidents?
- elimination of high-risk locations, whatever the accident frequency?
- inversion of the trend at locations with highest accident growth rates?
- give attention to the complaints of the public?

The following priorities for the selection of locations for study are recommended:

Severity of the Consequences of Accidents

The locations with the highest frequencies of personal injury accidents should have priority. Within this group, pedestrian accidents should be given more weight than other types, since the victims usually sustain more severe injuries than occupants of vehicles in other types of accidents. In Brazil, about 60% of fatal victims of traffic accidents are pedestrians, a figure that is typical of many other countries in Latin America and the Caribbean.

High Frequency versus High-risk

In locations with high accident frequencies, a pattern of accidents probably exists. One or sometimes two types predominate, making it possible to eliminate a significant number of accidents with just one project.

High-risk locations may have many accidents and large traffic volumes or, at the other extreme, low accident frequencies and small traffic volumes. Within the high-risk group, spots with the highest accident frequencies should be given priority for study and improvement, since one cannot eliminate many accidents where few occur. Conversely, when dealing with spots with the highest frequencies of accidents, priority should be given to the spots with the highest risks.

Locations with High Accident Frequency Growth Rates

These are priority locations, whether they have high or low frequencies of accidents, since there is usually some easily identifiable change that has caused the growth in accidents.

Locations Indicated by the Population

These locations should be studied for two reasons.

- The city administration basically works for the public and should respond to the anxieties of the citizens, correcting failures in the traffic system or, when they do not exist, responding to the public with adequate explanations.
- These locations may be potential critical spots, due to recent changes in the road network or vehicle and pedestrian flows that have not yet shown up in the accident statistics.

6.4 Accident Rates and Standard Unit of Severity

A commonly used concept of a critical spot or section refers to a relatively high accident frequency compared to the volume of traffic. The relative danger levels of different intersections (or sections of roadway) may be expressed using formulas such as the following:

$$T_J = \frac{A_J}{(P)\ (ADT_J)} .10^6 \qquad (1)$$

Where:

- T_j = accident rate at intersection[1] j
- A_j = number of accidents at intersection j in time period P
- **P** = study period, in days
- ADT_j = average daily traffic passing through the intersection, in vehicles (sum of the n approaches)
- 10^6 = factor to avoid very small numbers

The rates obtained with this formula vary widely and depend on the accident category used: total accidents; fatal accidents; pedestrian accidents; non-pedestrian personal injury; or property damage only. When applying this formula, calculations should be made for the different categories and the results for all the spots being studied should be compared, to identify patterns (of similarities and differences), among the various indicators, categories, critical spots, and sections.

In Formula (1), a weighted average of the different accident categories, such as the Equivalent Accident Number (EAN), may be used instead of A_j, attributing weights to the various accident categories. For example, based on DNER cost estimates, DENATRAN (1987, p.31) uses the following weights, without differential treatment for pedestrian accidents, which are included in the personal injury category:

DO = 1
PI = 5
Fatal = 13

The following formula is thus obtained:

$$T'_J = \frac{EAN_J}{(P)\ (ADT_J)} .10^6 \qquad (2)$$

where:

EAN = 1 (nº DO accidents) +5 (nº of non-fatal PI accidents) + 13 (nº of fatal accidents); and the remaining terms maintain their previous definitions.

The CET uses other weights, based on an analysis of the distribution of fatal victims between pedestrian and non-pedestrian accidents in São Paulo:

DO = 1 (property damage only)
PI = 4 (non-pedestrian injury accident)
PE = 6 (pedestrian accident)

These rates may provide some useful additional information, but should never be used alone or without careful qualitative evaluation of other types of data. They could lead, for example, to an erroneous decision not to treat many of the busiest intersections in city centres. Many accidents occur in these locations due to the high vehicle and pedestrian flows, despite the low probability of a given driver or a pedestrian being involved in an accident when passing through. However, they are often excellent locations for the implementation of projects with high benefit/cost ratios, because, in any one of these locales, many accidents may be avoided with just one project.

Accident rates, as normally calculated, can lead to absurd conclusions concerning pedestrian safety. This happens because the formulas include only vehicle traffic flows, ignoring pedestrian flows crossing the road. The following example illustrates this point:

Location	A	B
Study period (days) – P	365	365
Annual pedestrian accidents	5 fatal	5 fatal
EAN (using fatal = 13)	65	65
Average daily pedestrian crossings	1,000	1,000
Average daily vehicle traffic – ADT	10,000	20,000
Accident rate (formula 2) – T	17.8	8.9

The accident rate for location A (17.8) is twice that of location B (8.9), implying that it is twice as dangerous and should have double the priority for implanting safety improvements. However, these accident rates consider only the relative risks for vehicle occupants, ignoring the risks for pedestrians. A driver passing through location A is twice as likely to hit a pedestrian than at location B, while the probability of each pedestrian being killed when crossing the road is the same in the two locations: $5/(1{,}000 \times 365) = 0.0000136$. For pedestrians, both locations are equally dangerous and deserve the same priority.

To compensate for this bias, the traffic engineer should also calculate the Pedestrian Accident Rate (PAR) for locations with pedestrian accidents, using formula 2, above, with the following modifications:

- the Equivalent Accident Number (EAN) becomes EPAN – Equivalent Pedestrian Accident Number, considering only pedestrian accidents;
- Average Daily Traffic (ADT) becomes ADPT – Average Daily Pedestrian Traffic, calculated as the average total number of pedestrians crossing the road per day at the location.

Locations A and B have identical PARs, correctly indicating that they present equal risks for pedestrians:

$$PAR = (5 \times 13)/(365 \times 1{,}000) \times 10^6 = 178$$

Locations with both pedestrian and non-pedestrian accidents should be analysed twice: once using the general accident rate and once using PAR. The general accident rates may be used to compare the relative risks between different locations for drivers and passengers, and the PARs to compare relative risks for pedestrians.

A further problem of accident rates, as normally used, is that they ignore the hourly and daily distribution of the accidents. In São Paulo, for example, most pedestrian and non-pedestrian personal injury accidents occur during the night of weekdays, and during the entire weekend. During these periods traffic flows are low and bear little relation to the Average Daily Traffic, which reflects mainly traffic during working days. General accident rates, if used alone, provide little useful information for comparing different locations, planning site visits, or analysing possible improvements. The analyst should therefore calculate separate traffic flows and accident rates for different periods, including normal working hours, nights of weekdays, and weekends.

Góes (1983, p. 137-8) observes that: (1) the utilisation of equivalent accident numbers may generate distortions; (2) generally, the division of accidents in personal injury and property damage only would be sufficient; (3) probability methods[2] would be more adequate; and (4) numerical methods should not be used in isolation from other methods.

[1] When dealing with a section, divide the term Tj obtained from Formula (1) by the length of the section, in km. (Be careful: the results are very sensitive to section length).

[2] These methods are not covered in this book.

CHAPTER 7

PRELIMINARY ANALYSIS OF AVAILABLE ACCIDENT DATA

Analysis may begin once a critical spot (section, area) has been selected, and the police accident reports have been obtained, read, and processed. The objectives of this analysis are to characterise possible safety problems and identify common factors or patterns among the accidents.

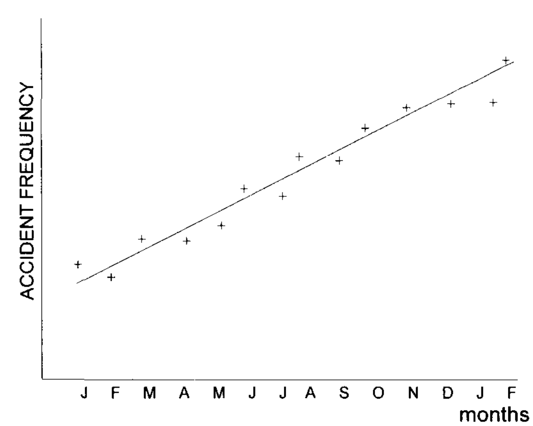
7.1 Evolution of the Accident Frequency

The evolution of the accident frequency should be examined for tendencies or sudden changes. A graph should be made from lists in the general accident file, as described in Chapter 5, for a period of at least one year, broken down by months.

Constant Growth of Frequency (Figure 7.1)

A tendency of gradual, but constant, growth of the accident frequency may reflect an increase in the volume of vehicles or pedestrians. Alternatively, it may reflect the gradual deterioration of some factor, such as the visibility of road markings worn away by constant vehicle movement, or of a sign, impaired by growth of vegetation.

FIGURE 7.1
GROWTH OF ACCIDENTS AT CONSTANT RATE



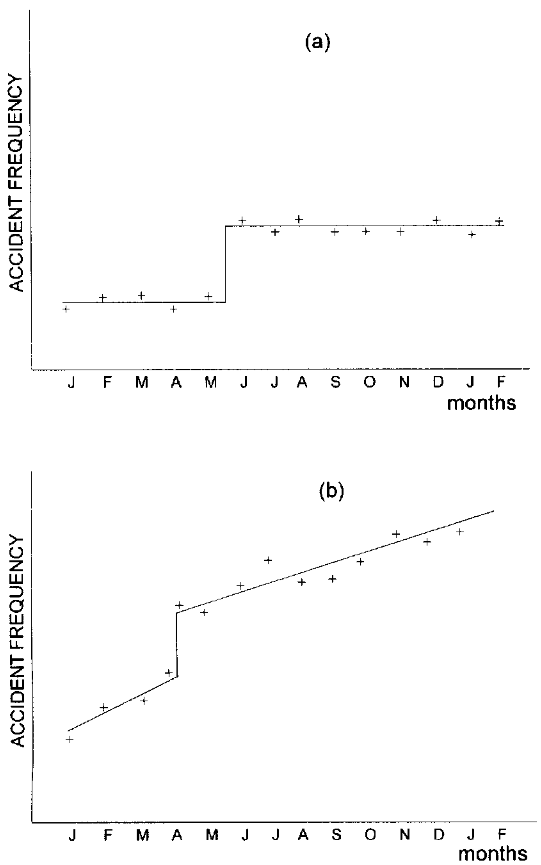
Sudden Increase and Growth (Figure 7.2)

A sudden increase in the accident frequency may indicate:

- a negative result of some project, implemented at the location;
- an increase in the volumes of vehicles and/or pedestrians, resulting from a change made to the road system;
- a sudden deterioration of signs and signals, such as a sign that has fallen from its post; or
- some other event that suddenly occurred.

These sudden changes may be followed by a tendency towards stabilisation (Figure 7.2 a) or by additional increases in frequency (Figure 7.2 b). A tendency to increase normally reflects factors different from those that caused the sudden change.

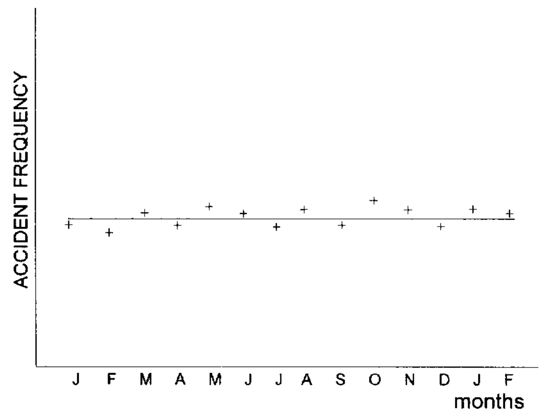
FIGURE 7.2
SUDDEN CHANGES IN ACCIDENT LEVELS



Constant High Frequency (Figure 7.3)

Constant high accident frequency is never due to a recently implemented project or to factors such as gradual growth of traffic volume. Usually it is due to certain permanent characteristics of the location and/or to the existence of high volumes of vehicles and/or pedestrians.

FIGURE 7.3
CONSTANT ACCIDENT FREQUENCY



7.2 Distribution by Time of Day and Day of the Week

From the accident data bank, the traffic engineer may plot the accident distribution by time of day and day of the week, for accidents registered during a certain period, as shown in Figure 7.4. This table reveals that the accidents are concentrated in certain days and/or hours.

The site inspection schedule should include the days and hours with the most accidents. Some periods of typical low accident occurrence should also be included, to supplement and verify hypotheses and conclusions concerning the causes of the accidents.

All diagnoses should consider the distribution of accidents by time of day and day of the week. For example, there are locations in São Paulo where pedestrian movement is intense, where many pedestrian accidents were registered, but where the majority of them occur outside peak hours of vehicle and pedestrian traffic.

Figure 7.4 shows that over half of the pedestrian accidents in the example occurred at night, many during periods of low vehicle and pedestrian movement. The greatest concentration of pedestrian accidents occurred on Fridays, between 18h00 and 22h00, and the next highest concentration on Sundays, during the same period. With the exception of these concentrations, the pedestrian accidents occurred at almost all times of day and days of the week.

These data indicate the existence of general problems that can cause accidents at any time, along with some factor associated with the times of greatest movement at the nearby interurban bus station, on Friday and Sunday nights, which are precisely the times of greatest flows of boarding and alighting passengers, respectively. The consumption of alcoholic beverages by pedestrians and drivers at the end of work on Fridays, and during leisure time on Sunday afternoons, probably influenced the accident frequency.

FIGURE 7.4
PEDESTRIAN ACCIDENT DISTRIBUTION BY TIME OF DAY AND DAY OF WEEK
DUQUE DE CAXIAS AVENUE x RIO BRANCO AVENUE (SÃO PAULO – 1979)

Day of Week \ Time	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	TOTAL
MON	△		△								△			△		△			△			△	△		8
TUE	△			△														△				△			4
WED													△								△	△△			4
THU								△						△											2
FRI													△	△					△	△	△△	△	△		8
SAT			△						△	△		△									△				5
SUN			△																△△		△△		△		6
TOTAL	2		3	1				1	1	1	1	1	2	3		1		1	4	1	6	5	3		37

Source: CET

7.3 The Accident Diagram

Because of the high percentage of pedestrian accidents in developing countries, this book uses the term "accident diagram" rather than "collision diagram," which appears in other works but implies only non-pedestrian accidents. An accident diagram provides a global view of the accidents registered at the study location, highlighting the approaches and conflicting movements that generate most accidents, along with the most common types of accidents.

Constructing the Accident Diagram

The accident diagram is drawn on a sketch of the location, with symbols designed to show the following basic information, extracted from the police reports, for each accident:

- type of accident;
- directions of movement of vehicles and pedestrians involved in the accident;
- approximate location of the impact;
- existence of injured persons, when pertinent; and
- state of the road surface (dry or wet).

Figure 7.5 shows a real example of an accident diagram and Figure 7.6 defines the symbols used in this and the following figures.

FIGURE 7.5
ACCIDENT DIAGRAM – EXAMPLE I

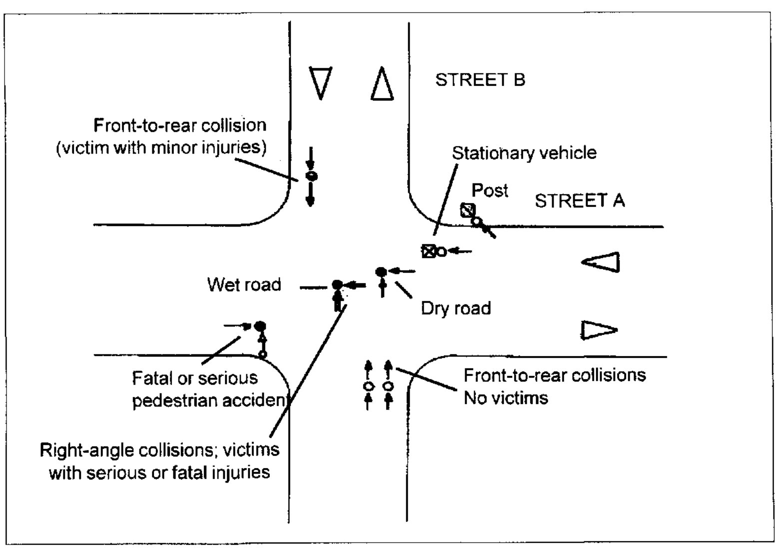


FIGURE 7.6

SYMBOLS TO REPRESENT ACCIDENTS IN SKETCHES AND DIAGRAMS

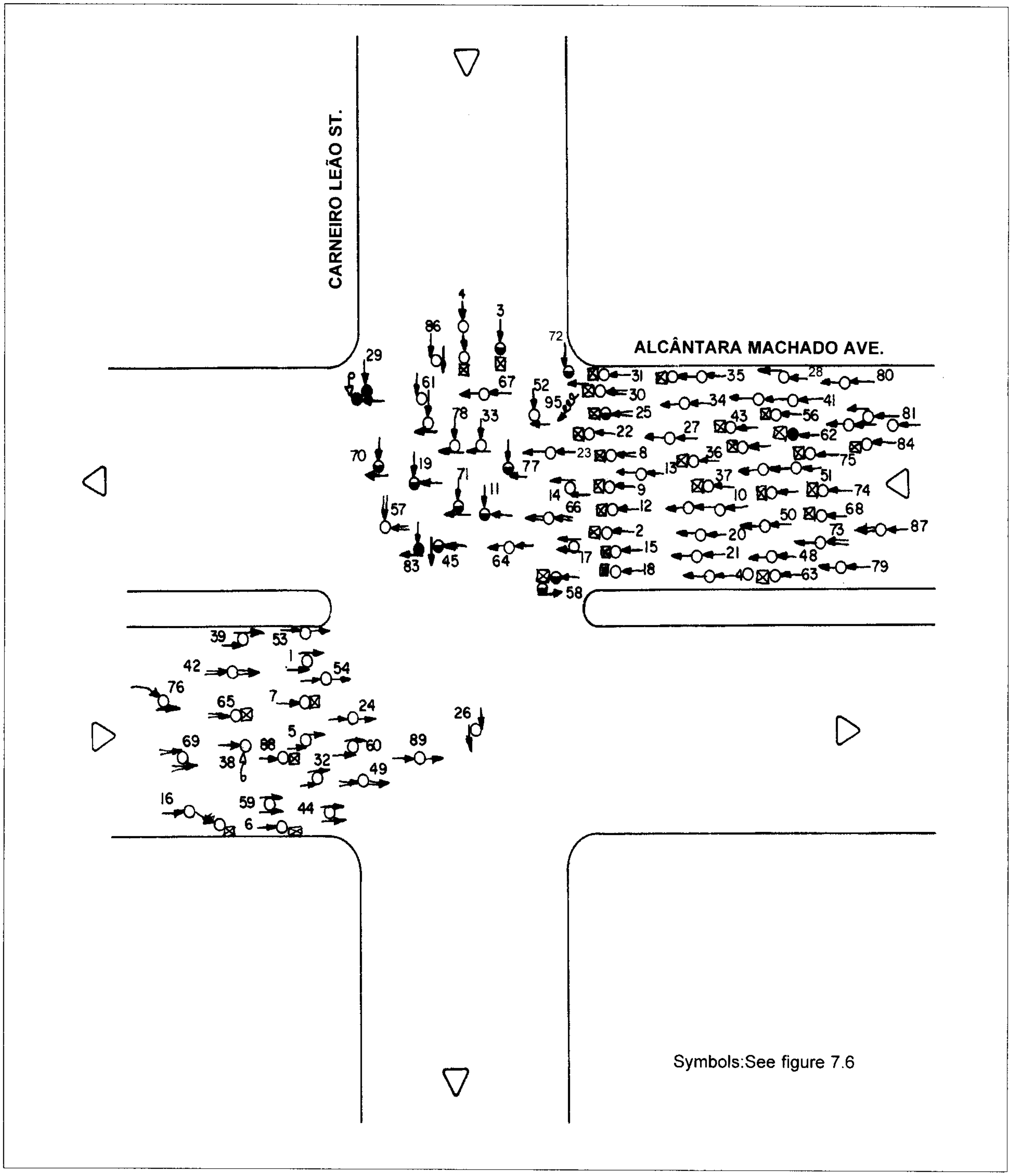
▶	direction of vehicle
▷	direction of pedestrian
—	dry road
=	wet road
□	fixed object
○	property damage-only accident
◒	injury accident (minor injuries)
●	injury accident (serious or fatal injuries)
P	pedestrian
A	animal

TYPE		SYMBOL	DESCRIPTION
Collisions	Moving vehicles	→ ←	head-on
		→ →	front-to-rear (rear-end)
		→ → →	pile-up
			sideswipe
		→ ↓	right angle, front-middle
		→↓	right angle, front-front
		⇆	sideswipe, opposite directions
	Fixed object	→⊠	stationary or parked vehicle
		→◪	post
			traffic light post
		→▬	tree
		→■	public works or obstacles in the road
	Pedestrian/animal hit by vehicle*		front of vehicle
			side of vehicle
			rear of vehicle
			between two vehicles
			vehicle out of control
			partial or complete overturn

Source: CET

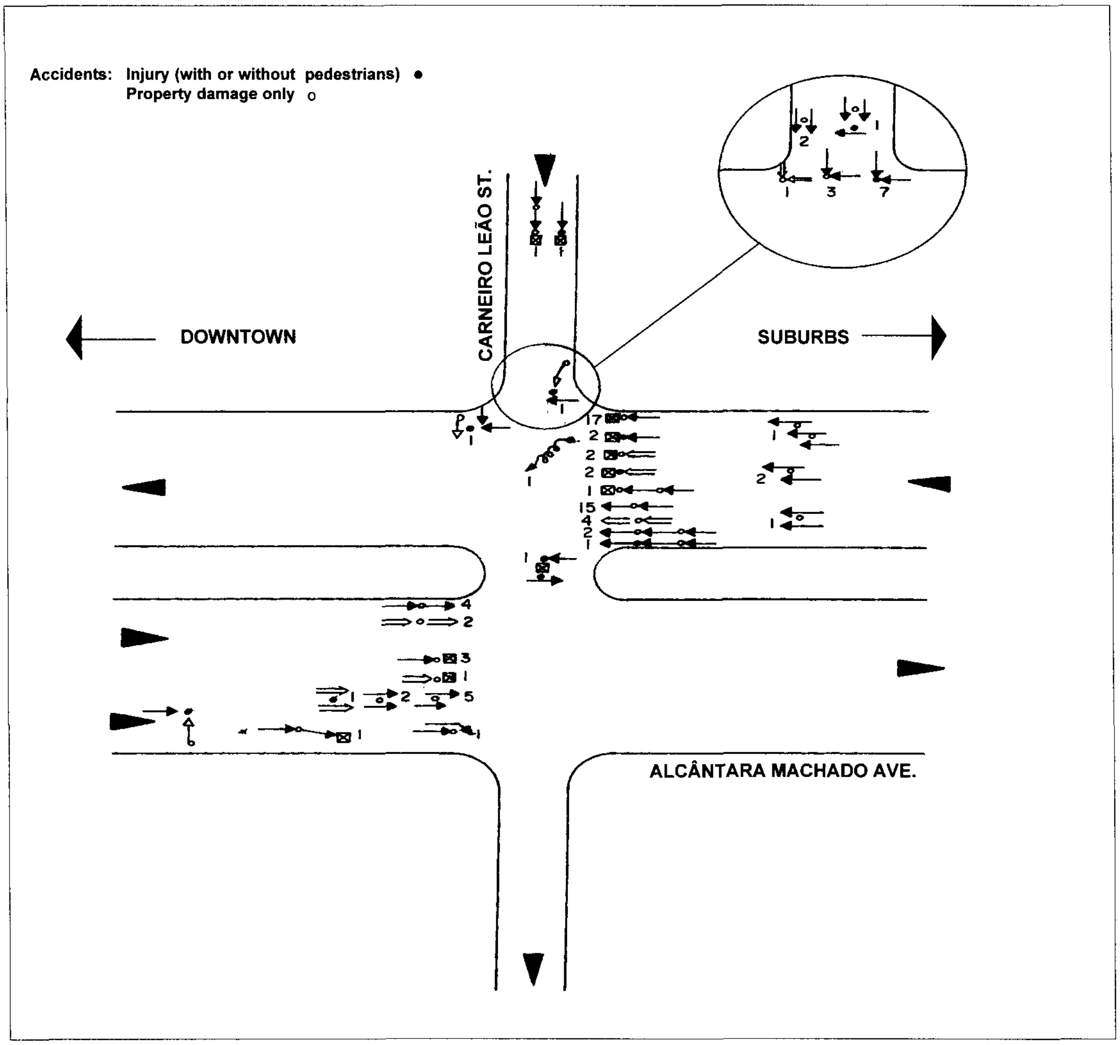
*For accidents with animals, replace P by A

FIGURE 7.7
ACCIDENT DIAGRAM – EXAMPLE 2
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET
(JULY 1978 – APRIL 1980)



Source: CET

FIGURE 7.8
SIMPLIFIED ACCIDENT DIAGRAM
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET
(JULY 1978 – APRIL 1980)



Source: CET

Simplification

Figure 7.7 shows an intersection with so many accidents that it is difficult to mark them all separately on the accident diagram. The accidents are numbered sequentially to facilitate identification of corresponding police reports. Missing numbers in the sequence indicate the data in the police report are insufficient to understand the accident; this occurs principally with pedestrian accidents.

When there are many accidents, the diagram may be simplified by using just one symbol for each group of accidents with identical basic characteristics. The number of accidents in each group may be noted beside its symbol. Figure 7.8 shows a simplified version of the same example seen in Figure 7.7.

Aspects Requiring Special Care

- Incomplete information

  In many cases the information available in the police report is insufficient to include the accident in the diagram, resulting in the omission of a significant part of the accidents registered. If this information were available, perhaps other critical spots or other types of accidents would stand out. This possibility does not invalidate the probable contributing factors identified from the available data. However, site inspections may reveal other potentially dangerous factors not highlighted in the accident diagram. These factors might not be causing accidents or they may cause a type of accident that does not appear in the diagram due to the lack of information in the police reports.

- Accident severity

  An accident diagram that shows only accidents with personal injury (pedestrian and non-pedestrian) often has different characteristics from one that includes all accidents. A comparison of Figures 7.8 and 7.9 shows that most of the property damage only accidents are rear end collisions, with both vehicles in movement or with one stopped at a traffic light, whereas most personal injury accidents involve vehicles travelling at right angles to each other.

The difference occurs because some types of accidents generate more victims than others. In general, priority should be given to accidents with personal injury. However, some critical spots have exceptionally high frequencies of property damage only accidents, but very few pedestrian and non-pedestrian personal injury accidents. Locations of this type are often suitable for the design and implementation of relatively simple projects that significantly reduce the accident frequency.

These considerations show the importance of defining the objective of the work before planning and producing the accident diagram: to reduce the general accident frequency; or to reduce the number of victims.

7.4 Historical Summary of Accidents

In the search for common factors between accidents, the next step is to organise, in a succinct and useful form, all the information contained in the police reports.

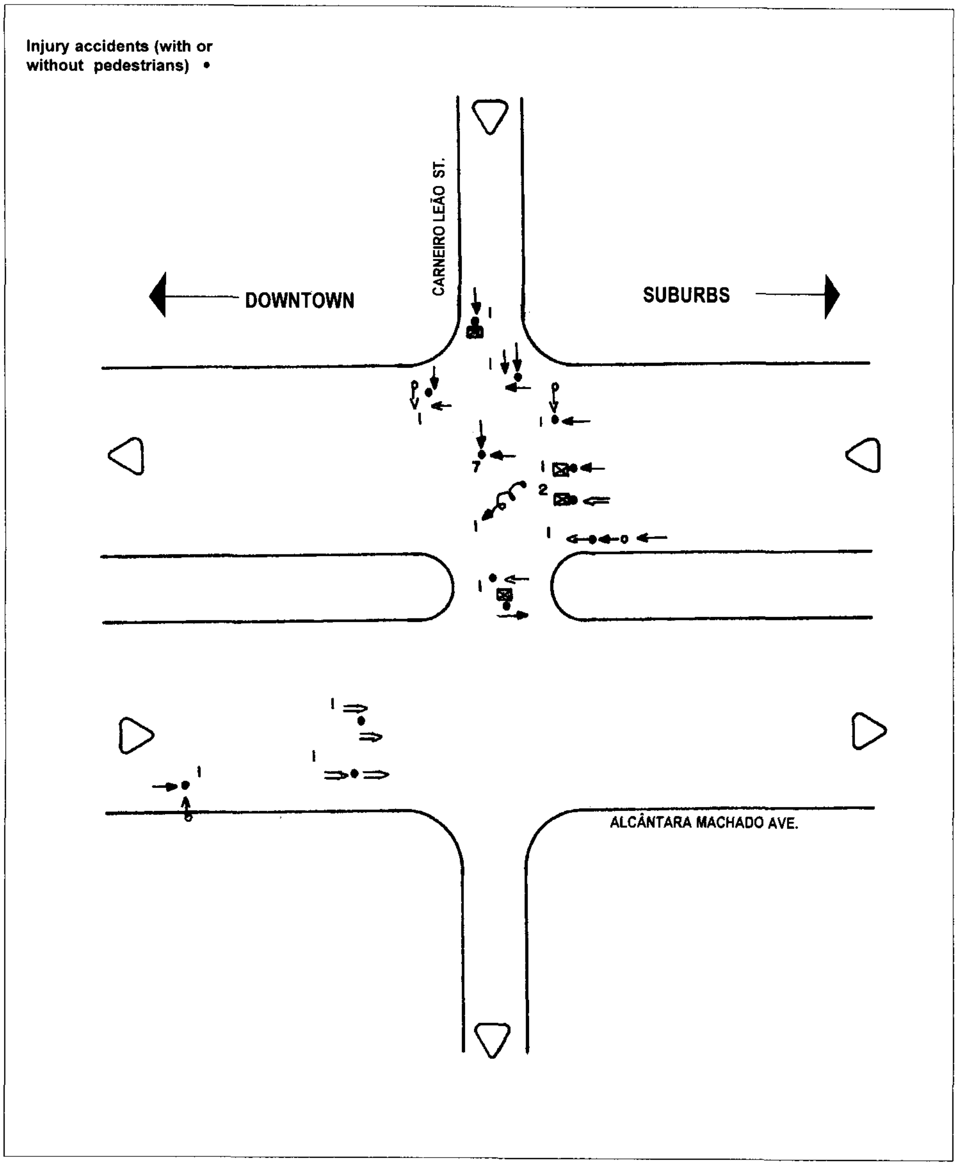
Table 7.1 shows a historical summary of the accidents with the information on each accident organised in a column. This format provides, for example, a visual comparison of all the accidents that occurred at night, to see if there is a common accident type, or a predominant type of vehicle, or similarities between the directions of vehicle movement when the accidents occurred.

If there are many accidents, the analysis may be facilitated by separating the columns, cutting the paper along the vertical lines, and rearranging the accidents in groups. For example, all weekend accidents may be grouped together, or all right-angle accidents, or all those that occurred on a wet surface. Table 7.2 illustrates a grouping of the accidents presented previously in Table 7.1.

Sometimes there are no common factors between significant numbers of accidents. This may be due to the lack of information in the police reports, or to the lack of common factors, with all the accidents having different causes and contributing factors.

The next step after this preliminary analysis of the available information is to complete or supplement it with site inspections, using the methodology described in Chapter 8.

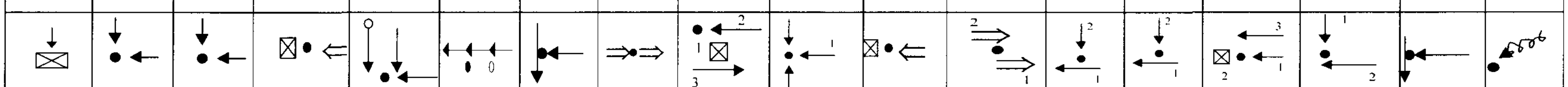
FIGURE 7.9
ACCIDENT DIAGRAM (PI + PE)
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET
(JULHO 1978 – ABRIL 1980)



Source: CET

TABLE 7.1
SUMMARY OF NON-PEDESTRIAN INJURY ACCIDENTS
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET
PERÍOD: 7/78 – 4/80
TOTAL INJURY ACCIDENTS: 33 (18 WITH SUFFICIENT INFORMATION FOR SKETCH)

Code Nº	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Police Rep. Nº	3	11	19	25	29	41	49	49	58	61	62	69	70	71	74	77	83	85
Date	8/8/78	9/3/78	10/27/78	11/11/78	12/6/78	3/6/79	3/17/79	3/24/79	6/16/79	7/27/79	7/25/79	9/17/79	1/3/79	9/19/79	10/23/79	12/11/79	2/8/79	3/23/80
Day of Week	Thu	Sun	Fri	Sat	Wed	Tue	Sat	Sat	Sat	Sun	Wed	Mon	Wed	Tue	Tue	Tue	Mon	Sat
Time	09:25am	03:30pm	11:45am	09::40pm	06:50am	02:40am	01:30pm	06:30pm	07:30pm	01:10pm	08:30am	01:35pm	12:05pm	12:25pm	06:50am	09:05pm	10:20pm	07:00am
Day/Night	d	d	d	n	d	d	d	n	d	d	d	d	d	d	d	n	n	d
Weather	f	f	c	f	f	f	f	r	f	f	r	r	f	f	f	f	f	f
Road Surface Condition	d	d	d	w	d	-	d	w	d	d	w	w	d	d	d	d	d	d
Type of Accident	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
Vehicles	c x c	c x bus	c x c	c x c	c x c	c x c x c	c x c	c x c	c x c x bus	c x c x c	c x mo	c x c	c x c	c x mo	c x bus x bus	c x mo	c x tr	c
Sketch																		
Observations	Vehicle stopped at yellow traffic light			Vehicle stopped at red traffic light	Pedestrian accident that resulted in collision	V1 and V2 braked because of traffic light	Police report shows point of impact		V1 waiting for green light, V2 pushed V1 which collided with side of V3	VI entered intersection with red traffic light	Car waiting for green light	V2 changed lanes while approaching viaduct, colliding with side of V1 on Alcântara Machado Avenue	Police report shows point of impact	V2 fled from the scene of accident	V2 waiting for green light	V2 entered intersection with red light. Underaged driver.	Police report shows point of impact	



Source: CET

Legend:
Weather: f-fine; c-cloudy; r-rain
Road Surface: d-dry; w-wet
Vehicles: c-car; bus-bus; mo-motorcycle; tr-truck

TABLE 7.2
ANALYSIS OF SUMMARY OF NON-PEDESTRIAN INJURY ACCIDENTS
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET
TOTAL INJURY ACCIDENTS: 33 (18 WITH SUFFICIENT INFORMATION FOR SKETCH)

Common facto in accidents	9									Involved 3			2		2		2	
Code Nº	2	3	14	13	17	7	5	16	10	9	15	6	11	4	12	8	1	18
Police Rep. Nº	11	19	71	70	83	49	29	77	61	58	74	41	62	25	69	49	3	85
Date	09/03/78	10/27/78	10/09/79	10/03/79	02/08/79	03/17/79	12/06/78	12/11/79	07/22/79	06/16/79	10/23/79	03/06/79	07/25/79	11/11/79	09/17/79	03/24/79	08/08/79	03/22/80
Day of Week	Sun	Fri	Tue	Wed	Fri	Sat	Wed	Tue	Sun	Sat	Tue	Tue	Wed	Sat	Mon	Sat	Thu	Sat
Time	03:30pm	11:45am	12:25pm	12:05pm	10:20pm	01:30pm	06:50am	09:05pm	01:10pm	10:30am	06:50am	02:40pm	08:30am	09:40pm	01:35pm	06:30pm	09:25am	07:00am
Day/Night	d	d	d	d	n	d	d	n	d	d	d	d	d	n	d	n	d	d
Weather	f	c	f	f	f	f	f	f	f	f	f	f	r	f	r	r	f	f
Road Surface Condition	d	d	d	d	d	d	d	d	d	d	d	-	w	w	w	w	d	d
Type of Accident	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
Vehicles	c x bus	cxc	cxmo	cxc	c x tr	cxc	cxc	cxmo	cxcxc	cxcx bus	cxbusx bus	cxcxc	cxmo	cxc	cxc	cxc	cxc	c
Sketch																		
Observations			V2 fled from the scene of accident	Police report shows point of impact	Police report shows point of impact	Police report shows point of impact	Pedestrian accident that resulted in collision	V2 entered intersection with red light. Underaged driver	Vi entered intersection with red traffic light	V1 waiting for green light, V2 pushed V1, which collided with side of V3	V2 waiting for green light	V1 and V2 braked because of traffic light	Car waiting for green light	Vehicle stopped at red traffic light	V2 changed lanes while approaching viaduct, colliding with side of V! on Alcântara Machado Ave.		Vehicle stopped at yellow traffic light	

14 - With one of the vehicles travelling on Alcântara Machado Ave., direction: suburbs - downtown

7 - With vehicles trying to enter the intersection against a red light on Alcântara Machado Ave, direction: suburbs - downtown

4 - With wet road

Source: CET

Legend:
Weather: f-fine; c-cloudy; r-rain
Road Surface: d-dry; w-wet
Vehicles: c-car; bus-bus-mo-motorcycle; tr-truck

CHAPTER 8

SUPPLEMENTING AVAILABLE DATA

8.1 When no Data are Available

Previous chapters have discussed ways of using available data to diagnose causes of accidents and to identify measures to reduce them. The accuracy of the analysis and diagnosis depends on the quantity and quality of this available data. Even if data are limited, however, traffic safety work may still proceed, provided that some information is available. This may be as simple as the information that, in a certain location, an average of x traffic accidents occur per year, of which y are pedestrian accidents and z are accidents involving only vehicles. Using the site inspection methodology, described in this chapter, the traffic engineer can detect some probable contributing factors and identify compatible corrective measures.

8.2 Site Inspection: General Methodology

A site inspection should follow the data analysis to establish causal relationships between the accidents and the following factors:

- inadequate aspects of the behaviour of drivers, pedestrians and other road users;
- inadequate traffic-engineering characteristics; and
- vehicle-vehicle and vehicle-pedestrian conflict situations that result from these inadequacies.

The site inspector should observe the location, from the points of view of four different types of users (along with his or her own, more objective, point of view) that display distinctly different behaviour when approaching, passing through, and departing from, the location:

- pedestrians familiar with the locale
- pedestrians not familiar with the locale
- drivers familiar with the locale
- drivers not familiar with the locale

The word "drivers" is used here to mean all road users in control of vehicles that are involved in traffic accidents; it includes cyclists and motorcyclists in addition to drivers of automobiles, vans, buses, and trucks.

Pedestrians familiar with the location know, without stopping to think consciously, the approach directions of vehicles with which they may come into conflict when crossing the road. They know where it is dangerous to cross and where it is relatively safe. They already have skills in evaluating gaps in the traffic flow.

Pedestrians not familiar with the location are more cautious and try to understand the local traffic circulation and control systems. They try to evaluate, often with difficulty, the gaps in the vehicle flow, taking into account possible approach directions.

Drivers that take the route daily between home and workplace, approach confidently, without looking at directional, warning, or regulation signs. They have memorised all information in the signs, know all the unsigned dangers, believe they can drive to their destinations with precision and safety (whether or not they obey the signs and signals), and are confident in their awareness of what will be found ahead. Sometimes, excess confidence leads drivers to put their safety at risk: in certain places almost all people involved in accidents are those who pass through every day.

Drivers not familiar with the location will look for directional signs to decide which route to take, and they depend on the warning and regulation signs to adjust their behaviour to the local conditions. Unaware of unsigned dangers, such as the sudden appearance of pedestrians in places with impaired visibility, they generally proceed more carefully and at lower speeds than drivers more familiar with the locale. Sometimes they will stop in unsuitable places or unexpectedly change lanes.

The site inspector should also remember that drivers of trucks and buses are seated in much higher positions than drivers of automobiles and have a very different view of the traffic. Field visits should be planned in accordance with the distribution of accidents by day of the week and time of day, to observe the location under conditions most favourable to the occurrence of accidents. It is also useful make observations during a typical period of low accident frequency, to detect the differences in the conditions of the road, the traffic, and the behaviour of pedestrians and drivers.

The site inspector should study a suitable map to become familiar with the study area and to identify the main traffic origins and destinations of interest.

The minimum materials necessary for site inspections are pencil or pen, clipboard, and paper. A watch or chronometer may be useful to measure traffic light phases, pedestrian crossing times, etc. A 35-mm camera may be used to visually register interesting aspects that might be useful for later analysis and to illustrate technical reports. Video filming is even better, and projection of such videos can enrich technical meetings. Lastly, if at least two people are carrying out the site inspection, a steel tape measure is useful to measure widths of sidewalks, roads, etc.

The site inspection should be planned and carried out on three distinct levels:

Level 1: details of the location

Level 2: approaches and exits

Level 3: origin/destination of vehicle and pedes trian flows

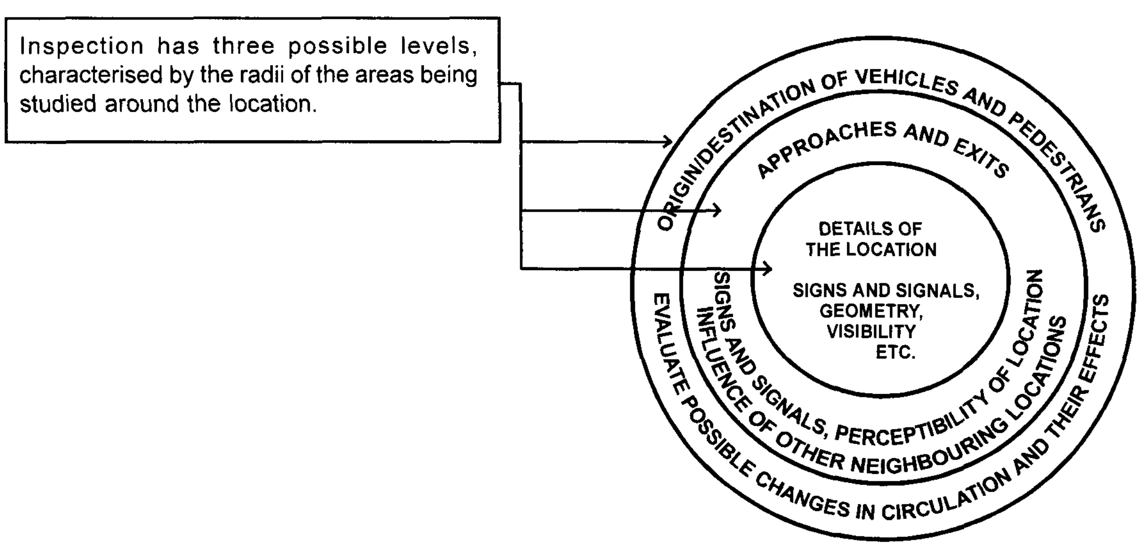
First, the details of the location should be studied, such as signs and signals, geometry, visibility, and road surface conditions, to determine possible factors contributing to accidents at the location.

Second, the approaches and exits should be studied to understand: (i) the general impression users have of the location during approach and departure; (ii) if this impression is true or false; (iii) the influence of the preceding intersection(s); and (iv) if there are any visibility problems.

Lastly, the origins and destinations of the pedestrian and vehicle flows should be studied, as inputs to the design and evaluation of possible changes in the circulation system, and to evaluate probable driver and pedestrian reactions to these changes. Solutions should avoid measures that create unnecessary difficulties for users or accident potential in other locations.

The three inspection levels and their respective functions are shown schematically in Figure 8.1. Other sources that are often rich in useful information about the accidents

FIGURE 8.1
THE THREE LEVELS OF CRITICAL SPOT INSPECTION



include people who live or work near the location, eyewitnesses of one or more accidents, and the people directly involved in the accidents.

8.3 Checklist for Site Inspections

A checklist such as that in Table 8.1 should be taken to each site inspection. All the items could be relevant and should be considered during the inspection, to avoid losing important information. The item-by-item analysis of the location should be followed by a final check, before concluding the inspection. The checklist also includes spaces where the inspector can add items as necessary.

The number of observations may be large and, to avoid forgetting anything, all relevant information should be noted, *immediately*, on a sketch of the location or on blank paper.

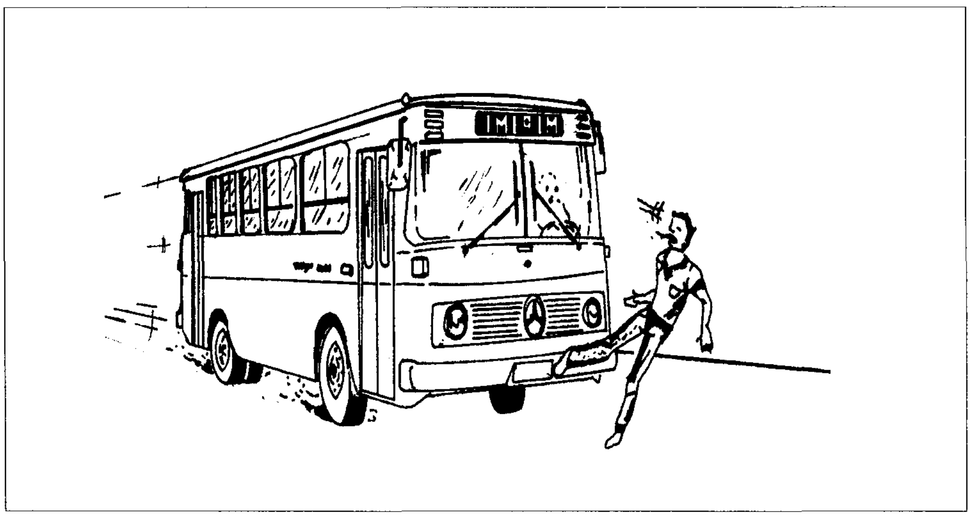
Complex locations may require several sketches (e.g., a sketch of basic data and selective use of road space; another for signs and signals, road markings, channelisation and speed-reducing devices; and a third for contributing factors).

The following paragraphs suggest how to analyse the types of accidents that cause most personal injuries. These suggestions are related to the relevant parts of the traffic legislation, exemplified by the new Brazilian Traffic Code (CTB), which dates from January 1998. On Brazilian two-way streets, cars travel on the right-hand side. All examples in this book refer to this condition, and readers from countries that drive on the left should make the appropriate adaptations.

8.4 Pedestrian Accidents

Most pedestrian accidents occur when the pedestrians are crossing the road. Pedestrians may also be hit when walking along the side of a roadway, especially interurban highways, and on urban streets without sidewalks, often found on the outskirts of city centres in developing countries. Pedestrians are occasionally even hit while on the sidewalk.

FIGURE 8.2
PEDESTRIAN HIT BY BUS ON THE ROAD, NEAR THE SIDEWALK



Drawing: René José Micheletti

The next paragraphs present an analytical view of the problem, based on:

- clauses of the CTB that refer to pedestrians
- a characterisation of general pedestrian and driver behaviour
- a discussion of aspects of vehicle traffic flow and traffic-engineering that determine the safety conditions for pedestrians when crossing the road.

Appendix 1 (Tables A1.1 to A1.9) presents a framework for analysis of typical pedestrian accident locations. There is a table for each type of location, characterised by geometric design, signs, signals and road markings.

Rights and Obligations of Pedestrians and Drivers in Brazil

The main clauses of the Brazilian Traffic Code (CTB) that refer to pedestrians and their interactions with vehicle flows, define the main rights and obligations of pedestrians as follows:

- **Signs, signals and roadmarkings**
  - ◆ The locations designated by the traffic authority for pedestrians to cross the road must be shown by stripes, painted or marked in the road (CTB, chapter VII, clause 85).

TABLE 8.1
A CHECKLIST FOR CRITICAL SPOT SITE INSPECTIONS

ANALYSIS LEVELS

- ❑ Level 1 – At location
- ❑ Level 2 – Approaches
- ❑ Level 3 – Origin / Destination

TYPES OF ROAD USERS

- ❑ Car driver, well-acquainted with location
- ❑ Car driver, not well-acquainted with location
- ❑ Truck/bus driver, well-acquainted with location
- ❑ Truck/bus driver, not well-acquainted with location
- ❑ Pedestrian, well-acquainted with location
- ❑ Pedestrian, not well-acquainted with location
- ❑ Characterization of pedestrians (children, adults, elderly, handicapped or with limited mobility/vision)

SKETCH – BASIC DATA

- ❑ Location
- ❑ Date
- ❑ Day of the week
- ❑ Holiday
- ❑ Inspection start time
- ❑ Inspection end time
- ❑ Geometry
- ❑ Upward/downward grades
- ❑ Street names
- ❑ Traffic flow directions
- ❑ North
- ❑ Numbers (km, buildings)
- ❑ Width - roads
- ❑ Numbers of traffic lanes
- ❑ Width - sidewalks
- ❑ Width – median strip
- ❑ Lowered kerbs
- ❑ Paving type (road and sidwalk)
- ❑ Superelevation
- ❑ Land use
- ❑ Public lighting (night)
- ❑ Drainage for rainwater
- ❑ Works in progress
- ❑ Other
- ❑ Other
- ❑ Other

- ❑ State of road surface
- ❑ State of sidewalk
- ❑ State of median strip
- ❑ State of street lighting
- ❑ State of rainwater drainage system

SELECTIVE USE OF ROAD

- ❑ Exclusive bus lane
- ❑ Shared bus lane
- ❑ Bikeway
- ❑ Pedestrian street
- ❑ Restricted periods by vehicle type – traffic
- ❑ Restricted periods by vehicle type – parking
- ❑ Reversible traffic Lanes

SSRM*

- ❑ Road markings (painted)
- ❑ Signs
- ❑ Traffic lights/programming
- ❑ Traffic lights/special types
- ❑ Studs (type, size, reflective)
- ❑ Predecessors of studs
- ❑ Restricted parking – general
- ❑ Parking – pharmacy
- ❑ Parking for handicapped
- ❑ Parking – other special categories
- ❑ Bus stop
- ❑ Parking area – conventional taxi
- ❑ Parking area – mini-bus/taxi
- ❑ Parking area – truck
- ❑ Sound emission for the blind
- ❑ Fixed objects on the sidewalk
- ❑ Works
- ❑ Other
- ❑ Other
- ❑ Other
- ❑ SSRM – mistakes
- ❑ SSRM – missing
- ❑ SSRM – broken
- ❑ SSRM – hidden, covered
- ❑ Lack of definition
- ❑ Lack of information
- ❑ Lack of logic
- ❑ Lack of standardization
- ❑ Difficult/impossible to understand

CHANNELISATION

- ❑ Concrete prisms
- ❑ Guardrail (pedestrians)
- ❑ Fences
- ❑ Studs
- ❑ Other
- ❑ Other
- ❑ Channelisation – state
- ❑ Channelisation – visibility
- ❑ Channelisation – effectiveness

FIXED, AUTOMATIC ENFORCEMENT EQUIPMENT

- ❑ Speed – radar
- ❑ Speed – detector coupled to camera
- ❑ Red light violation – traffic light with camera
- ❑ Other
- ❑ Other

SPEED REDUCTION/CONTROL MEASURES

- ❑ Speed humps
- ❑ Depressions
- ❑ Large studs
- ❑ Small studs
- ❑ Vehicle vibrators
- ❑ Road markings
- ❑ Other
- ❑ Other
- ❑ Other
- ❑ Speed reducers – state
- ❑ Speed reducers – visibility

TRAFFIC/BEHAVIOUR

- ❑ Principal vehicle flows
- ❑ Origin/Destination of vehicle flows
- ❑ Composition of vehicle flows
- ❑ Vehicle speeds
- ❑ Vehicle turning movements
- ❑ Pedestrians – principal flows
- ❑ Pedestrians – origin/destination
- ❑ Correctly parked vehicles
- ❑ Incorrectly parked vehicles
- ❑ General driver behaviour
- ❑ General pedestrian behaviour
- ❑ Illegal driver behaviour
- ❑ Illegal pedestrian behaviour
- ❑ Other
- ❑ Other

DETECTING CONTRIBUTING FACTORS

- ❑ Vechicle/vehicle visibility obstacles
- ❑ Vehicle/pedestrian visibility obstacles
- ❑ Vehicle/(signs, signals) visibility obstacles
- ❑ Pedestrian/(signs, signals) visibility obstacles
- ❑ Obstacles on the sidwalk
- ❑ Crossing conditions for pedestrians/cyclists
- ❑ Interviews with residents/shopkeepers etc.
- ❑ Ocurrence of "near accidents"

* SSRM – SIGNS, SIGNALS AND ROAD MARKINGS

- ◆ Pedestrians crossing the road at designated crossings will have right of way, except at locations with traffic lights, at which the pertinent clauses of the Code must be respected (CTB, chapter IV, clause 70).

- **Obligations of drivers**
  - ◆ While abiding by the rules established in this clause, in descending order, the drivers of larger vehicles will always be responsible for the safety of smaller ones; those driving motorised vehicles are responsible for the safety of non-motorised ones; and, together, they are responsible for the safety of pedestrians (CTB, chapter III, clause 29, last paragraph).

- **Rights and obligations of pedestrians**

  Duties of the pedestrian:

  - ◆ In urban areas without sidewalks, or when it is impossible to use the sidewalks, pedestrians will walk in the carriageway, with priority over vehicles, along the edge of the road, in single file, except in locations with signs prohibiting walking and in situations where traffic safety would be jeopardised (CTB chapter IV, clause 68, 2nd paragraph).
  - ◆ On rural roads, when there is no hard shoulder, or when it cannot be used, pedestrians will walk in the carriageway, with priority over vehicles, along the edge of the road, in single file, in the opposite direction to that of vehicles, except in locations with signs prohibiting walking and in situations where traffic safety would be jeopardised (CTB chapter IV, clause 68, 3rd paragraph).
  - ◆ When crossing the carriageway, the pedestrian will do so carefully, taking into account, principally, the visibility, the distance and the speed of vehicles, and will always use the designated locations (pedestrian crossings, footbridges, or underpasses), when these exist within 50 metres, observing the following rules:

    I - where there is no marked pedestrian crossing place, footbridge or underpass, the road should be crossed perpendicular to its axis;

    II - when crossing at a marked pedestrian crossing: if there are traffic lights for pedestrians, obey them; if there are no traffic lights for pedestrians, wait until the traffic lights, or the traffic agent, interrupt the vehicle flow;

    III - at intersections and along the approaches to them, where there are no marked pedestrian crossings, the pedestrians should cross the road along the continuation of the sidewalks, obeying the following rules:

    a) do not enter the carriageway without first making sure that this may be done without obstructing the vehicle flow;

    b) once having started to cross the road, the pedestrian must not lengthen the route used, linger, nor stop unnecessarily on the roadway.

Obviously, many pedestrian accidents occur because neither the behaviour of pedestrians nor that of drivers conforms to the model used to design the road system and its signs and signals. The reasons are discussed in the following paragraphs.

The General Behaviour of Pedestrians

Pedestrians in most Latin American and Caribbean countries:

- include people of all ages: children and adults;
- may be in any mental or physical state;
- may have received no traffic education;
- may not be able to read or to understand signs and signals;
- wish to cross the street by the shortest possible route;
- most are able to dodge moving vehicles;
- some are able to pass over, through or under many types of obstacles;
- become almost invisible to drivers at night, unless they wear light-coloured clothes;
- think that they can cross the street anywhere, which is usually possible, except where there are no gaps in the vehicle flow or physical barriers are present.

The General Behaviour of Drivers of Vehicles

Drivers of motor vehicles in most Latin American and Caribbean countries:

- are normally at least 18 years of age;
- should have passed a medical exam;[1]
- should possess a driving license, which implies that they have received some type of traffic education;
- should be literate, as they possess driving licenses;
- often want to travel at speeds higher than those permitted;
- do not want to make unnecessary stops or stop for long periods;
- often obey signs and signals and the clauses of the traffic code only when disobedience would obviously threaten their own safety (for example not stopping at a red traffic light at a busy intersection) or when disobedience would result in punishment or detention (for example, when a traffic police officer is watching);
- most drivers are unconscious of, or little interested in, the rights of pedestrians, or of the unsafe road conditions that pedestrians face, and frequently act in disaccord with signs, signals and traffic regulations in general;
- often circulate at night, without headlights switched on or using only parking lights, violating the law and being unable to see pedestrians that may appear on the roadway in time to avoid hitting them.[2]

Analysis of Crossing Conditions for Pedestrians

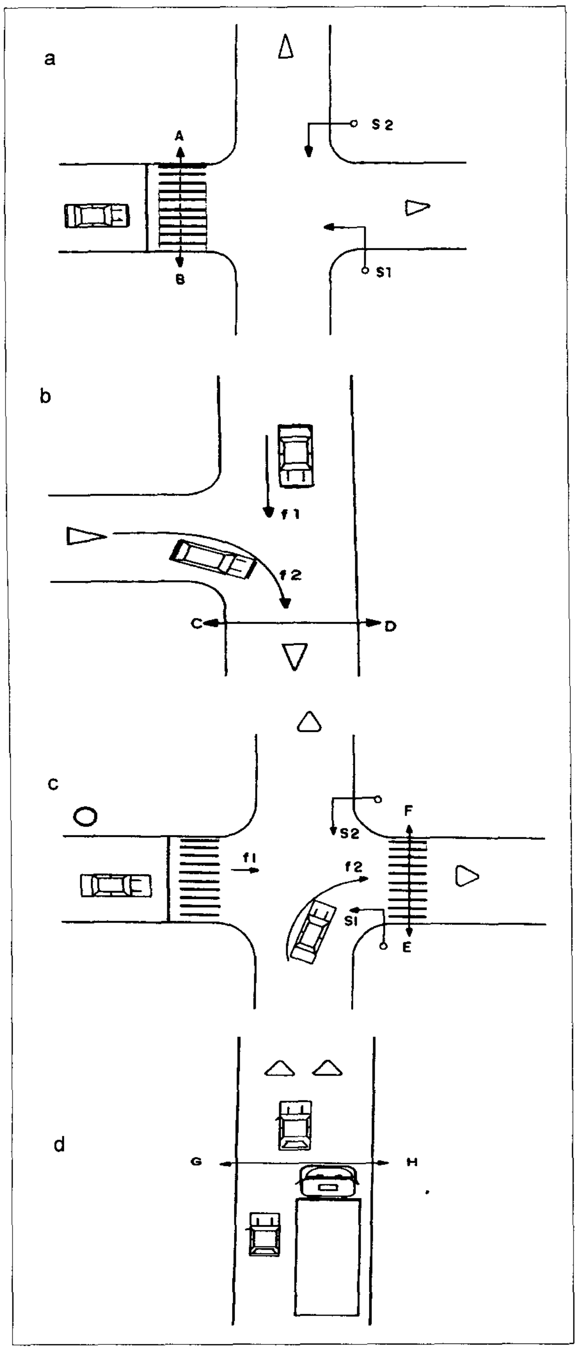
These observations show that an analysis of the causes of pedestrian accidents should consider real pedestrian and driver behaviour, not only the idealised behaviour prescribed in norms and traffic regulations.

With this in mind, the traffic engineer should proceed to analyse the real crossing conditions that determine the ease or difficulty pedestrians face in avoiding conflict with vehicles. These conditions are a function of traffic-engineering and driver behaviour.

Basic crossing conditions exist at a particular location when it is possible to show, in simple and clear terms, to any pedestrian who wishes to cross the street:

- *where* the road may be crossed safely – CORRECT LOCATION;
- *when* the road may be crossed safely – APPROPRIATE MOMENT;
- *how* the correct location and the appropriate moment may be identified – PERCEPTIBILITY.

FIGURE 8.3
PEDESTRIAN CROSSING CONDITIONS



These are basic conditions because, in the absence of any one of them, a safe crossing is either nonexistent or imperceptible to the pedestrian. Absence of these basic conditions occurs because of traffic-engineering deficiencies and/or when drivers disobey signs, signals, and traffic regulations. The only exceptions are those where there is deliberate intent to keep pedestrians from crossing, such as a physical barrier installed on the median of a highway.

Consider the following examples:

1. Location with basic crossing conditions (Figure 8.3a)

Desired path: AB

Safe location: marked pedestrian crossing.

Adequate moment: traffic light S1 red and vehicles stopped behind stop line.

Perceptibility: marked pedestrian crossing, traffic lights (visible to pedestrians), stopped vehicles.

2. Location without basic crossing conditions: absence of safe location (Figure 8.3b)

Desired path: CD

Safe location: nonexistent. There are no traffic lights and vehicle flows f1 and f2 generate continuous traffic with no gaps. There is no marked pedestrian crossing and no better alternative location in sight.

3. Location without basic crossing conditions: no adequate moment (Figure 8.3c)

Desired path: EF

Safe location: marked pedestrian crossing.

Adequate moment: change of phase of traffic light S1 from green to red, but there are many vehicles turning right (f2) and the drivers do not yield to the pedestrians.

4. Location without basic crossing conditions: no perceptibility (Figure 8.3d)

Desired path: GH, a pedestrian path with no alternative nearby.

Safe location: GH, where there is no marked pedestrian crossing.

Adequate moment: adequate gaps occur, but with a very low frequency and with barely enough time to cross the street.

Perceptibility: adequate gap difficult to perceive due to low frequency, short duration, and mixture of vehicles with different speeds.

The existence of *basic* conditions does not guarantee that conditions will be *adequate*. If the waiting time and/or the additional distance from the desired path exceed limits normally tolerated by pedestrians, some of them will cross the street in dangerous conditions.

Adequate crossing conditions exist when the basic conditions exist and there is also:

- a tolerable waiting time; and
- the distance from the desired path is tolerable

What is tolerable depends on the situation. The pedestrian reacts to danger and will wait more on wide streets where vehicles travel at high speeds than on narrow streets, with few vehicles, moving at low or medium speeds (Figure 8.4).

The existence of *basic* conditions and *adequate* conditions still does not guarantee that it will be *easy* to cross the street *safely*.

Where basic and adequate conditions exist, the ease and safety of crossing the street depend on the characteristics of the street and the traffic flow. These are partially or totally controllable by traffic engineering, and determine the perceptibility of the adequate moment for crossing, as illustrated below and in Chapter 10.

- ***Crossing distance***

  The shorter the distance, the less risky the crossing. A crossing of 9 metres or more may be divided into shorter stages by building a safety island (pedestrian refuge).

- ***Duration of gaps in the vehicle flow***

  The longer the duration, the easier to perceive adequate gaps. In street networks with traffic lights, the gaps are partially determined by the interruptions the red lights cause in the flow. These may sometimes be programmed to increase the duration of the gaps.

- ***The frequency of adequate gaps in the vehicle flows***

  The higher the frequency of adequate gaps, the more apparent they become. The frequency may also be increased by programming the traffic lights.

- ***Vehicle speeds***

  The lower the speeds, the easier the evaluation of gaps. Vehicle speed may be reduced by installing regulation signs, widening the sidewalk to reduce the width of the carriageway, and installing speed humps, raised crossing and special enforcement devices.

- ***Variation of vehicle speeds***

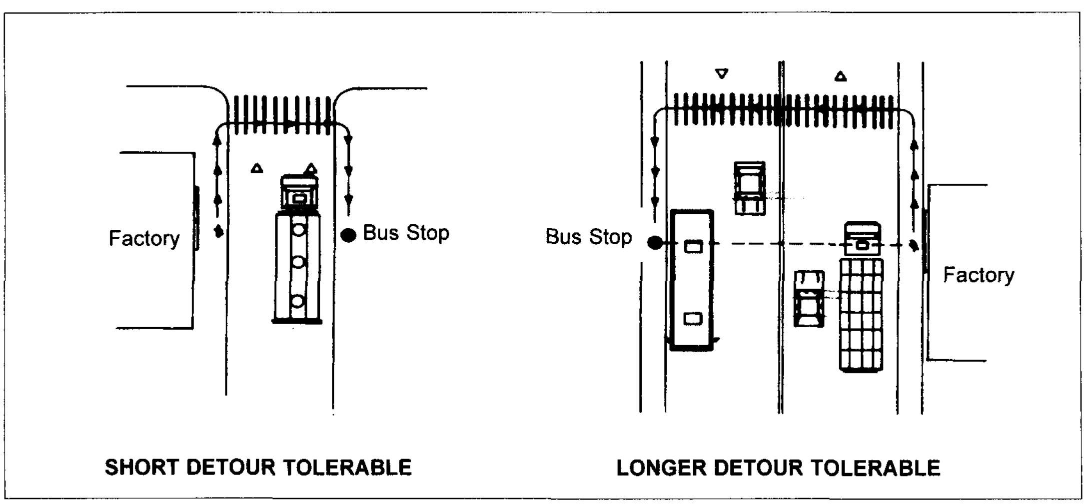
  The less varied the speeds of the vehicles in the vehicle flow, the easier the evaluation of the time available for crossing.

  Traffic engineering can generate variation in vehicle speed by installing exclusive bus lanes and areas where flows with different average speeds converge. Engineers should be aware of these potential problems and provide compensating measures to assure safe crossings.

- ***Directions of vehicle movement***

  A gap in a one-way traffic flow is much easier to evaluate than a gap in a two-way flow. Intersections of two-way streets may be simplified by introducing a dividing strip (safety island, or refuge zone), separating the opposing flows, or by transforming the two-way street into a one-way street.

FIGURE 8.4
TOLERANCE OF DETOURS



- ***The number of sources of vehicle flows:***

  The fewer the sources, the easier the evaluation (Figure 8.5).

  A simple case:

  Approaching traffic in a one-way street: only one source (Figure 8.5a).

  A complex case:

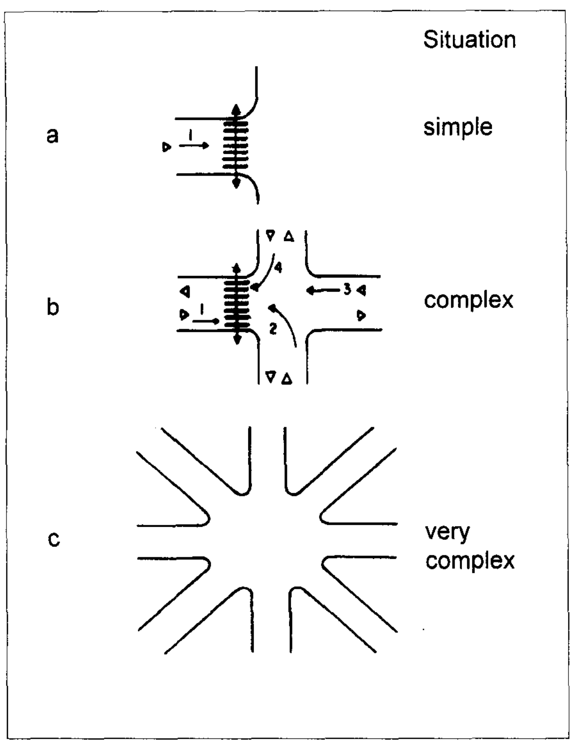
  Two-way vehicle flow at an intersection: up to four sources (Figure 8.5b).

  Crossings with complex situations may be simplified by building safety islands (refuges), changing two-way roads to one-way roads, implementing separate left or right turn lanes, and other measures, such as installing traffic lights with a pedestrian phase.

  A very complex case:

  In the centre of the city of Belo Horizonte, Brazil, many intersections had from five to eight approaching vehicle flows (Figure 8.5c). A traffic engineering program in 1981 reduced this excessive number by simplifying the design of the intersections, installing traffic lights with pedestrian phases, carrying out some local urban environmental improvements, and modifying bus stops and itineraries. These measures produced a 70% reduction in pedestrian deaths in the city by virtually eliminating them in the area where most of them occurred previously.

FIGURE 8.5
VEHICLE MOVEMENTS



- ***Change of conditions during crossing***

  The less conditions change, the less risky it is to cross the street (Figure 8.6).

  Little change:

  One-way street with only one lane of traffic (Figure 8.6a). Conditions do not change.

  A lot of change:

  Two-way street with exclusive bus lanes in both directions (Figure 8.6b).

  Lane 1: low frequency bus flow.

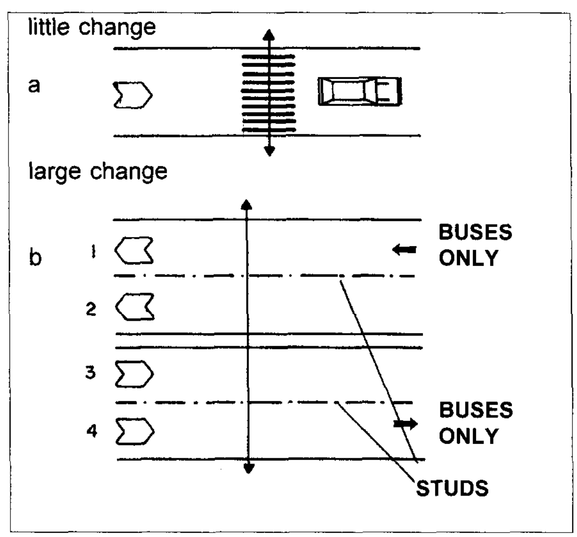
  Lane 2: other vehicles with high frequency and speeds different from those of the buses.

  Lane 3: change of the direction of flow, other vehicles with high frequency and speeds different from those of the buses, and perhaps different from the vehicles in Lane 2.

  Lane 4: low frequency bus flow with speeds different from those of vehicles in Lane 3.

  Flows with different characteristics may be separated by a series of small safety islands (refuges) or continuous median strips. The installation of an exclusive lane is a measure that increases average bus speeds, benefiting bus passengers. However, it changes the crossing conditions and may require compensating measures to avoid impairing pedestrian safety, including that of the bus passengers, in the vicinity of the bus stops.

FIGURE 8.6
CHANGES IN CONDITIONS
DURING CROSSING



- ***Pedestrian/vehicle and driver/pedestrian visibility***

  The more barriers to visibility between vehicles and pedestrians, the more difficult it will be for pedestrians and drivers to evaluate the situation. The elimination of parked vehicles near corners helps to preserve visibility. The irregularly parked car forces the pedestrian into the street, outside the designated crossing zone and lower than he/she would be if on the sidewalk. This impairs the pedestrian's view of the traffic and the drivers' view of the pedestrian (Figure 8.7). The problem is even more serious when larger vehicles, such as trucks and buses, are parked near corners.

  In this case, one solution is to widen the sidewalk, taking over the space where automobile A is parked. If the poor visibility is due to some more permanent factor, such as with pedestrian accidents at curves, then pedestrian flows could be channelised, with the installation of signs and equipment (flower boxes, guardrails), to move the crossing point to a safer location.

  Table 8.2 summarises the factors that govern pedestrian crossing conditions.

FIGURE 8.7
PEDESTRIAN-VEHICLE VISIBILITY

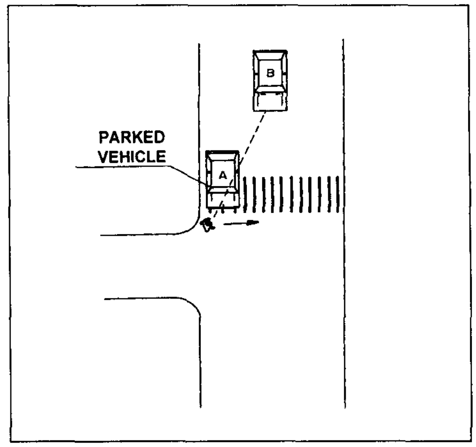


TABLE 8.2
CROSSING CONDITIONS ANALYSIS FACTORS

CONDITIONS	FACTORS
Basic conditions	- correct location for crossing - adequate moment - perceptibility
Adequate conditions	- basic conditions - tolerable waiting time - tolerable detour from desired route
Ease of crossing	- crossing distance - gap durations - frequency of adequate gaps - vehicle speeds - variation of vehicle speeds - number of directions of traffic flow - number of sources of vehicle flows - alterations of conditions during crossing - pedestrian/vehicle and driver/pedestrian visibility

Source: CET

To treat a critical spot of pedestrian accidents adequately requires creating the basic conditions by improving the perceptibility of the correct location and of the adequate moment for crossing. The traffic engineer should also strive to create adequate conditions by decreasing waiting times and distances from the desired path and by adjusting the associated factors.

8.5 Right-angle Collisions at Intersections without Traffic Lights

Many non-pedestrian personal injury accidents are of this type. The vehicles approach the intersection of two orthogonal streets and both drivers intend to go straight through. The accident occurs when the two vehicles enter the intersection simultaneously.

In the following paragraphs we will analyse the behaviour required of the drivers, how this information is communicated, the possible reasons for the behaviour that results in the accidents, and how to recognise these reasons during site inspection. We will also identify traffic engineering measures designed to avoid these accidents.

Desirable Driver Behaviour

The traffic control principal applicable to this situation is simple: only one of the drivers has the right of way. For situations with no signs or signals, the national traffic codes define who has right of way. In Brazil, the code specifies that (CTB, chapter III, clause 29, item III):

When vehicles, travelling in flows that cross each other, approach a location without signs, signals or road markings, the right of way goes to:

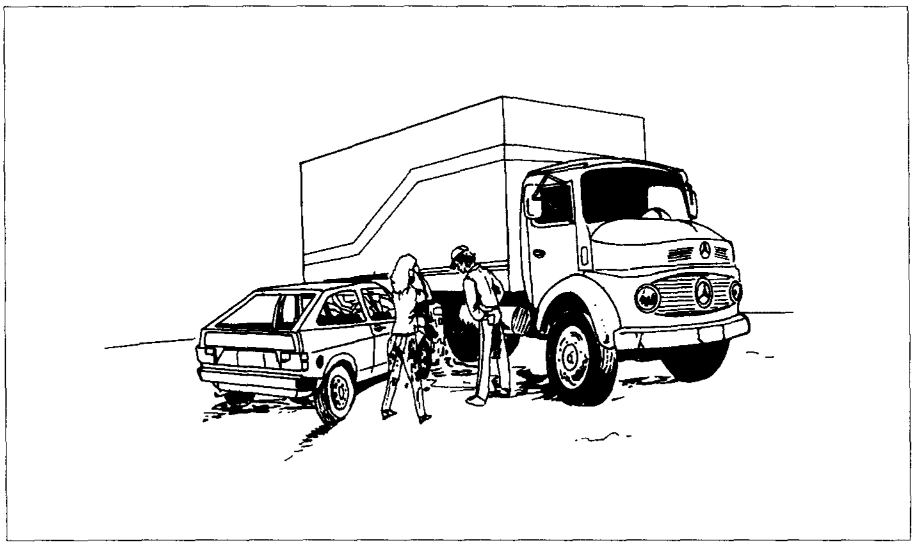
a) the vehicle on the highway, where only one flow comes from an intercity highway;

b) in the case of a roundabout, the vehicle already within the roundabout; and

c) in other cases, the vehicle approaching from the right side of the driver.

For drivers to behave correctly, both must know the traffic regulations, distinguish between left and right, and apply this knowledge with the speed of a conditioned reflex. Since this is not always the case, traffic engineers usually attempt to regulate driver behaviour by using a STOP sign (Figure 8.9), sometimes reinforcing the message by painting the word STOP on the road surface.

FIGURE 8.8
RIGHT-ANGLE CRASH



Drawing: Renê José Micheletti

This traffic sign and its use should be well defined in each country's traffic code. In Brazil, the definition is:[3]

Name: mandatory stop.

Intended meaning: indicates to drivers the obligation to stop before entering an intersection.

Use: when it is considered necessary for all approaching vehicles to stop before entering an intersection.

The use of this sign to define right of way at intersections without traffic lights is very common. The Brazilian code states that the sign should be directed exclusively towards the approach that does not have the right of way, and may be used either to reinforce the general rule of right of way for vehicles coming from the right, or to invert it.

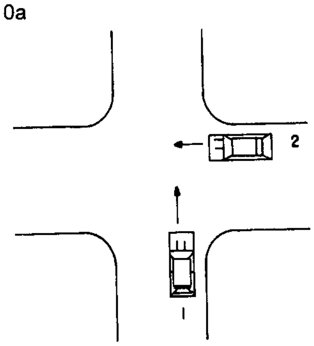
FIGURE 8.9
SIGN R-1: MANDATORY STOP

When analysed from the viewpoints of the two drivers, the set of controls, consisting of the two elements (STOP sign and right of way for vehicles coming from the right) creates three different possible situations when two vehicles approach each other from right angles, at intersections without traffic lights.

I. No signs or road markings (Figure 8.10a)

Behaviour controlled by the general rule of right of way for vehicles coming from the right. Vehicle 1 approaches from the left and should yield to vehicle 2, approaching from the right. The driver of vehicle 2 sees that vehicle 1 is approaching the intersection from his left and, therefore, assumes that the driver of vehicle 1 will yield.

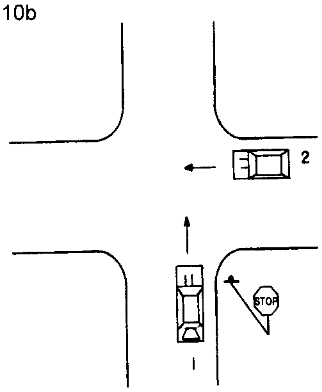
FIGURE 8.10a



II. STOP sign, reinforcing the right of way for vehicles approaching from the right (Figure 8.10b)

The STOP sign, directed towards vehicle 1, approaching from the left, reinforces the requirement that the driver of this vehicle yield to vehicle 2, approaching from the right. The driver of vehicle 2, seeing no signs which indicate to the contrary, sees that vehicle 1 is approaching from her left and assumes that its driver will yield.

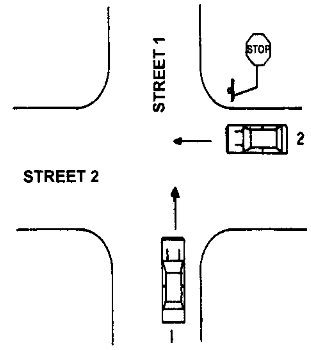
FIGURE 8.10b



III. STOP sign, inverting right of way for vehicles approaching from the right (Figure 8.10c)

In this situation, the intention is to designate right of way for vehicles travelling on Street 1. The need for this situation may arise when the volume of vehicles in Street 1 is much larger than that in Street 2.

FIGURE 8.10c



However, this use of the STOP sign in conjunction with the general rule of right of way for vehicles approaching from the right, generates the following *anomalous situation*:

- the driver of vehicle 2, seeing the STOP sign, thinks that he should yield to the driver of vehicle 1;
- the driver of vehicle 1, not seeing any sign, is obliged by the general rule of right of way for vehicles approaching from the right, to yield to vehicle 2.

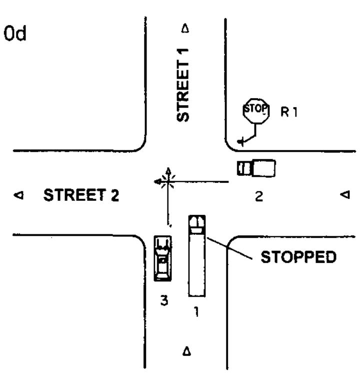
Given this situation, three problems may appear:

- Both drivers stop their vehicles, each thinking he should yield to the other. The first to proceed does so thinking he is infringing the traffic regulations, but that the other driver does not understand the signs.
- Both drivers proceed simultaneously, resulting in an accident.

Either of these two results encourages the drivers to disobey traffic signs and regulations, and not to respect other drivers in general.

- The third situation occurs when both drivers stop and the driver of vehicle 2 decides to proceed and hits a third vehicle, travelling in Street 1 in the left lane. The driver of the third vehicle, familiar with the location and the STOP sign in Street 1, crosses Street 2 without stopping, overtaking vehicle 1. Vehicle 3 remains hidden from the view of the driver of vehicle 2 until the moment of impact (Figure 8.10d).

FIGURE 8.10d



This anomalous situation in many intersections without traffic lights contributes to accidents and should be analysed during the diagnosis of possible causes and evaluated regarding the reasons for disobedience of STOP signs in general. The anomaly illustrates the importance of analysing traffic conditions from the points of view of the road users. The traffic engineer may think a situation is well defined (one street was designated as preferential and marked with signs), while users find it illogical (inverting expectations without strong, highly visible messages to that effect).

In the absence of a sign indicating to a driver that she has the right of way at an intersection, the situation may be improved (on paved carriageways), using road markings, as shown in Figure 8.11. However, this solution can be incompatible with painted pedestrian crossings.

Another solution is to install speed-reducing devices, such as speed humps, on Street 2, together with pertinent warning signs (see Chapter 10).

Situations that Result in Accidents

Summarising the analysis of desirable driver behaviour in the preceding paragraphs, we may identify two situations that cause accidents:

- *The driver without the right of way fails to yield to the driver with the right of way.*
- *The signs, together with the general rule of right of way for vehicles coming from the right, indicate that neither of the two drivers has the right of way (anomalous situation). Both advance simultaneously, either wrongly interpreting the momentary stop of the other, or disobeying the general rule of right of way.*

Methodology for Reducing Accidents

Where the right of way is established, the objective of the site inspection is to answer the following question:

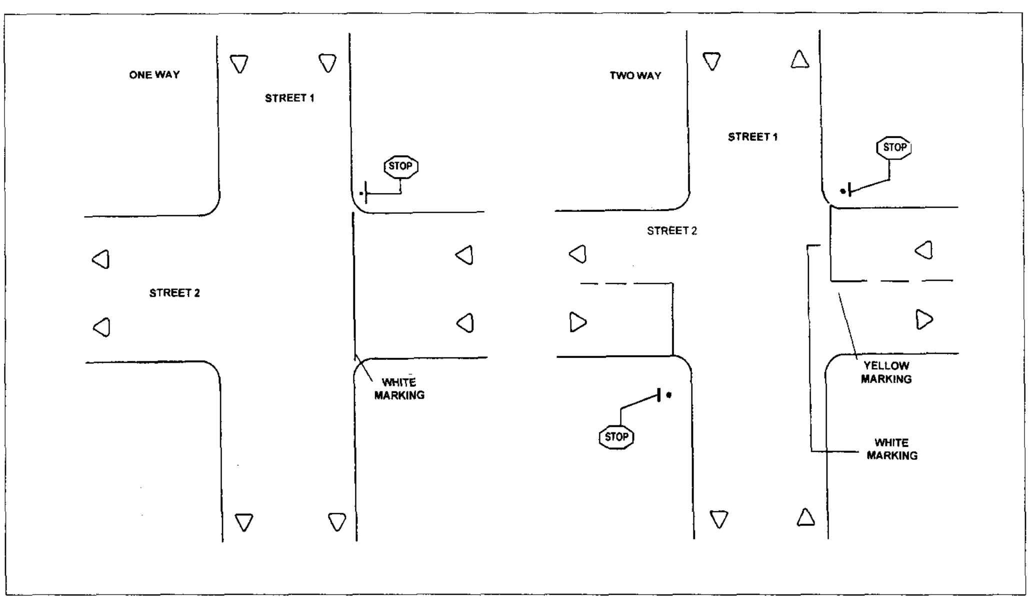
> *Why did the driver without the right of way not yield to the driver with the right of way?*

Table A1.10(a) in Appendix 1 is designed for use during site inspection. It presents types of driver behaviour, along with a selection of dangerous actions by drivers. This table facilitates the identification of the reasons for different aspects of observed dangerous behaviour.

The *anomalous situations* in undefined right of way require careful analysis to identify driver behaviour most likely to cause accidents and possible reasons for this behaviour. The selection of measures to improve the situation is more complex, as the undefined right of way may be a decisive contributing factor and a study of a larger area is needed. This study should include the characteristics of each street and intersection, on the street sections situated before and after the critical spot, to define which street should have right of way, and the signs, road markings, or other elements needed to provide clear information to drivers on each of the two intersecting streets.

Table A1.10(b), in Appendix 1, presents possible improvement measures for each contributing factor corresponding to observed behaviour. The choice of the most appropriate improvements depends on the particular conditions of the location and of the traffic.

FIGURE 8.11
PRIORITY ROAD MARKINGS



Summarizing, the methodology consists of the following steps:

- identify the types of behaviour presumed to be associated with the accidents;
- identify dangerous driver behaviour in general;
- identify possible reasons for these aspects of behaviour.

Using the improvements Tables A1.10(b):

- list available types of improvements for each contributing factor identified previously during the analysis of behaviour, using Table A1.10(a);
- eliminate from the list any possible improvements that already exist at the location; and
- from the remaining improvements, select the most adequate one(s) for the situation under study, considering all the particular conditions of the location and the traffic.

8.6 Rear-end Collisions (involving moving and stationary vehicles)

Characterisation of Rear-end Collisions (Figure 8.12)

In most of these accidents, the driver of the first vehicle reduces his speed and the driver of the second vehicle does not reduce speed accordingly and crashes into the rear end of the first vehicle.

Sometimes, the collision occurs immediately after the first vehicle stops, for example, at a red traffic light. Rear-end accidents also occur when the first vehicle is parked, usually without its driver present at the moment of the accident.

Methodology for Reducing Rear-end Collisions

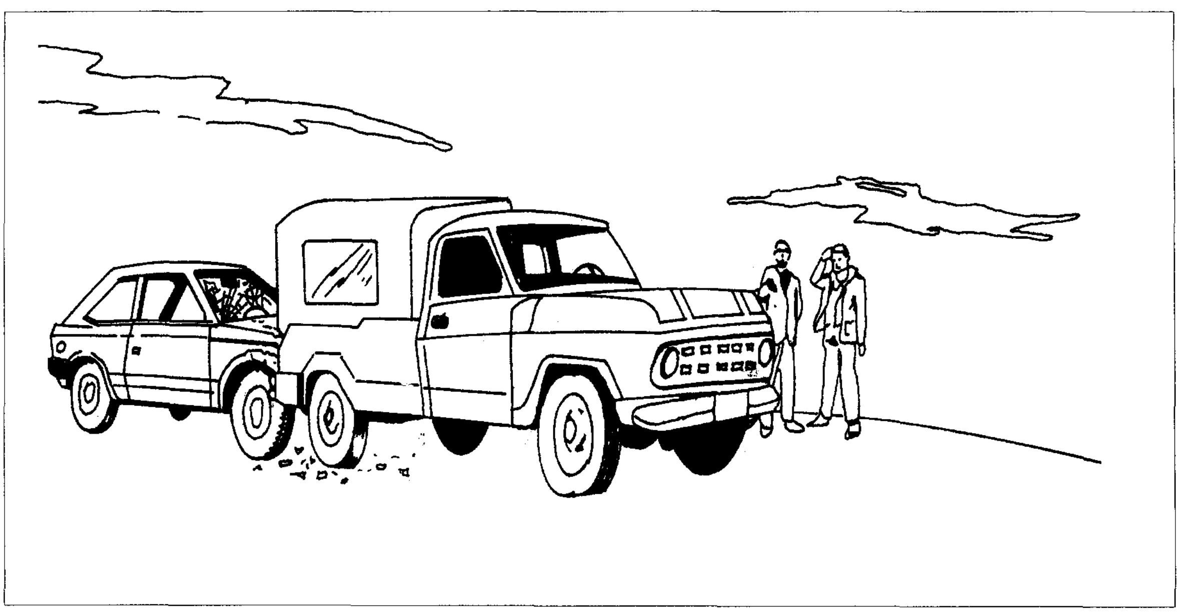
Where these accidents proliferate, improvements are recommended that:

- eliminate the need to reduce speed (if possible);
- make speed reductions more gradual when it is not possible to eliminate them, advising drivers, well before they arrive at the location, that they should slow down;
- check for kerb cuts placed too near to intersections and insufficient yellow time or traffic lights (see p. 127); and
- diminish the possible negative consequences of the speed reductions.

To reduce the number and severity of these accidents, local traffic should be observed to identify the most common reasons for speed reduction, selecting those that offer greatest potential for rear end collisions. Among these, the situations that cause sudden braking are usually responsible for the most serious accidents.

When many collisions involve stationary vehicles, visibility problems should be studied and signs installed to prohibit parking. Alternatively, the street network may be modified to reduce the collisions. Table A1.11 of Appendix 1 presents recommendations for each contributing factor corresponding to observed dangerous behaviour.

FIGURE 8.12
FRONT-TO-REAR COLLISION



Drawing: René José Micheletti

8.7 Other Types of Accidents

The types of accidents analysed in the previous topics (pedestrian accidents, right-angle accidents at junctions without traffic lights and rear-end collisions) are usually the most common in urban areas.

The same type of analysis may be applied to other types of accidents, such as:

- right-angle accidents at intersections with traffic lights
- accidents involving only one vehicle
- accidents involving motorcycles

As an exercise, the reader should create analysis tables, similar to those in Appendix 1, for each accident type, using as an aid the following pertinent observations for each of the three mentioned accident types.

Right-angle Accidents at Intersections with Traffic Lights

Normally in these accidents, one of the drivers involved ran a red traffic light. In very large intersections, an accident may also occur between the last vehicle that passed with a yellow light on one of the approaches and the first to pass on green in the orthogonal street.

For cases where drivers run red lights, three basic explanations exist:

- simple disobedience
- poor visibility or timing of traffic lights
- *excess visibility* of traffic lights

Excess visibility refers to a situation in which the traffic lights are positioned so a driver sees both the traffic light directed towards him and that directed towards the conflicting traffic flow in the orthogonal street. Instead of waiting for his green light, the driver starts entering the intersection on red, during the yellow phase of the orthogonal street.

The most adequate types of treatment for these cases are presented and discussed at length in Chapter 10.

Accidents Involving a Single Vehicle

In this type of accident, the vehicle may leave the carriageway and crash against a tree, some fixed object on the sidewalk, or the front of a building.

When these accidents occur repeatedly at the same point, the analyst will be able to identify traffic engineering improvements to prevent these accidents or to reduce the severity of their consequences. Typical measures include:

- increased superelevation at curves
- warning signs
- removal of fixed objects to positions further from the road
- shock-absorbing barriers
- speed-reducing devices
- improvement of the paved surface of the road

The measures should be selected in accord with the results of the analysis of contributing factors.

Accidents Involving Motorcycles

The use of motorcycles is not recommended from the standpoint of traffic safety. Lack of safety is an inherent characteristic of this vehicle, whose indices of deaths per vehicle-km are 42 times those of automobiles (Wright, 1992:104). The vehicle is unstable and the rider lacks the physical protection afforded by cars and buses to their drivers and passengers, resulting in more accidents and more serious consequences from the accidents. Despite the danger, the number of motorcycles tends to increase rapidly, as they cost much less than automobiles and, consequently, are within reach of consumers that cannot afford cars.

There are two corrective traffic engineering measures:

- avoid damaged road surfaces, especially holes
- install exclusive routes or lanes for motorcycles

The first proposal is important, as any defect in the road, even a slight one, may be lethal. The second proposal is seldom practicable due to the scarcity of space in cities, the incompatibility of the motorcycle with pedestrian and bicycle traffic, and the high cost of such projects.

A partial solution may be found in more defensive behaviour of motorcyclists, more policing and traffic education, instilling more tolerance and respect in the drivers of other vehicles. Motorcyclists should protect themselves by always keeping their headlights on and by using crash helmets, boots, and other protective clothing.

Some authors suggest that traffic authorities should discourage the use of motorcycles, requiring long periods of training with low-power motorised bicycles (Powden and Hillman, 1984: 63-65) or simply by limiting their use on public roads to the police (Wright, 1992: 111).

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[1] In many Latin American and Caribbean countries, a driver may not have a recent medical exam and traffic education is minimal. There are also cases of illiterate, or semiliterate, drivers being licensed.

[2] Low beam headlights are required at night in urban areas. This maximises visibility of the vehicle to other drivers and illuminates pedestrians and other vehicles. High beams are illegal where there is oncoming traffic, as they interfere with the vision of oncoming drivers. It is illegal to drive with only the parking lights on; however, it is common in some Latin American and Caribbean cities, with São Paulo presenting one of the worst examples.

[3] Source: *Urban Sign and Signals Manual: Design Norms*, Volume 2 Vertical Regulatory Signs PMSP; SMT, DSV, CET, DENATRAN-CET Agreement, 1978.

CHAPTER 9

ANALYSIS AND DIAGNOSIS (Illustrative Examples)

This chapter presents two complete critical spot case studies. The first is of a simple intersection, with an accident frequency comparable to many critical spots found in medium-sized cities throughout the Americas.

The second critical spot was one of the worst in São Paulo during the eighties: the intersection of Alcântara Machado Avenue (East Radial Avenue) and Carneiro Leão Street, where there were many pedestrian and other personal injury accidents. The location, an intersection with some of the greatest motorised traffic flows in São Paulo, was chosen because it brings together many of the problems found in this type of study, and illustrates a wide range of real accident causes and alternative solutions.

9.1 Case Study 1

MAMORÉ STREET X NEWTON PRADO STREET

Characteristics of the Location

Figures 9.1 and 9.2 show the intersection of these two one-way streets, in the borough of Bom Retiro, in the older part of the City of São Paulo. Land use was mixed, composed of residences (houses and apartment buildings), and commercial establishments. Traffic volumes were low and similar in both streets, and speeds low. Pedestrian traffic volumes were also low and similar on both streets. There were no traffic lights: traffic was controlled by one STOP sign in the Mamoré Street approach and by signs defining the direction of one-way traffic on each street, in accordance with city's norms at the time.

FIGURE 9.1
LOCATION OF CRITICAL SPOT
MARMORÉ STREET x NEWTON PRADO STREET

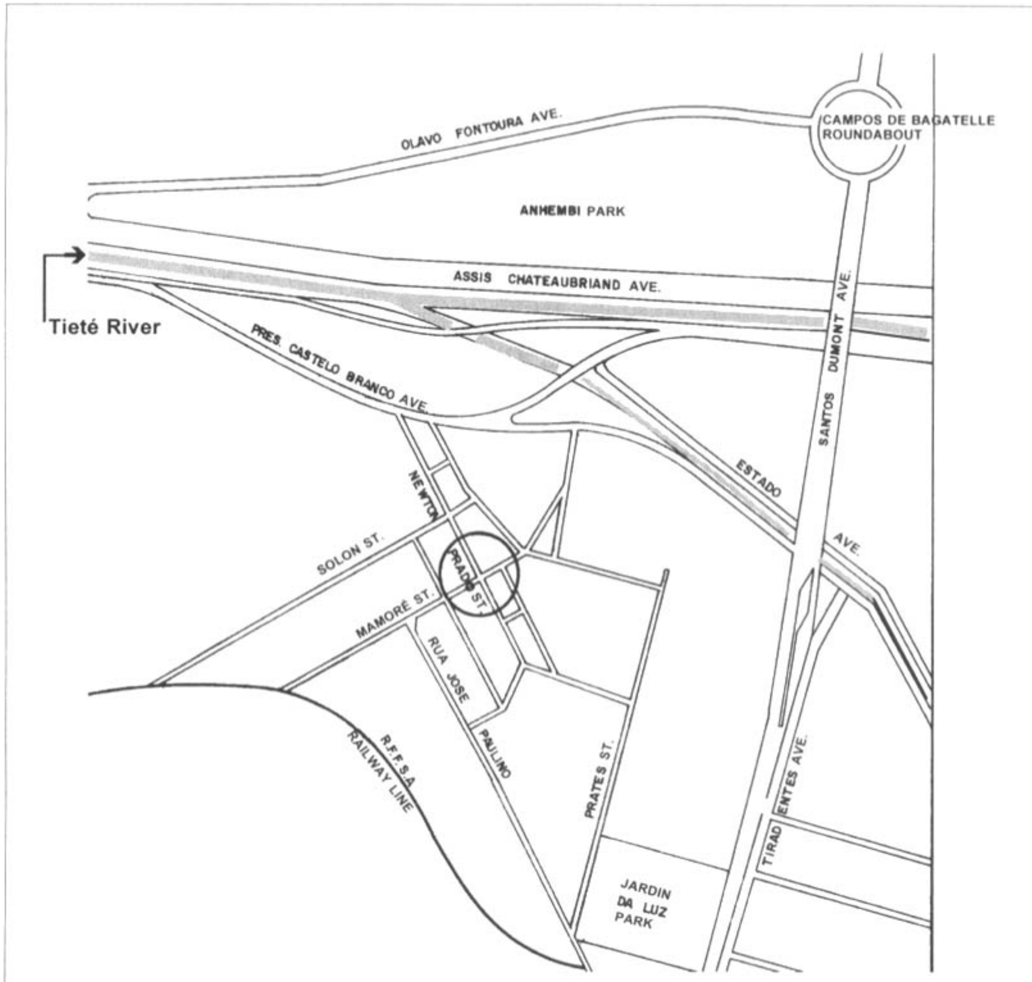
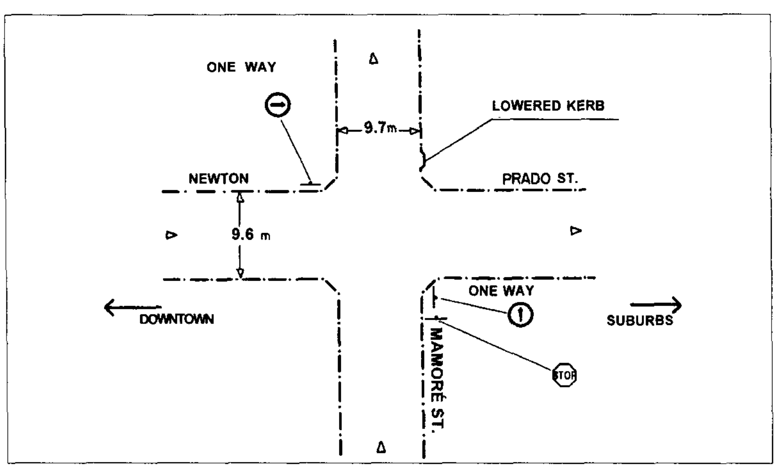


FIGURE 9.2
SITUATION BEFORE PROJECT IMPLEMENTATION
MARMORÉ STREET x NEWTON PRADO STREET



Source: CET

Analysis of Available Data

Table 9.1 shows data on the accidents registered six months before and six months after the implementation of the project, developed as a result of the case study (see this and the following tables at the end of this chapter, pp. 100-104). The analysis in the next section examines the data on accidents that occurred prior to project implementation.

A – EVOLUTION OF THE FREQUENCY OF ACCIDENTS

Table 9.2 shows the monthly evolution of accidents during the six months preceding project implementation. A period of at least one year is recommended for examination of tendencies in accident frequency. In this case, however, data were available for only six months, during which the monthly figures showed no tendency to increase or decrease.

B – DISTRIBUTION BY TIME OF DAY AND DAY OF WEEK

Table 9.3 shows the accident distribution by time of day and day of the week, before project implementation.

Eleven of the twelve accidents occurred during weekdays, only two occurred at night and eight (including the two with personal injuries) occurred during weekday working hours (between 9h00 and 18h00).

This eliminates deficient street lighting as an important contributing factor, along with factors associated with weekends, such as low traffic volumes and consequent high-speeds, or higher percentages of drunk drivers.

C – ROAD SURFACE CONDITIONS

Of the five accidents with this information available, four occurred with a dry road surface. Consequently, the pavement condition (wet or dry) was probably not a significant influence in the accidents.

D – ACCIDENT DIAGRAM

Diagrams were available for five accidents. All of them were right-angle collisions between two motor vehicles, one in each street and none of them travelling in the wrong direction. This indicates failure to yield by drivers on Mamoré Street. This apparent disobedience may have been voluntary or due to drivers' ignorance of which street had the right of way.

Completing the Available Data: Diagnosis

A site inspection was carried out on a weekday afternoon, typical of the time most accidents occurred. As predicted, many drivers approaching from Mamoré Street did not yield, despite the STOP sign. The visibility of this sign was poor; it was hidden by a tree and there were no other signs or road markings indicating right of way.

The characteristics of the two streets, especially width and traffic intensity, were almost identical, providing no right of way information for drivers. This problem was aggravated by the existence of the *anomalous situation* described in item 8.5. The traffic code's rule of preference for vehicles coming from the right, in intersections without traffic lights, had been inverted at the location by the use of a STOP sign, with the intention of giving the right of way to drivers approaching from Newton Prado Street. No signs were directed towards drivers on this street and, in fact, no sign exists in Brazilian norms to indicate to a driver in this situation that he/she has the right of way.

This problem appears to be common in the Americas; some European countries indicate to drivers when they have right of way, using a special sign or road markings for this purpose.

The Project

Figure 9.3 shows the project as designed and implemented. The STOP sign was transferred to a visible location and the definition of the right of way was reinforced, with the introduction of a second STOP sign on the left side of Mamoré Street. No special measures were needed for pedestrian safety, since there were few pedestrians and no pedestrian accidents had been registered at the intersection. However, road markings of four pedestrian crossings were introduced to improve the visibility of the intersection by approaching drivers and to define the limits of the area of conflict.

Results and Evaluation

The accident frequency diminished by 75%, from 12 cases in the sixth months prior to project implementation, to three cases in the following six months. The type of accident registered remained the same: right-angle accidents involving two vehicles continued to predominate, due in part to the continuation of the *anomalous situation*, which contributes to this type of accident. Right of way for vehicles approaching from Newton Prado Street was maintained, along its entire extension, at all intersections without traffic lights.

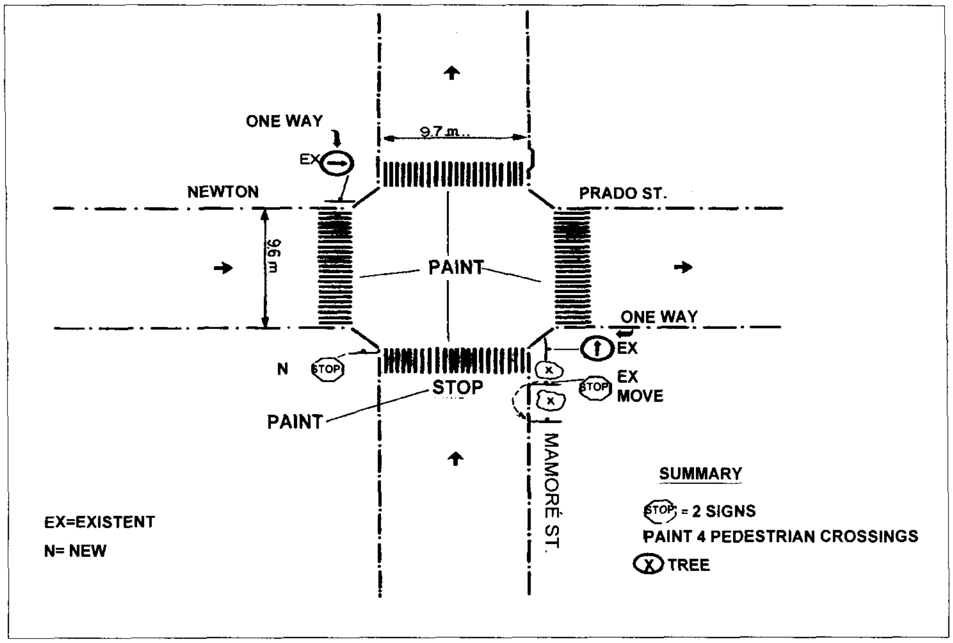
Conclusions

The measures eliminated three-fourths of the accidents through:

- reinforcement of right of way information;
- better visibility of the intersection for drivers; and
- better delimitation of the area of conflict.

These conclusions would be stronger if the accident reduction could be confirmed by data from at least one year before and after project implementation, eliminating any seasonal effects. In this case, accidents from July to December (before the project) were compared with data from February to July (after implementation). Moreover, traffic counts are needed before and after the project implementation to adjust for possible changes in vehicle flows. These counts were not taken, although traffic engineers working in the area stated that they observed no significant changes in vehicle flows.

FIGURE 9.3
SITUATION AFTER PROJECT IMPLEMENTATION
MAMORÉ STREET x NEWTON PRADO STREET



Source: CET

9.2 Case study 2

ALCÂNTARA MACHADO AVENUE (EAST RADIAL AVENUE) x CARNEIRO LEÃO STREET

Characteristics of the Location

Alcântara Machado Avenue (East Radial Avenue), one of the principal avenues of São Paulo, connects the suburbs in the East Zone to the downtown area and to other zones of the city (see Figures 9.4 and 9.5). This Avenue crosses Carneiro Leão Street, near the beginning of the bridge over the Tamanduateí River. At the time of the study, the intersection had traffic lights with no grade separation. (Subsequently the intersection was transformed into two «T» junctions, with the closure of the median strip and the elimination of the traffic lights).

To the west, starting at the bridge, Alcântara Machado Avenue becomes the East-West Connection, an elevated expressway of 5.5 km, with no intersections. To the east, the Avenue continues for a further 1.5 km, with no intersections, although this section was not considered an expressway. The first intersection occurred at President Kennedy Place, after the Alcântara Machado Bridge, passing over a railway.

Carneiro Leão Street served as a distributor for vehicles travelling from Gasômetro Street to the East-West Connection, to the East Zone via Alcântara Machado Avenue and to the Southwest Zone via Estado Avenue. In 1979, 99 traffic accidents were registered at the intersection, a number exceeded at only two intersections in São Paulo (Estado Avenue x Patriotas Street and Interlagos Avenue x Nossa Senhora do Sabará Avenue).

Analysis of the Available Data

Between July 1978 and April 1980, a total of 177 accidents were registered by the police telephone operators, but the police reports could be located for only 118. Details of the remaining 59 accidents were consequently omitted from the analysis.

A – EVOLUTION OF THE ACCIDENT FREQUENCY

Figure 9.6 shows the monthly accident frequency (personal injury, pedestrian accidents, and total accidents). The monthly total reached a maximum of 21, in March 1979, and afterwards diminished to an average of about 6.5 accidents per month. Personal injury accidents oscillated around 1.5 per month, with no tendency to increase or decrease.

The total accident frequency declined due to the reduction of accidents that caused only damage to property. This simply reflected the decision by police to concentrate their limited resources on personal injury and pedestrian accidents, neglecting to register many accidents that caused only damage to vehicles.

FIGURE 9.4
LOCATION OF STUDY AREA OF SECOND CRITICAL SPOT
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET

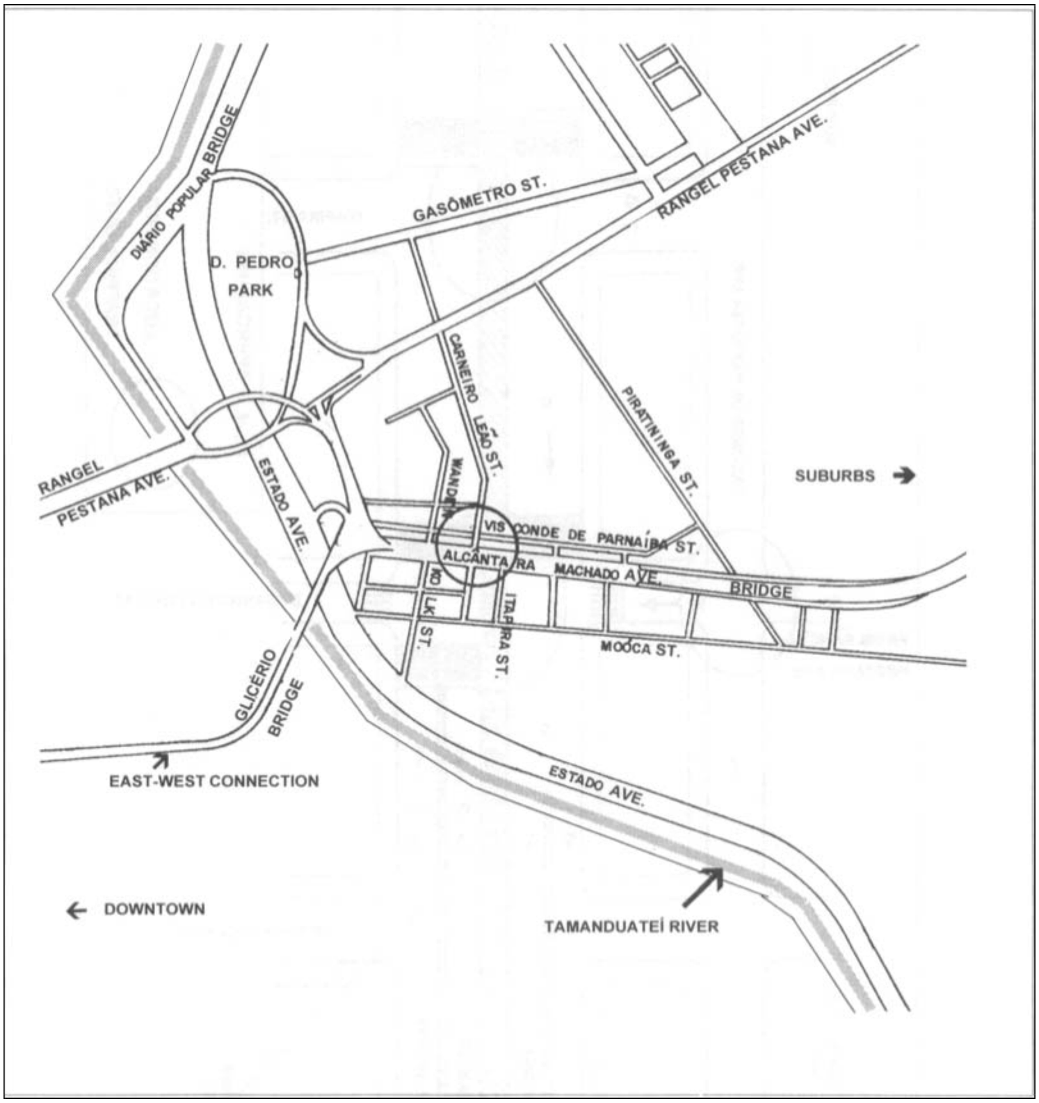
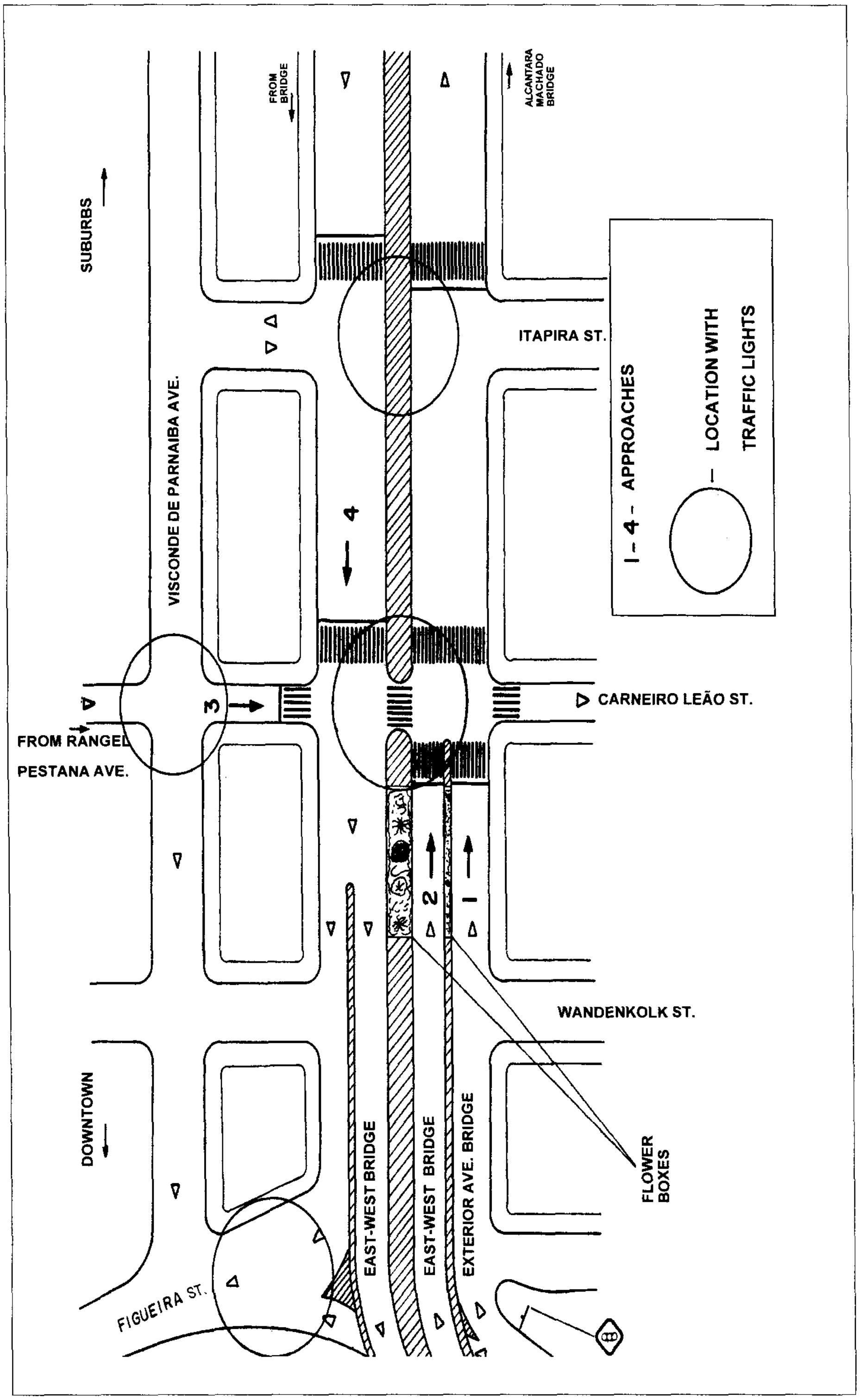


FIGURE 9.5
APPROACHES
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET

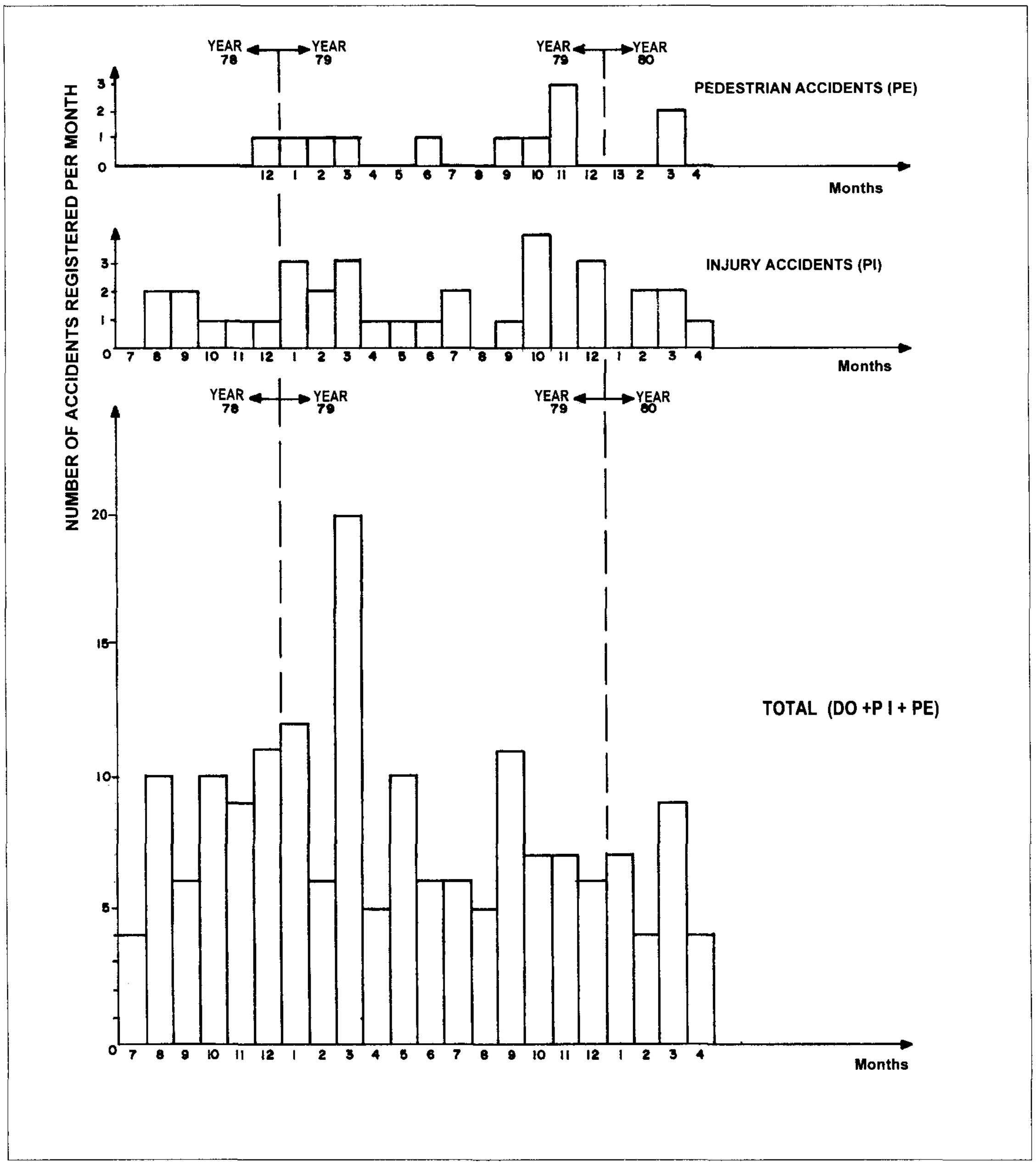


Source: CET

B – DISTRIBUTION BY TIME OF DAY AND DAY OF WEEK

A majority of the accidents occurred between 11h00 and 19h00 (Table 9.4); only a third occurred at night (between 18h00 and 6h00). The worst day was Tuesday and the worst period from 11h00 to 18h00. Personal injury accidents occurred on all days of the week within a wide time period (from 6h00 to 23h00), but 60% occurred between 6h00 and 15h00. A majority of pedestrian accidents occurred during daylight: 5 occurred on Wednesdays; 4 on weekends; and, probably by coincidence, none on Thursdays or Fridays. Hence, the intersection has most of its accidents on weekdays, during working hours.

FIGURE 9.6
MONTHLY DISTRIBUTION OF ACCIDENT FREQUENCIES
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET



Source of original data: CET

C – ROAD SURFACE CONDITIONS

Of the 118 accidents with information available, only 13 (approximately 11%) occurred with a wet road surface. Consequently, the state of the road surface (wet or dry) was not a significant factor.

D – ACCIDENT DIAGRAM

Table 9.5 shows the registered accidents by type (DO - property damage only; PI - personal injury; PE - pedestrian accident), indicating if the police report was located and if there was a usable accident diagram.

The table demonstrates that only 91 accidents (52% of those registered) had police reports that contained usable accident diagrams. For the remainder, there was only a simple form filled in by the telephone operators at the police station, after elimination of false alarms.

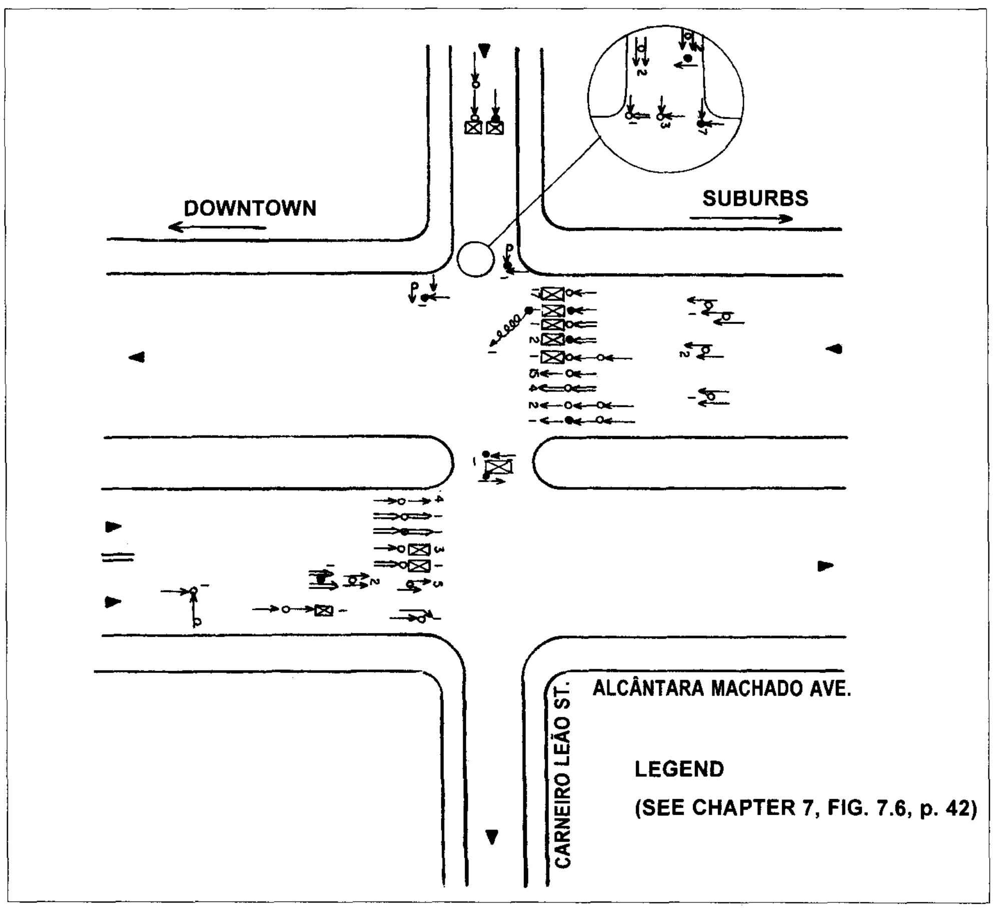
These 91 accidents may not be representative of all the accidents, but they are sufficient for a good analysis of many of the problems of the intersection. For the serious accidents, there were usable diagrams of 18 (55%) of the 33 personal injury accidents; for the 12 pedestrian accidents, only 3 (25%) had usable diagrams. This made the analysis of the causes of pedestrian accidents difficult and heavily dependent on site investigation.

The large volume of information required drawing a summarised accident diagram (Figure 9.7). The symbol of each accident type appears only once, with the number of similar accidents noted by the side of the symbol.

In the usable accident diagrams, the most common accidents were:

- rear-end collisions (including pile-ups) on Alcântara Machado Avenue, with the front vehicle stopped or moving and vehicles travelling from the suburbs towards the city centre (49);
- rear-end collisions on Alcântara Machado Avenue, with the front vehicle stopped or moving, and vehicles travelling from downtown to the suburbs (11);

FIGURE 9.7
SIMPLIFIED ACCIDENT DIAGRAM
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET



Source: CET

- right-angle accidents between vehicles, one (and in one case two) approaching from Carneiro Leão Street and the other from Alcântara Machado Avenue, travelling towards the downtown area (11); and
- pedestrian accidents (3).

This information gives some clues about the factors that generate accidents at the intersection.

The very high frequency of rear-end collisions on Alcântara Machado Avenue suggests that the traffic lights are not sufficiently visible and/or drivers approach with excess speed, especially those travelling towards the downtown area. The high incidence of right-angle accidents suggests that drivers enter the intersection after the beginning of the traffic light's red phase. There also may be insufficient time for traffic to clear the intersection when the light changes.

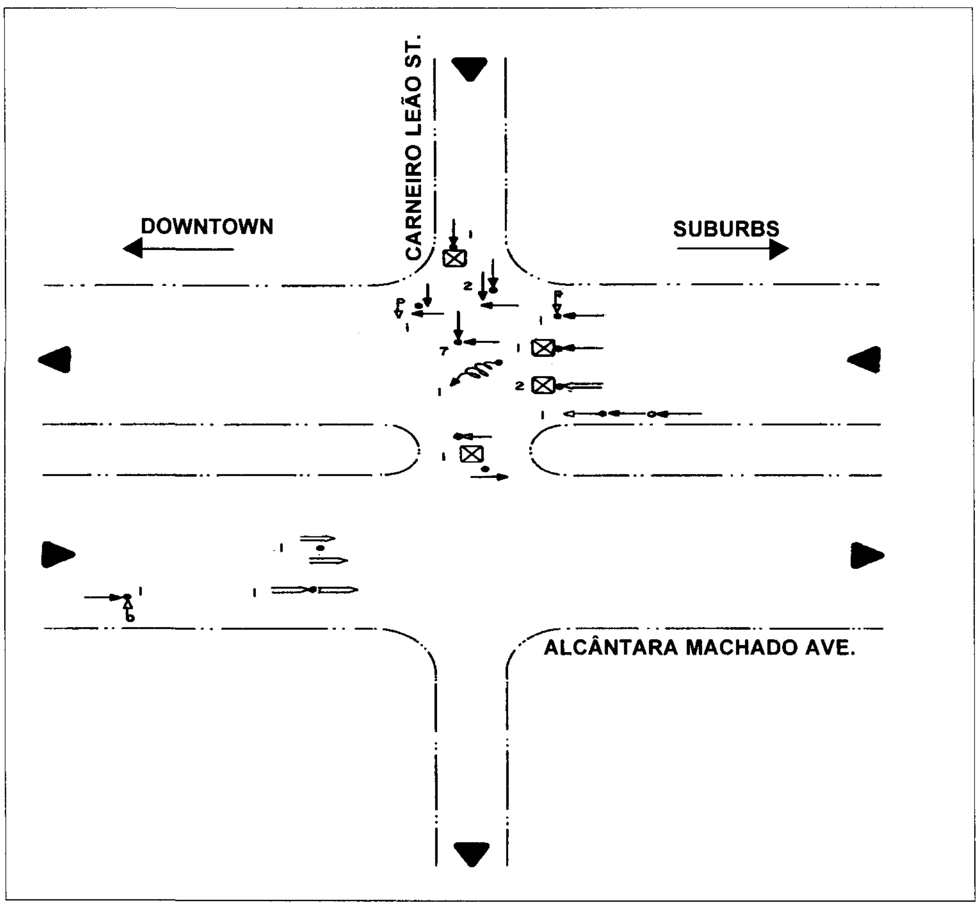
The sideswipe accidents indicate that drivers are turning right without adequately positioning their vehicles before arriving at the intersection. The lack of information about the pedestrian accidents makes it difficult to make useful hypotheses about their causes at this stage.

Figure 9.8 presents the accident diagram for the most serious accidents: personal injury accidents (18) and pedestrian accidents (3).

The outstanding characteristics are very different from those of the previous diagram. In this case, there are:

- 9 right-angle accidents between vehicles, one car (and, in a single case, two cars) approaching from Carneiro Leão Street and the other from Alcântara Machado Avenue, travelling towards the downtown area;
- 4 accidents (3 rear-end and one pile-up) involving vehicles stopped or reducing speed, while travelling towards the downtown area, probably because of the traffic lights on Alcântara Machado Avenue.

FIGURE 9.8
PEDESTRIAN AND NON-PEDESTRIAN INJURY ACCIDENTS
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET



Source: CET

These data indicate that site inspections should give priority to the following:

- reasons for the right-angle accidents between vehicles approaching from Carneiro Leão Street, and from Alcântara Machado Avenue, travelling towards the downtown area;
- reasons for the rear-end accidents on Alcântara Machado Avenue, involving vehicles travelling towards the downtown area; and
- reasons for pedestrian accidents in the entire area of the intersection.

A summary of the personal injury accidents was drawn up to examine the available data in more detail (see Table 7.1, Chapter 7). The accidents were also grouped to identify common factors (see Table 7.2, Chapter 7), revealing that:

- 14 accidents involved vehicles proceeding along Alcântara Machado Avenue, towards the downtown area, indicating problems on this approach to the intersection;
- in at least 7 accidents, the vehicle proceeding along Alcântara Machado Avenue entered (or tried to enter) the intersection during a red light and crashed into the rear of the other vehicle, which was stopped at, or slowing down for, the red light, suggesting traffic light visibility problems;
- six of the right-angle accidents occurred between 11h30 and 15h30, indicating this period should be included in the site inspections;
- no day of the week stands out specially with regard to the right-angle accidents; and
- of the 4 accidents that occurred when the road was wet, none was a right-angle accident.

Completing the Available Data: Diagnosis

Site inspections were carried out on three separate days, at different times of the day, using the methodology presented in Chapter 8, with the following phenomena observed.

A – APPROACHES (See Figure 9.5)

APPROACH 1

Alcântara Machado Avenue, approaching from downtown, continuation of Exterior Avenue. Horizontal approach during the last two blocks before the intersection. High-speed traffic descending from the bridge. Both the intersection and the traffic lights were almost invisible to drivers until they were very close to the intersection. The view of approach 3 was blocked by overgrown vegetation in the flower boxes on the median strip.

APPROACH 2

Alcântara Machado Avenue, approaching from downtown, from the East-West Connection bridge. There were no warning signs to advise drivers of the proximity of the intersection and the traffic lights. The approach descended to the level of Carneiro Leão Street very close to the intersection, with vehicles travelling at high-speed. During the approach, visibility of the intersection and of the traffic lights was poor and the view of approach 3 was blocked by the vegetation in the flower boxes on the median strip. About 100 m before the intersection, there was a slight kink in the alignment of the road, with a corresponding kink in the lane markings.

APPROACH 3

Carneiro Leão Street. At a distance of only three vehicle lengths (15 m) before the intersection, there was another intersection with traffic lights (Visconde de Parnaíba Street), with cycle and phasing identical to those at the intersection under study. Traffic approached at low speed, with good visibility for drivers of the intersection with Alcântara Machado Avenue.

APPROACH 4

Alcântara Machado Avenue, approaching from the suburbs. At a distance of 50 m before the intersection, just before Itapira Street, there was a pedestrian crossing, with traffic lights. The median strip was closed to vehicle traffic, and consequently there was no conflicting orthogonal traffic flow. (Subsequently this crossing was eliminated after the construction of a footbridge). The signs and traffic lights at the intersection with Carneiro Leão Street were similar to those at Itapira Street, with poor visibility of traffic lights and no signs warning of the orthogonal traffic flow.

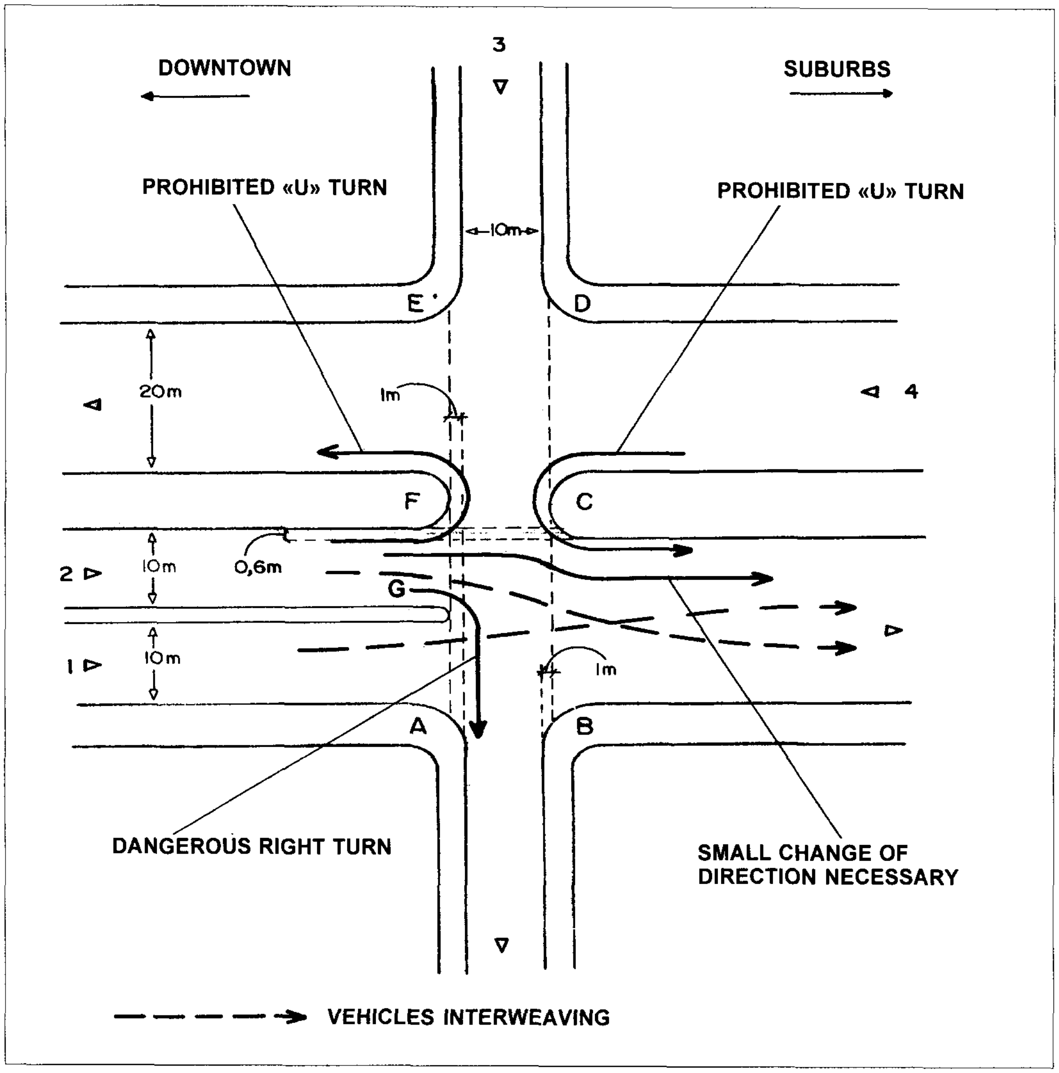
B – GEOMETRY (Figure 9.9)

The median strips were all curved at their extremes, facilitating prohibited vehicle movements, such as right turns from approach 2 to Carneiro Leão Street.

There was a difference in the alignment of median strips F and C before and after the intersection that caused a slight change of direction of the vehicles travelling out from downtown, in the lane closest to the median strip. These vehicles were normally those that approached with the highest speeds.

The end of the median strip between approaches 1 and 2 (Alcântara Machado Avenue, travelling out from downtown), combined with the absence of median strip after the intersection, resulted in weaving movements of vehicles with different speeds, precisely in the area of pedestrian crossing BC, increasing the danger of sideswipes and pedestrian accidents.

FIGURE 9.9
POOR GEOMETRY AS A POSSIBLE CAUSE OF ACCIDENTS



Source: CET

C – TRAFFIC LIGHTS

The intersection had traffic lights for vehicles and pedestrians (Figure 9.10) with the following characteristics.

Vehicles

Both approach directions of Alcântara Machado Avenue had 6 high-speed traffic lanes, controlled by only two traffic light signal heads. These were both located on the far side of the intersection and had neither black background screens nor high intensity bulbs.

Pedestrians

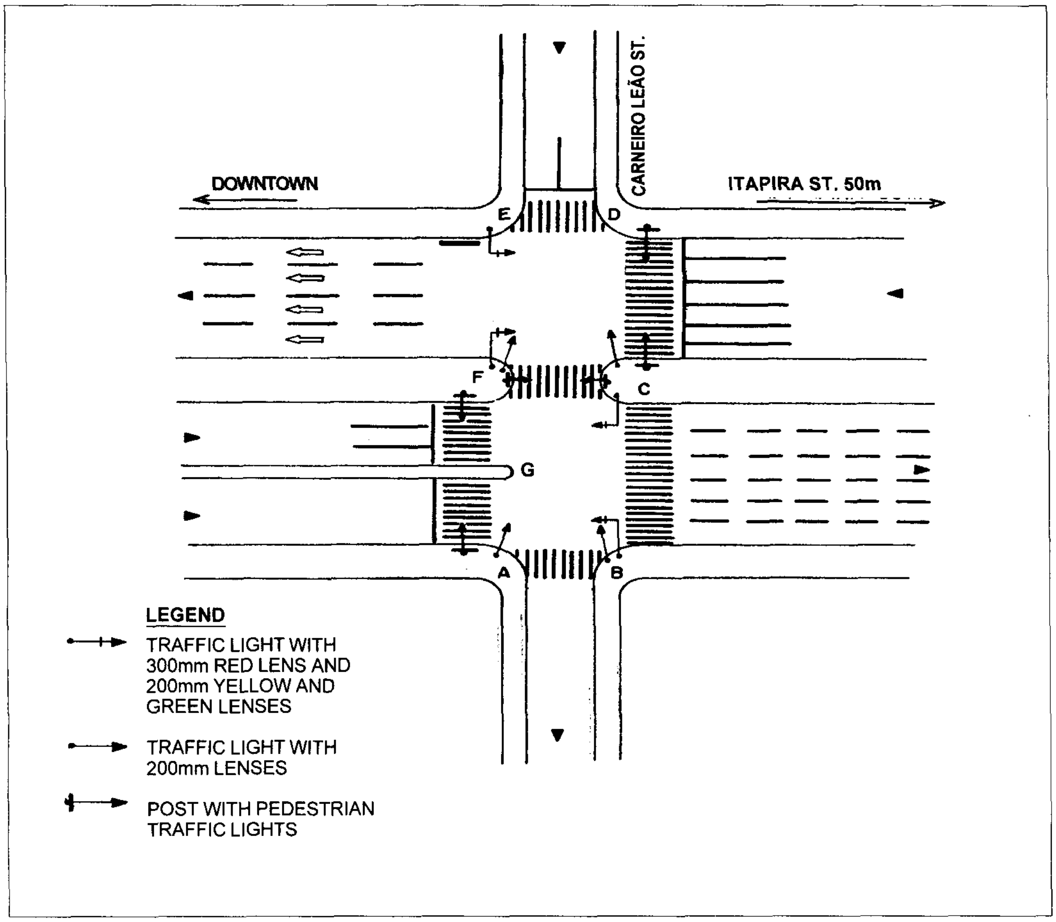
Only 3 of the 7 possible crossing points were equipped with pedestrian traffic lights: AF, FC and CD. (The crossing and safety of pedestrians are analysed later in this chapter).

Other locations

The intersection of Carneiro Leão Street with Visconde de Parnaíba Street had traffic lights with identical programming to those at the intersection of Alcântara Machado Avenue with Carneiro Leão Street (Figure 9.5).

The pedestrian crossing, in front of Itapira Street, had traffic lights with the same total cycle time as the others, but with different phase characteristics.

FIGURE 9.10
TRAFFIC LIGHTS
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET



Source: CET

D – TRAFFIC LIGHT PROGRAMS

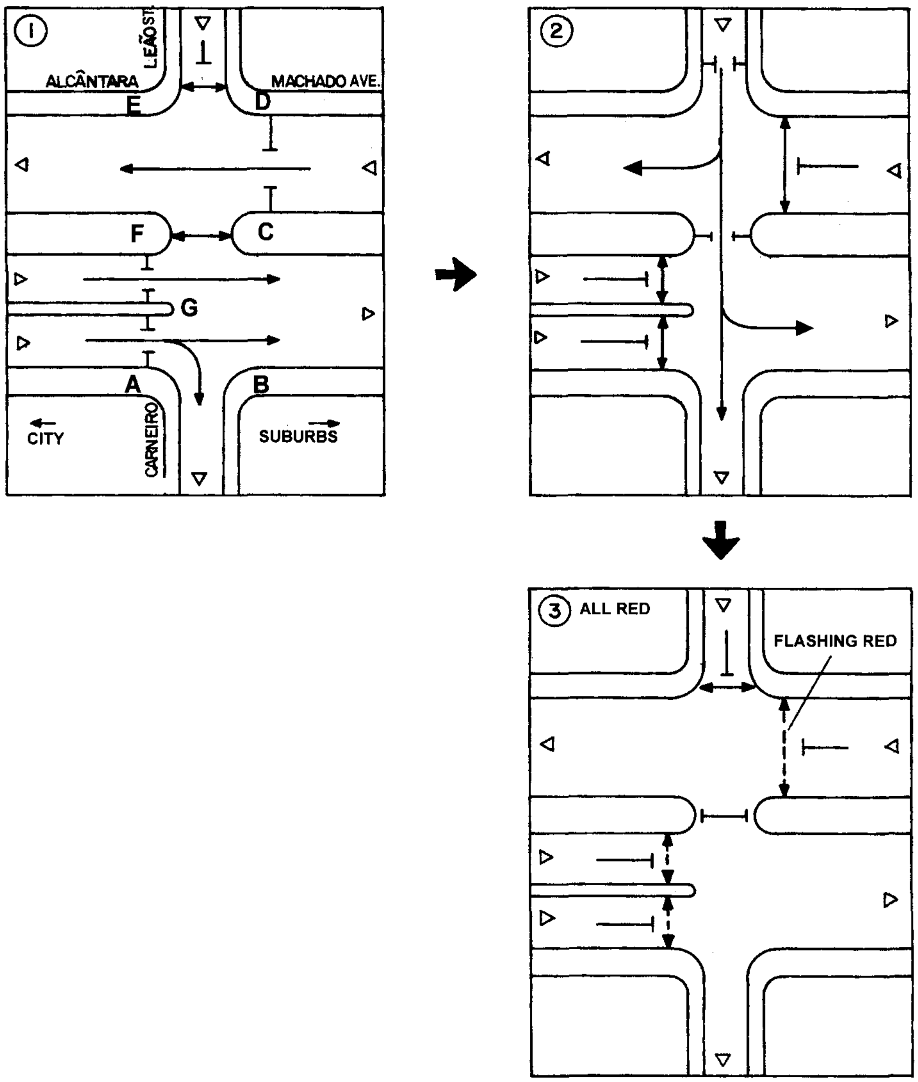
The characteristics of the traffic light cycles are indicated in Figures 9.11, 9.12 and 9.13.

Pedestrians (Figure 9.11)

At Itapira Street pedestrians could cross Alcântara Machado Avenue directly, without stopping on the median strip. At the intersection with Carneiro Leão Street, pedestrians who crossed Alcântara Machado Avenue, via the marked crossings with pedestrian traffic lights, always took more than a complete cycle and sometimes took almost two cycles, depending on the phase of the traffic light cycle when they arrived at the crossing. The cycle time was variable, from 2 to 5 minutes, depending on the time of day. Crossing time for pedestrians was always more than 2 minutes and could reach 9 minutes.

The flashing red time for pedestrians crossing the sections AF and CD was about 8 seconds, sufficient to cross only half of the distance of 20 metres. Hence, pedestrians who started crossing CD or DC towards the end of the pedestrian green phase found themselves in the middle of the road at the start of the green phase for vehicles. This resulted in risk of pedestrian accidents and rear-end collisions.

FIGURE 9.11
TRAFFIC LIGHT CYCLES



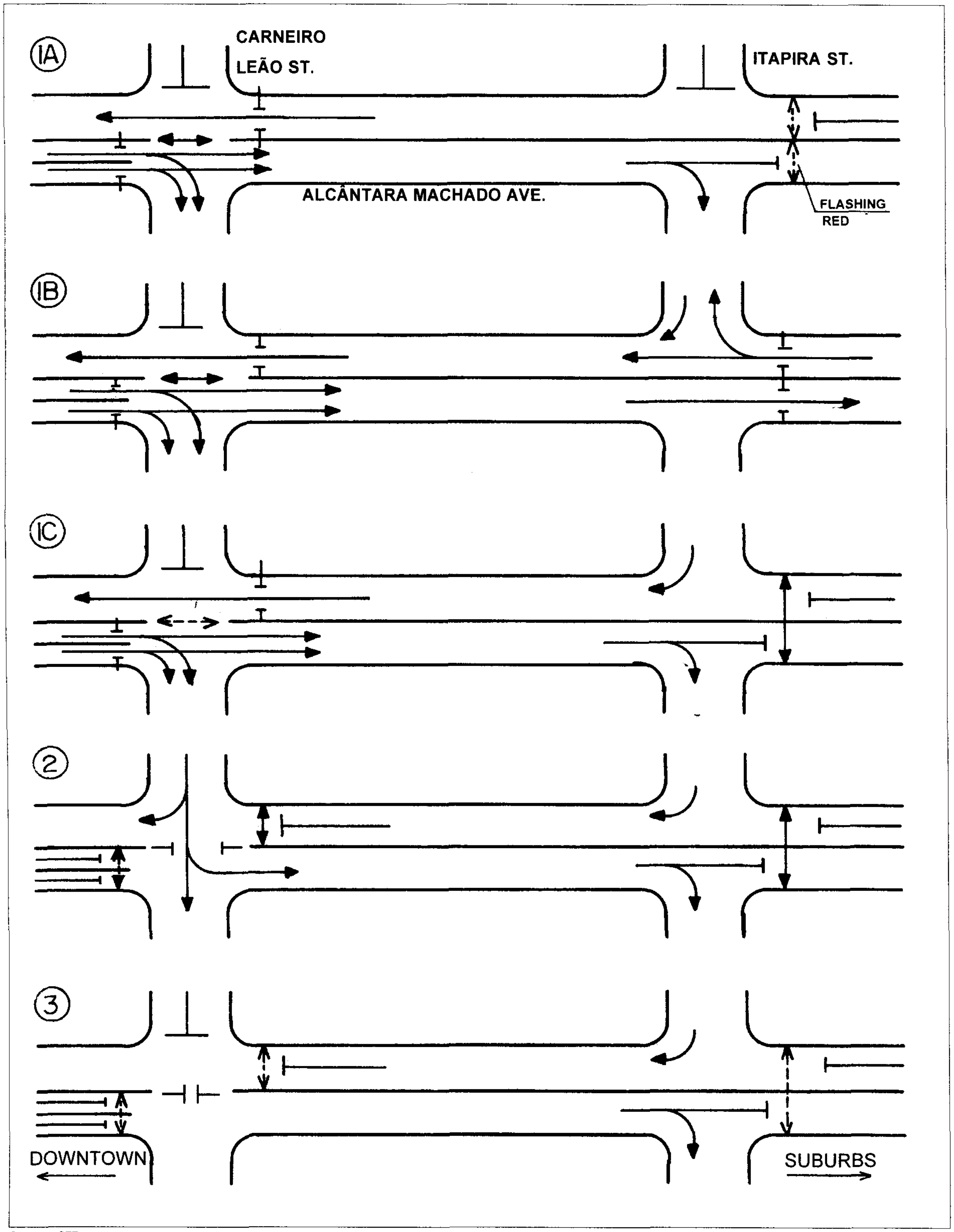
Source: CET

Vehicles (Figures 9.12 and 9.13)

On Alcântara Machado Avenue, there was a delay between the start of the red phase at Itapira Street and that at Carneiro Leão Street, for vehicles travelling towards the downtown area. This encouraged the last drivers passing through the intersection with Itapira Street on a yellow light to accelerate in an attempt to also get through the intersection of Carneiro Leão Street before the traffic lights changed to red (Figure 9.12, sequence 1B-1C-2).

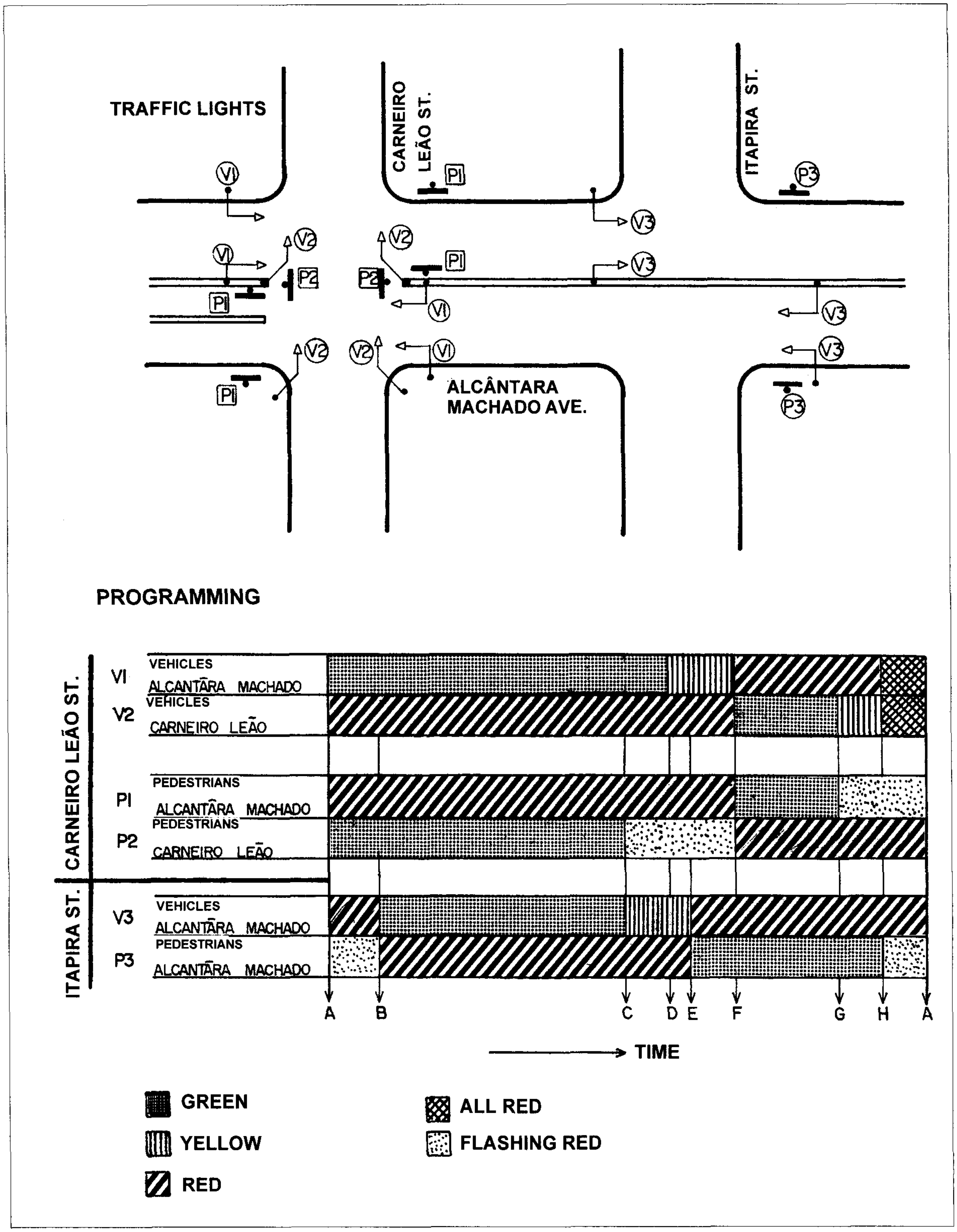
Figure 9.13 shows a delay between the start of the green phase at Carneiro Leão Street and that at Itapira Street, for vehicles travelling in the other direction on Alcântara Machado Avenue. This required a second stop, at Itapira Street, for the first vehicles that passed Carneiro Leão Street, especially when preceded by a large volume of vehicles coming from Carneiro Leão Street, with the formation of a queue on the approach to the intersection with Itapira Street (Figure 9.12, sequence 2-3-1A-1B).

FIGURE 9.12
TRAFFIC LIGHT CYCLES
PHASE DIAGRAM (INCLUDING THE INTERSECTION WITH RUA ITAPIRA)
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET



Source: CET

FIGURE 9.13
TRAFFIC LIGHT CYCLES
PROGRAMMING
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET



Source: CET

E – ROAD MARKINGS

The road markings were composed of white painted marks (Figure 9.14), with the following characteristics:

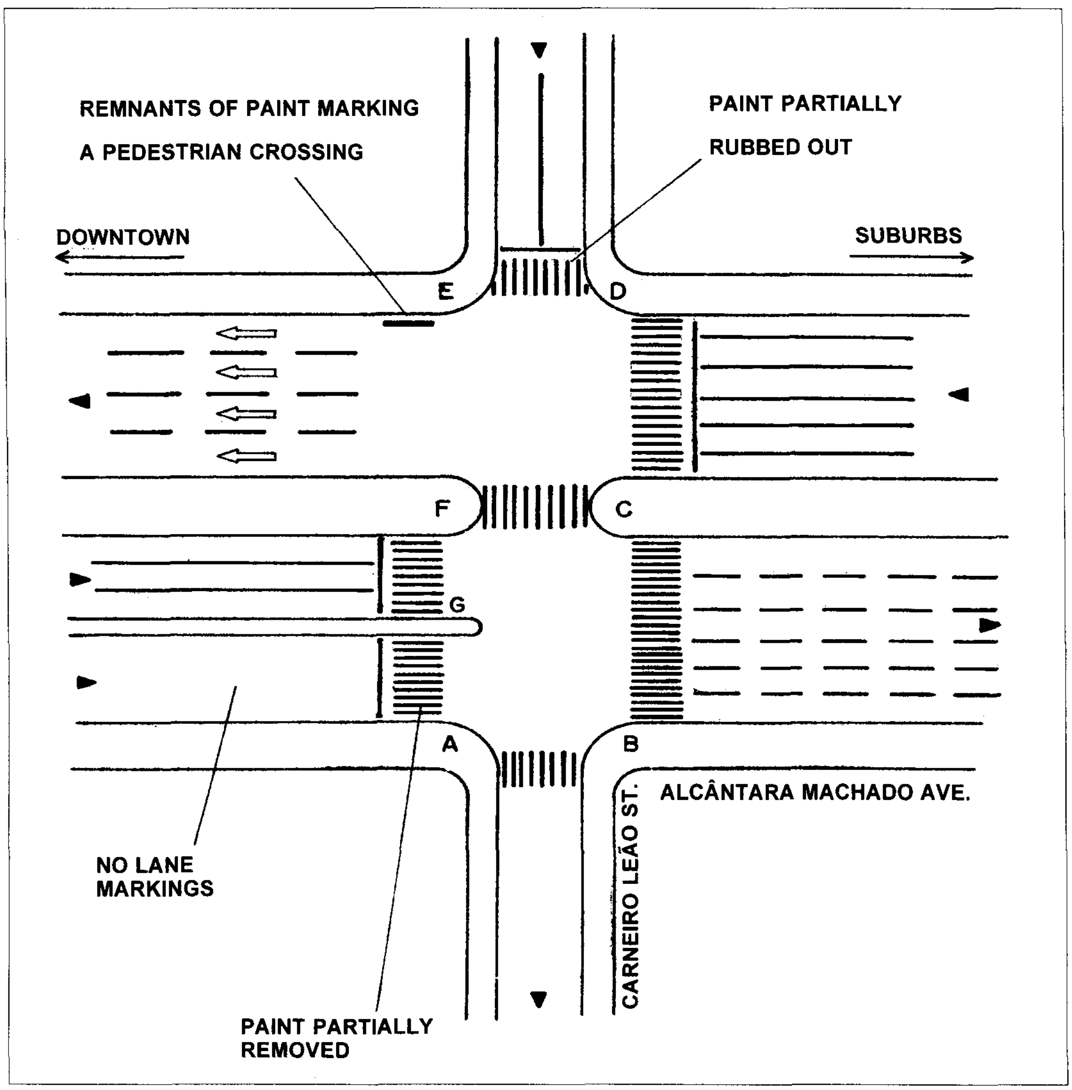
- the paint was partially rubbed out on pedestrian crossings AG and ED;
- one approach had no lane markings (AG);
- there were remnants of a pedestrian crossing (EF). Figure 9.15 shows a copy of a service order, dated 27 July 1979, requesting that this crossing be eliminated. However, the first stripe, nearest to sidewalk E, was not removed, giving pedestrians the impression that the crossing was still in use, although needing repainting after having been subject to public works or other temporary interference; and
- on Alcântara Machado Avenue, for traffic moving towards the dowtown area, 6 lanes were marked before the intersection and only 4 after; 200 metres ahead these 4 lanes were divided, 2 ascending in the direction of the bridge over the Tamanduateí River and 2 converging with an expressway. This change, from 6 to 4 lanes, caused dangerous weaving movements of vehicles within the area of the intersection, between CD and EF.

F – VERTICAL SIGNS

The vertical signs at the intersection were of the type used normally in São Paulo and presented the following characteristics (Figure 9.16):

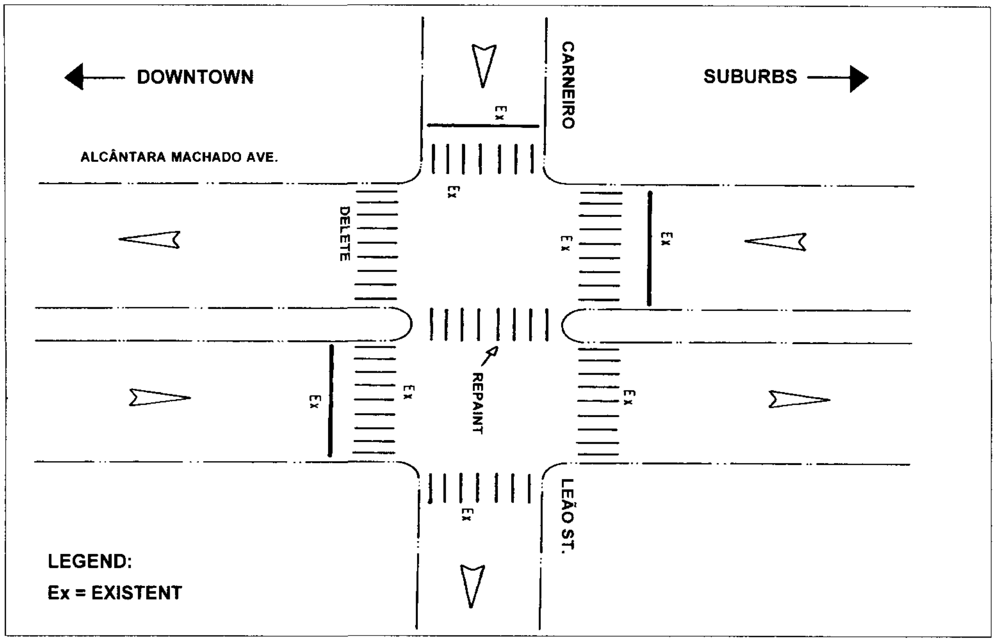
- there were no signs prohibiting parking on Carneiro Leão Street along sidewalk B; and
- a PARKING PROHIBITED sign was hidden behind a wide concrete post, on Alcântara Machado Avenue, on the approach towards downtown.

FIGURE 9.14
ROAD MARKINGS
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET



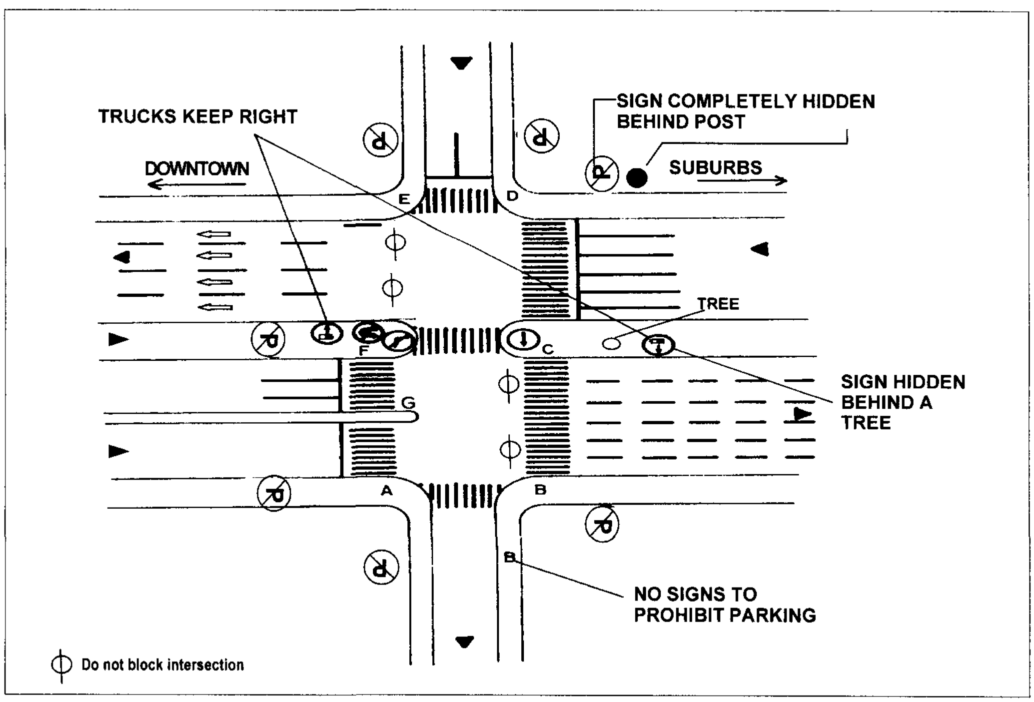
Source: CET

FIGURE 9.15
SERVICE ORDER
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET



Source: CET

FIGURE 9.16
VERTICAL SIGNS
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET



Source CET

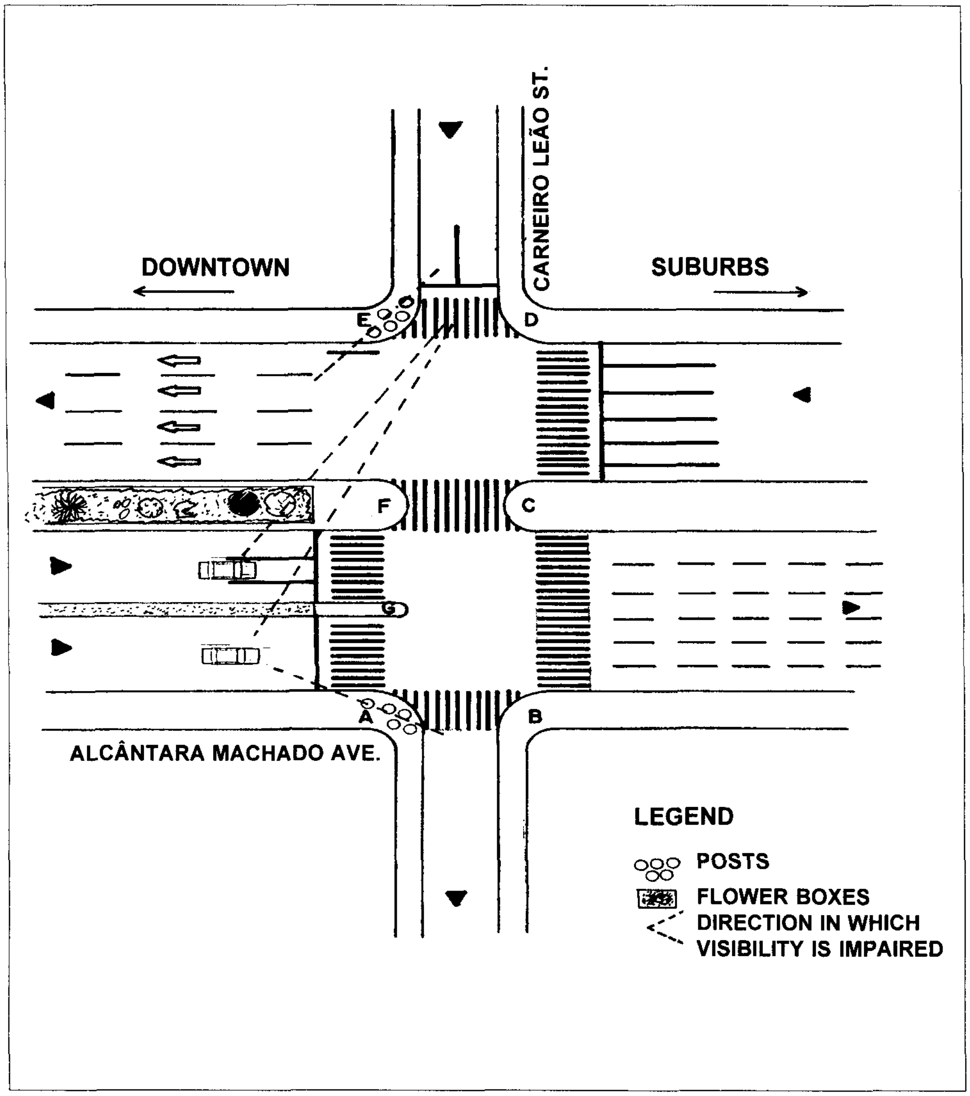
G - VISIBILITY

Figure 9.17 shows that the view of the pedestrian crossing AB was blocked by electricity posts and other fixed objects, located on the corner, for drivers of vehicles on approach AG, who could turn right.

Figure 9.18 shows that a similar problem existed for drivers approaching from Carneiro Leão Street (ED-EF). Posts blocked their view of traffic on Alcântara Machado Avenue, just after the intersection, and of pedestrians crossing at EF.

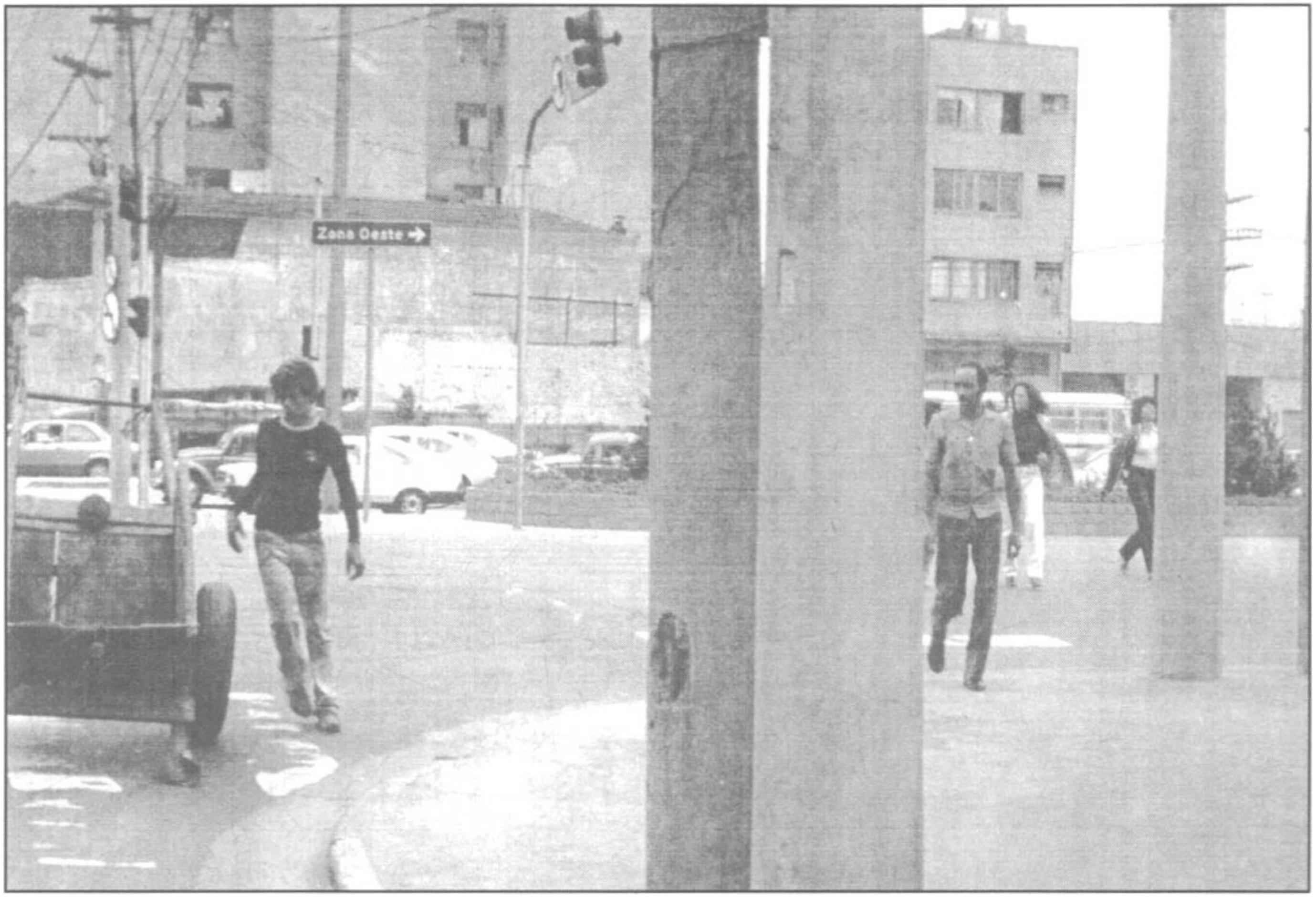
The flower boxes on the median strips reduced the visibility and perception of the intersection, for drivers on Alcântara Machado Avenue, approaching from downtown.

FIGURE 9.17
VISIBILITY
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET



Source: CET

FIGURE 9.18
VIEW FOR DRIVERS ABOUT TO TURN RIGHT FROM CARNEIRO LEÃO ST. TO ALCÂNTARA MACHADO AVE.. MANY PEDESTRIANS COULD BE HIDDEN BY THE POSTS



H – LAND USE (Figure 9.19)

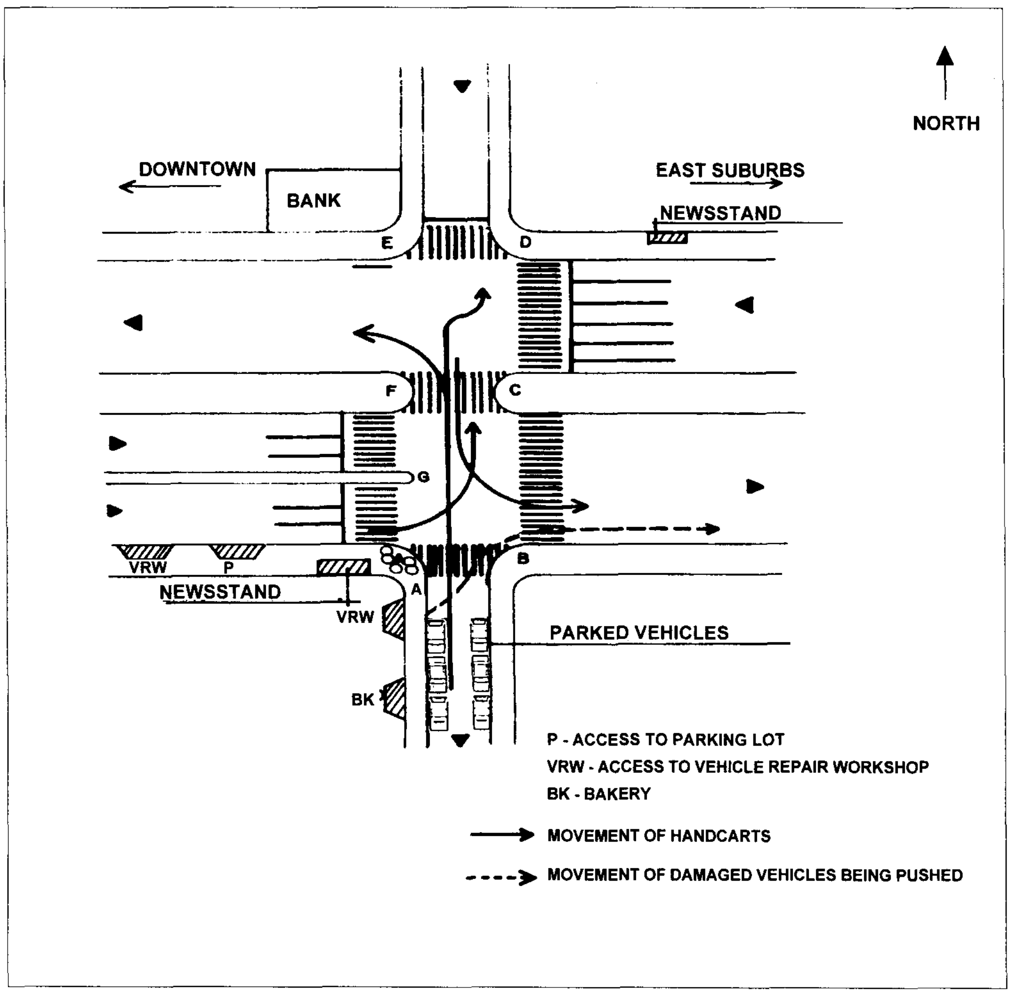
Some vehicles stopped at the two newsstands, located on the Alcântara Machado Avenue approaches, on both sides of the road and very close to the pedestrian crossings. Vehicles stopped at the newsstand near corner A, blocking the view of pedestrian crossing AB, on Carneiro Leão Street (more than the blockage mentioned in the previous item), in addition to causing danger to the high-speed vehicles on the Avenue.

The automobile repair workshop on Carneiro Leão Street generated dangerous vehicle movements, in the wrong directions on this street and on Alcântara Machado Avenue. The vehicles were often pushed by two or more mechanics.

The bakery on Carneiro Leão Street generated illegal parking on the west side and legal parking on the east side, interrupting the flow of vehicles onto Carneiro Leão Street. This caused queues on Alcântara Machado Avenue, along with sudden stops by vehicles turning right from the Avenue. Some customers went to the bakery by passing it, stopping, and backing up to park.

Many handcarts could be seen on the streets, passing through the intersection, often against the traffic. Even when travelling in the correct direction, the slow handcarts would come into conflict with the faster motor vehicles.

FIGURE 9.19
LOCAL LAND USE
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET



Source: CET

I – DRIVER BEHAVIOUR (Figure 9.20)

Normal behaviour

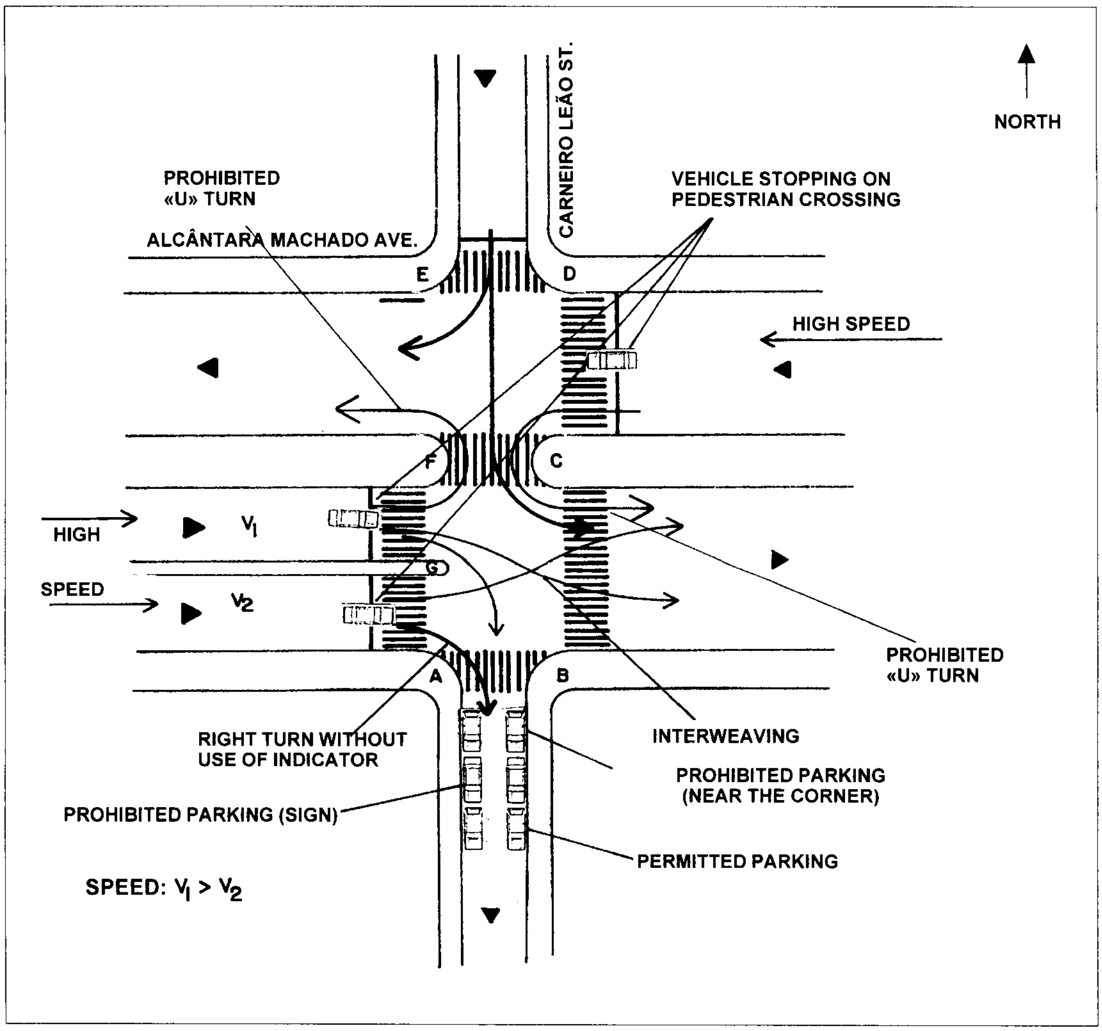
High-speed on approaches AG, GF and CD of Alcântara Machado Avenue. Vehicles encroaching on pedestrian crossings during green phase for pedestrians. Higher vehicle speeds on approach GF than on approach AG. Vehicle weaving movements in the area of pedestrian crossing BC. Parking on both sides of Carneiro Leão Street (south). Many drivers turning right from Alcântara Machado Avenue onto Carneiro Leão Street without using their turning lights. Many left and right turning movements of vehicles approaching from Carneiro Leão Street (north).

Low frequency behaviour

Prohibited "U" turns in both directions of Alcântara Machado Avenue. Right turns from GF to AB during green vehicle phase for Alcântara Machado Avenue. Running of red lights on Alcântara Machado Avenue, at the beginning of red phase.

All these behavioural aspects were observed at least once during each of the three site inspections, which lasted between 1 and 2 hours.

FIGURE 9.20
DRIVER BEHAVIOUR
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET



Source: CET

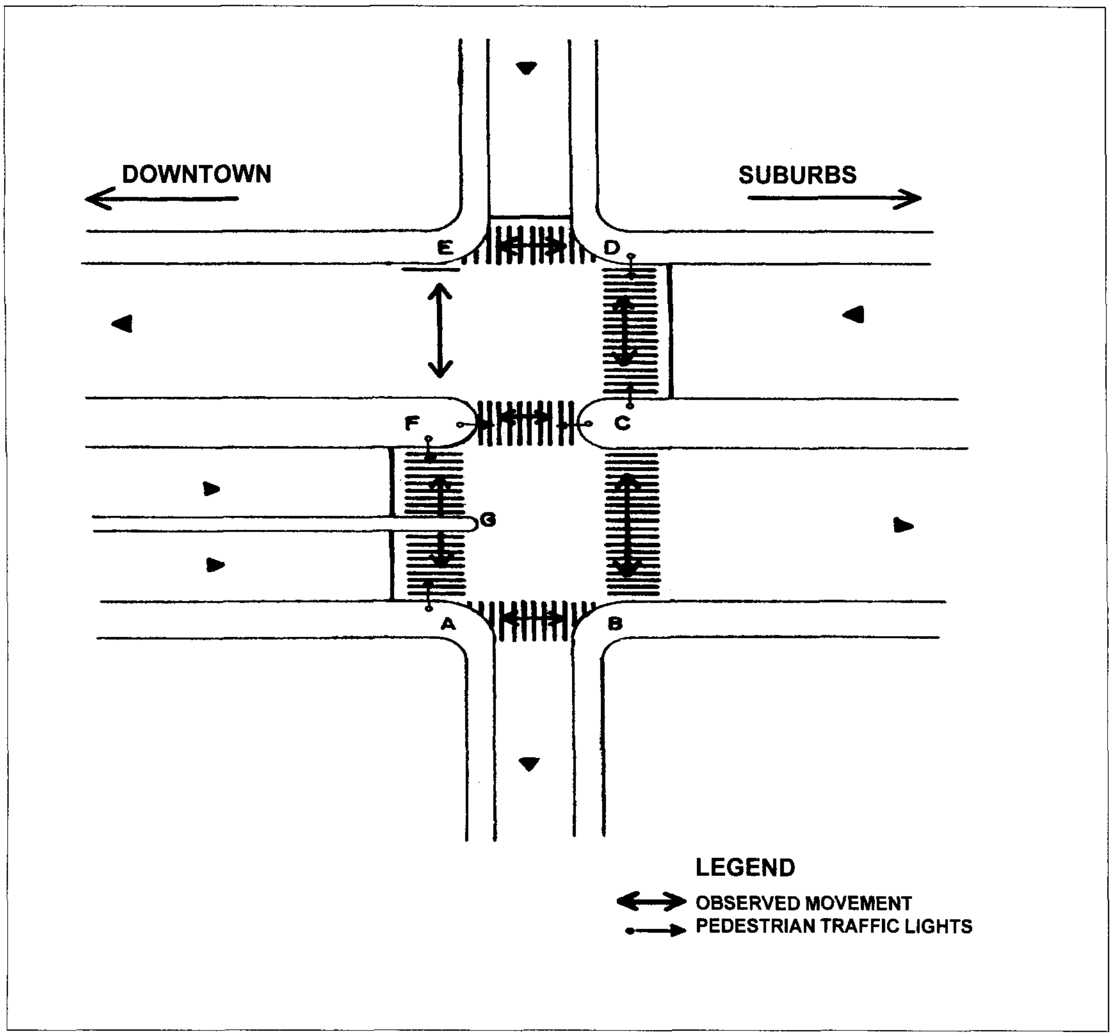
J - PEDESTRIAN BEHAVIOUR (Figure 9.21)

All marked pedestrian crossings were utilised, including EF, which had only one stripe (see previous subitem E). Crossing CF, part of the route A-F-C-D (and vice versa), with pedestrian traffic lights, was little utilised. Pedestrians preferred to cross the Avenue by more direct routes: A-F-E or D-C-B and then ED or BA.

Pedestrians crossed AB, which did not have pedestrian traffic lights, very often without paying attention to the traffic. Some pedestrians seemed not to know where vehicles were coming from.

The pedestrians using crossing CB (indicated by stripes but without pedestrian traffic lights) and crossing EF (not intended as a crossing but with a clearly visible stripe), usually crossed during the red vehicle phase for Alcântara Machado Avenue. Very often they were unable to complete the crossing, or only managed to do so if they ran, because of the large volumes of vehicles turning right (to EF) and left (to BC) from Carneiro Leão Street.

FIGURE 9.21
PEDESTRIAN BEHAVIOUR
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET



Source: CET

DIAGNOSIS

A – CHARACTERISATION OF THE INTERSECTION

The intersection was the only one with traffic lights and potentially conflicting traffic flows on a 7 km section of expressway (or semi-expressway). It merited a high level of signs, signals and road markings, because it required a very marked and sudden change of behaviour of drivers on Alcântara Machado Avenue. However, there were no warning signs and the traffic lights were substandard for the situation. In the suburbs-downtown direction, the programming of the traffic lights at Itapira Street and Carneiro Leão Street encouraged drivers approaching on Alcântara Machado Avenue to increase their speeds (see Figure 9.12).

The two streets that form the intersection had very different widths and vehicle volumes. A majority of vehicles approaching from the secondary street (Carneiro Leão Street) turned left or right into the principal street (Alcântara Machado Avenue). There were also many vehicles turning right from Alcântara Machado Avenue to Carneiro Leão Street. Considering the high pedestrian flows, the situation required very clear and well defined signs, signals and road markings for pedestrians, to show the correct crossing points. The crossings should have been designed to diminish the points of potential pedestrian/vehicle conflict. However, the signs, signals and road markings for pedestrians were very confusing. There was a mixture of marked and protected pedestrian crossings, with and without pedestrian traffic lights. Other marked crossings had no protected traffic light phase for pedestrians. And many pedestrians crossed at an unmarked location, since it was part of their most desired path.

B – CONDITIONS FOR DRIVERS

APPROACH 2 FROM THE EAST-WEST CONNECTION

Drivers unfamiliar with the area had no warning of the imminence of the intersection, when arriving from the East-West Connection (Figure 9.5). The alignments of buildings, median strips, the electricity posts, and the overhead trolleybus cables created a strong visual impression that there was no intersection in the vicinity. The flower boxes on the median strip separating the two west-east approaches left only one of the two existing traffic light units visible to approaching drivers until they were very close to the intersection, whereas on most main city streets two would be visible in such a situation. Dirt on the lenses, low intensity bulbs, and the absence of black screens to reduce reflection of the sun's rays further reduced the visibility of these traffic lights.

The right turn onto Carneiro Leão Street was apparently permitted. It was extremely dangerous, due to resulting conflicts with other vehicles arriving from Exterior Avenue viaduct, via Approach 1 (Figure 9.22). These vehicles became visible to drivers turning right only when they had already arrived at the intersection, after passing the flower boxes. With the existing program of the traffic lights, this right turn could only be made during the green phase for this parallel vehicle flow, and the drivers, when making the turn, also encountered pedestrians, crossing Carneiro Leão Street without a pedestrian phase.

The two parallel vehicle flows, coming from the two bridges, approached at significantly different average speeds, with East-West Connection traffic moving faster. The geometric design of the intersection allowed the weaving movements of these vehicles to start within the intersection, while the vehicles still had different speeds, creating a potential for sideswipe collisions.

APPROACH 1 FROM THE EXTERIOR AVENUE BRIDGE

This approach shared some characteristics with the approach just described. It operated in a similar manner and drivers who were turning right had difficulty seeing pedestrians. This created a very dangerous situation, since the pedestrian crossing on Carneiro Leão street was unprotected (see section C, Conditions for Pedestrians).

APPROACH 4 FROM THE EAST ZONE

This approach, from Alcântara Machado Avenue, had inadequate traffic lights and other undesirable factors. There was a pedestrian crossing 50 m before, at the intersection with Itapira Street, with the same problem of poor visibility of traffic lights, but with no opening in the median strip and, consequently, no conflicting traffic flows. Then, 50 m ahead, at the intersection with Carneiro Leão Street, there were identical, poorly visible, traffic lights and road markings, severely diminishing drivers' perception of the intersection.

The traffic light programs at Itapira Street and Carneiro Leão Street encouraged drivers to accelerate to get through the intersection with Carneiro Leão Street before the start of the red phase, which was lagged in relation to red at Itapira Street. Many drivers were going so fast that they could not reduce speed sufficiently at the start of the red phase. This resulted in either running the red light or braking violently. The red light violation caused right-angle collisions with vehicles from Carneiro Leão Street, and the sudden braking caused rear-end collisions. As the accident diagram shows, these were the most common situations that resulted in personal injuries and property damage only accidents, respectively.

APPROACH 3 FROM CARNEIRO LEÃO STREET

No problems were identified. Traffic lights, road markings and signs were all satisfactory: approach speeds were low and visibility was good.

However, all three possible exits from the intersection had pedestrian crossings, unprotected by pedestrian traffic light phases. Some of the pedestrians crossing at these locations could see pedestrian traffic lights that appeared to be for their use, but which were actually directed to other crossings. Drivers could think that all pedestrian crossings were protected (or at least those with road markings), and therefore not pay sufficient attention to pedestrians.

FIGURE 9.22
DANGEROUS RIGHT TURN
FROM APPROACH 2 TO CARNEIRO LEÃO STREET

Source: CET

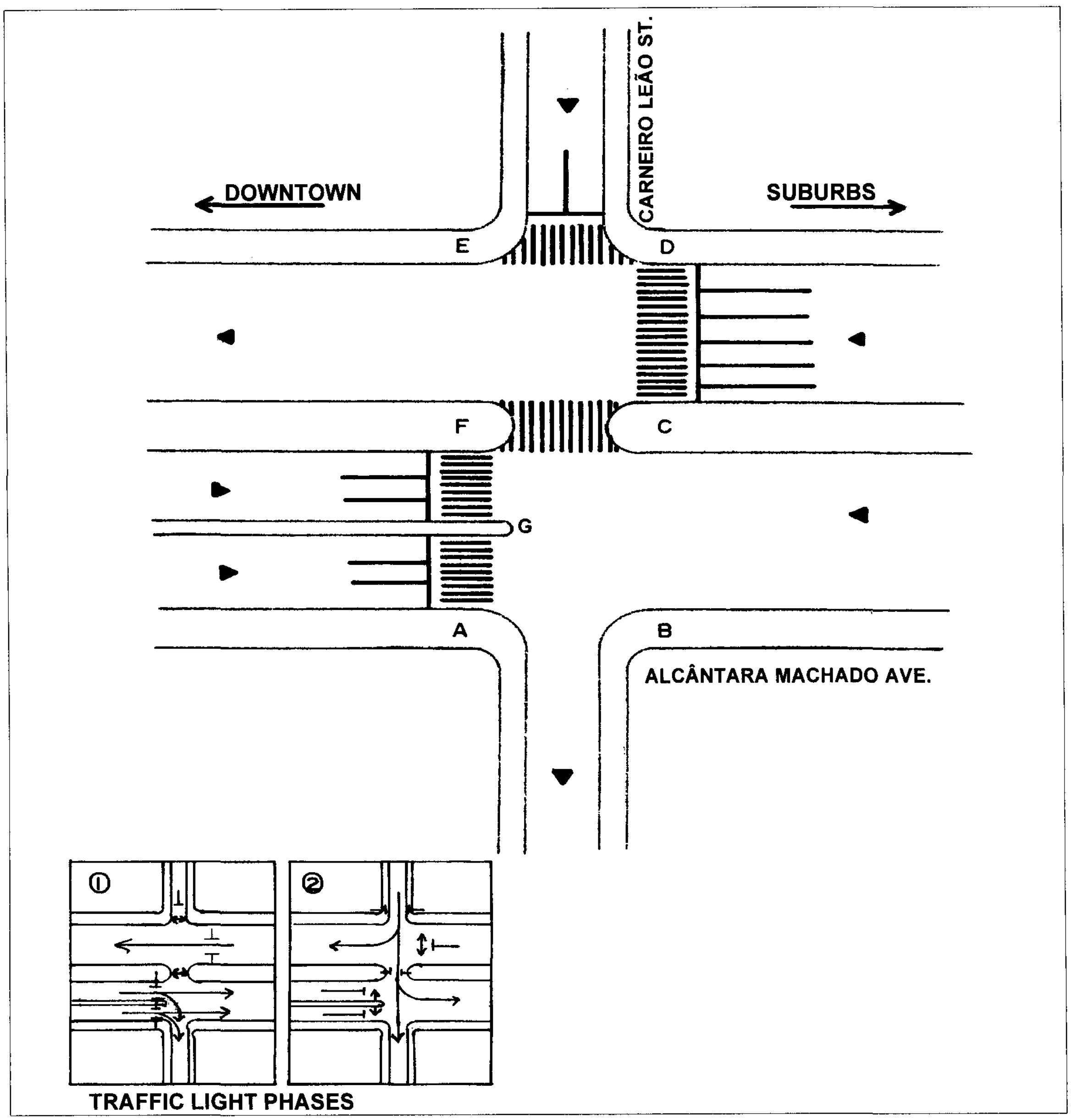
C – CONDITIONS FOR PEDESTRIANS

The traffic light program at the intersection did not include a specific pedestrian phase. Although there were many marked crossings and pedestrian traffic lights at the location, real crossing conditions for pedestrians were precarious, as described below.

Protected crossing

A *protected crossing* is a pedestrian crossing route where all vehicle flows are stopped by red traffic lights for sufficient time for pedestrians to cross at normal walking speed. The intersection had four crossings of this type (Figure 9.23): three vehicle approaches plus one along the alignment of the median strips. With the utilisation of only these crossings, the path between points A and E (with the highest demand) was composed of four crossing links (AF-FC-CD-DE), instead of the direct path AFE with only two crossing links. Completion of the four-link route took up to two complete traffic light cycles, which, in peak hours, took about nine minutes, excessive by any standard. In terms of protected crossings, point B was isolated from the rest of the intersection.

FIGURE 9.23
PROTECTED CROSSINGS IN THE ORIGINAL SITUATION
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET



Source: CET

Lack of Uniformity

- AF, FC, DC were protected crossings, with road markings and pedestrian traffic lights.
- DE was a protected crossing, with road markings, but without pedestrian traffic lights.
- AB and BC were unprotected crossings, but with road markings.
- EF was an unprotected crossing, without road markings, but with the remnants of road markings that were supposed to have been eliminated (Figure 9.24).

The result was confusing for pedestrians.

For example:

- Was EF a pedestrian crossing or not (Figure 9.25)?
- CB appeared to be, but was not, a continuation of crossing DC, which was a protected crossing with pedestrian traffic lights. Pedestrians crossing CB, in direction DB, were threatened by vehicles approaching from behind them.
- For pedestrians wishing to cross BC, in direction BD, there was no moment without potentially conflicting vehicle flows.

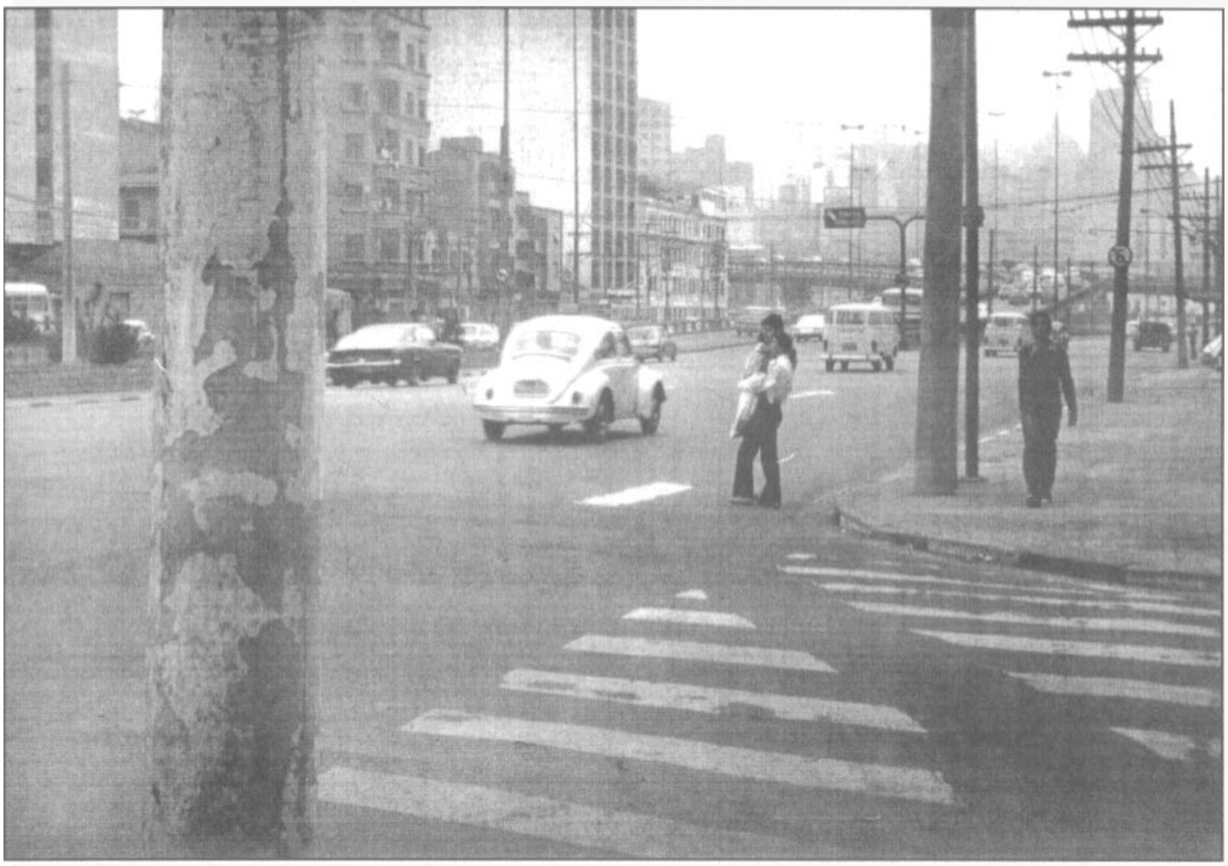
Additional problems

- Pedestrian crossing AB, on Carneiro Leão Street, was located at the beginning of a one-way section, with traffic exiting the intersection (Figure 9.26). There were no warning signs or road markings, to advise pedestrians of the one-way circulation, or of sources of potentially conflicting vehicle flows when crossing the street.
- Only 50 m away, there was a marked crossing, with pedestrian traffic lights, providing a protected crossing of the whole width of Alcântara Machado Avenue.
- Summarising: the traffic light program at the intersection did not meet the basic needs of pedestrians. The combination of road markings and the traffic light programs was very confusing and constantly put pedestrians and vehicles in conflicting situations.

D – OTHER USERS

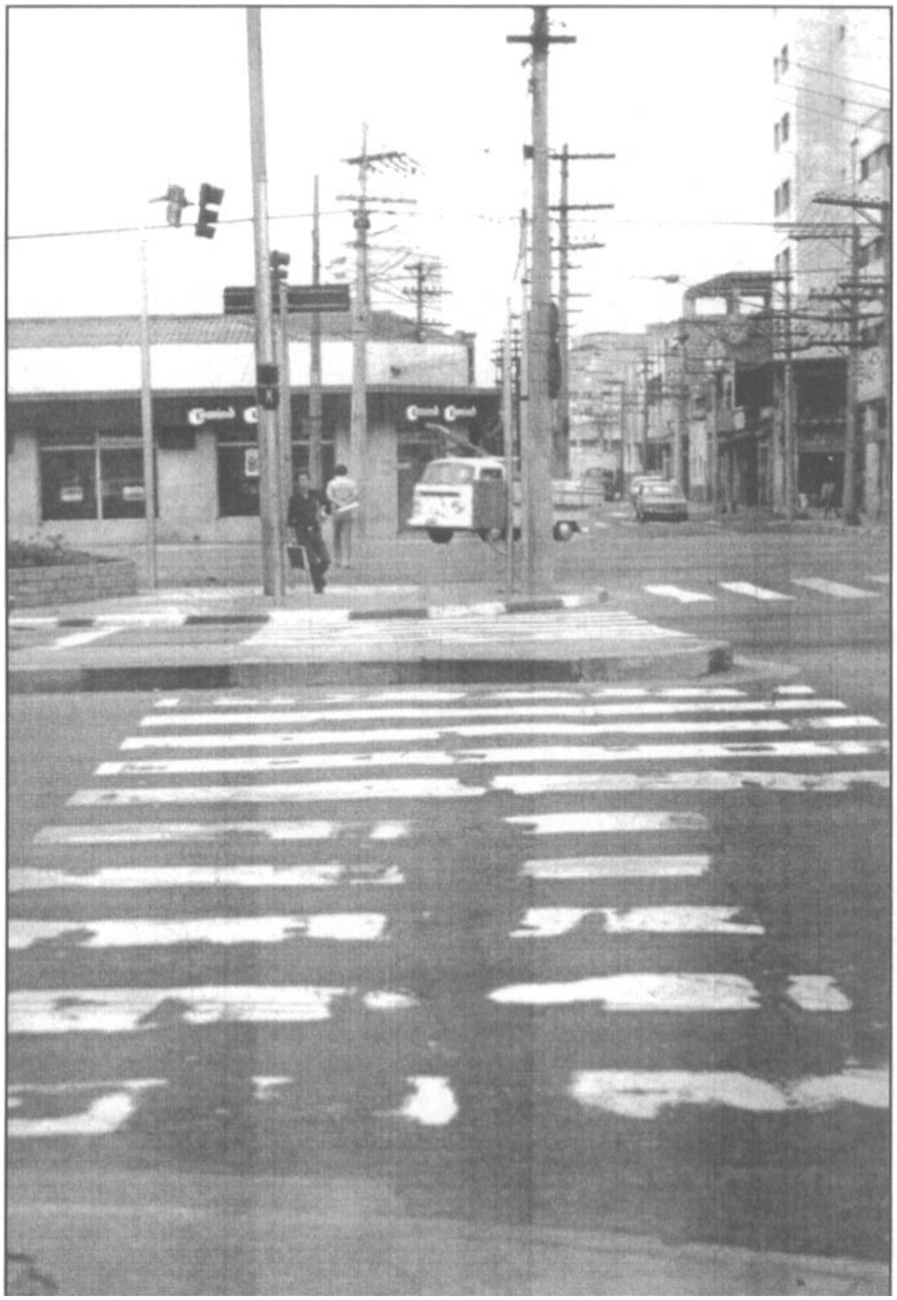
The traffic light program was inadequate for the needs of the users of hand carts, which constituted a small, but continuous, low speed vehicle flow, crossing Alcântara Machado Avenue (Figure 9.27).

FIGURE 9.24
PEDESTRIANS CROSSING AT EF,
MISLED BY REMAINS OF ROAD MARKING



Source: CET

FIGURE 9.25
PEDESTRIANS CROSSING AT EF IN DANGER OF
BEING RUN OVER BY VEHICLE TURNING RIGHT
FROM CARNEIRO LEÃO STREET



Source: CET

FIGURE 9.26
CROSSING AB. THE WOMAN ON THE RIGHT IS LOOKING THE WRONG WAY. THE WOMAN ON THE LEFT IS LOOKING BEHIND, TAKING CARE WITH RIGHT-TURNING VEHICLES

Source: CET

FIGURE 9.27
HAND CART CAUGHT IN THE MIDDLE OF THE VEHICLE FLOW

Source: CET

Proposals for Improvements

A - INCREASE VISIBILITY OF INTERSECTION FOR DRIVERS

Traffic Lights (Figure 9.28)

The following measures were suggested to make the intersection and the traffic lights more visible for drivers approaching at high speed on Alcântara Machado Avenue:

- utilisation of high intensity bulbs;
- introduction of secondary traffic lights (for reinforcement) before and after the area of the intersection, in both directions;
- utilisation of black screens around the principal traffic lights;
- introduction of secondary traffic lights (for reinforcement), at Itapira Street.

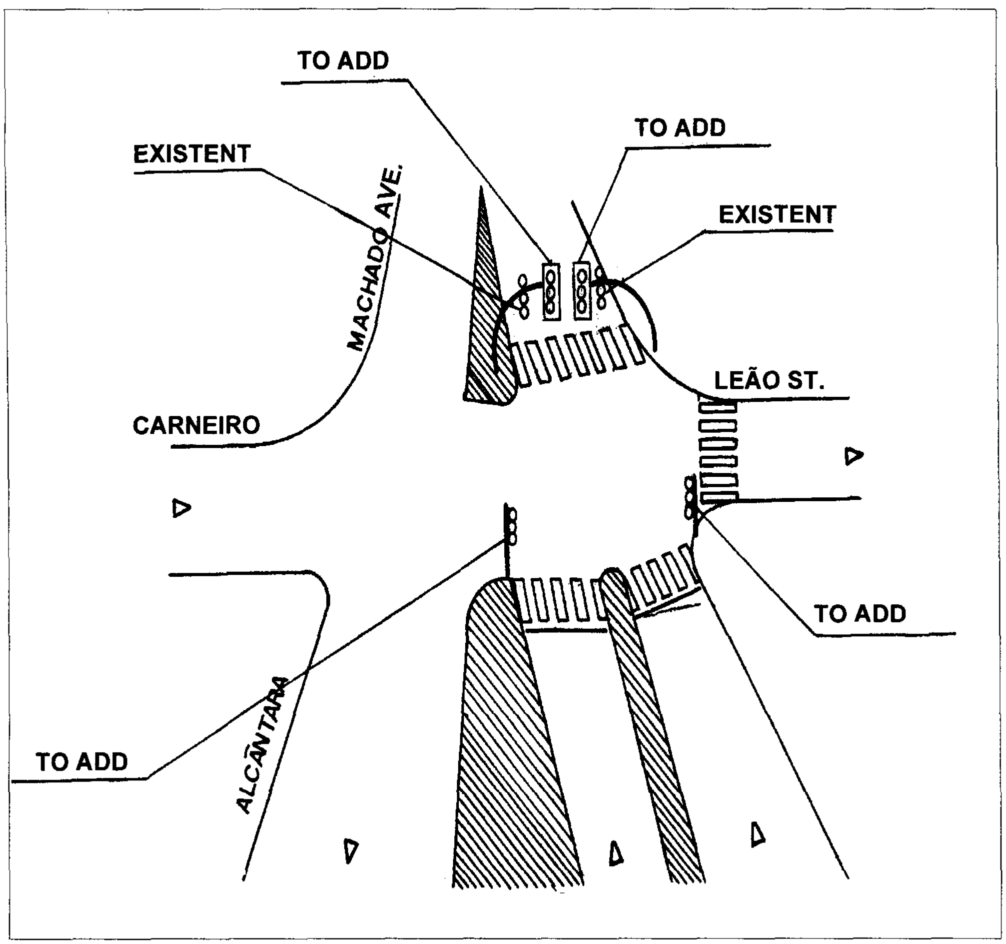
Road markings

Paint TRAFFIC LIGHTS AT X METRES, or a similar warning, along the exits of both the bridges over the Tamanduateí River, at 200 m, 100 m, and 50 m before the intersection.

Vertical signs

Introduce warning signs (for example: SLOW: DANGEROUS INTERSECTION AT 350 m (250 m and 150 m) before the intersection, on both sides of the bridge, continuation of the East-West Connection and also along the parallel approach. Introduce the same type of sign, in the suburbs-downtown direction, before Itapira Street, and between Itapira Street and Carneiro Leão Street.

FIGURE 9.28
PROPOSAL FOR TRAFFIC LIGHT IMPROVEMENTS
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET



Source: CET

B – REDUCE UNDESIRABLE DRIVER BEHAVIOUR

- Eliminate or reduce the difference between the starting times of the red phases of the traffic lights, for traffic on Alcântara Machado Avenue, at Itapira Street and Carneiro Leão Street.
- Modify the median strips, to make (prohibited) U-turns difficult and to avoid: (i) the need for drivers, arriving from the East-West Connection, to make a small change of direction (Figure 9.29); and (ii) the dangerous right turn onto Carneiro Leão Street.
- Move the newsstands to safer positions.
- Paint yellow lines parallel to the kerbs to avoid parking of vehicles near the corners, especially at Carneiro Leão Street, south.

C – VISIBILITY

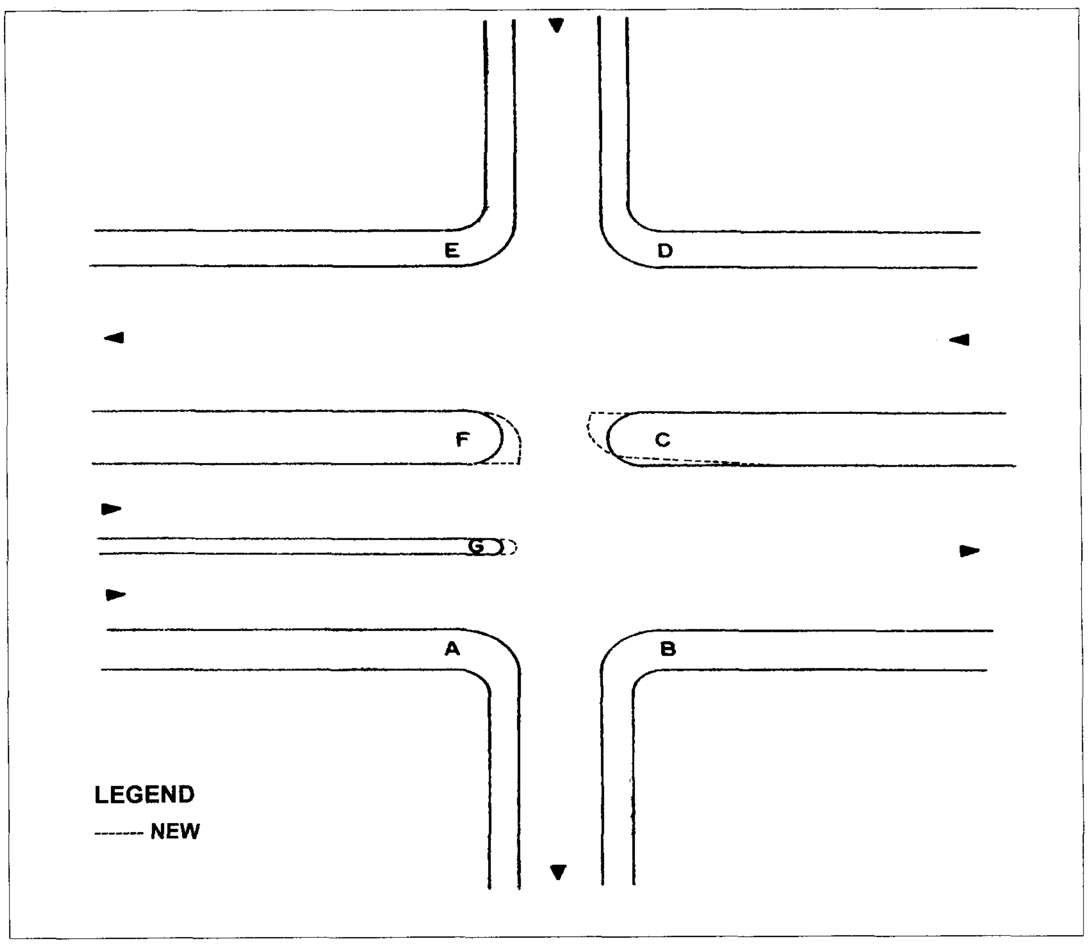
If possible:

- Remove the posts from points A and E, as they impair visibility for approaching drivers.
- Lower the flower boxes on the median strips (downtown-suburbs) and/or modify the type of vegetation.

D – PEDESTRIAN CROSSING CONDITIONS

- Pedestrian crossings should be painted only where the crossings are protected; all these protected crossings should be equipped with pedestrian traffic lights.
- Other proposals included one to interconnect all street corners and median strips at the intersection by protected pedestrian crossings with pedestrian traffic lights.

FIGURE 9.29
PROPOSED MODIFICATION: GEOMETRY
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET



Source: CET

Three alternatives were identified to achieve these objectives.

Alternative I (Figure 9.30)

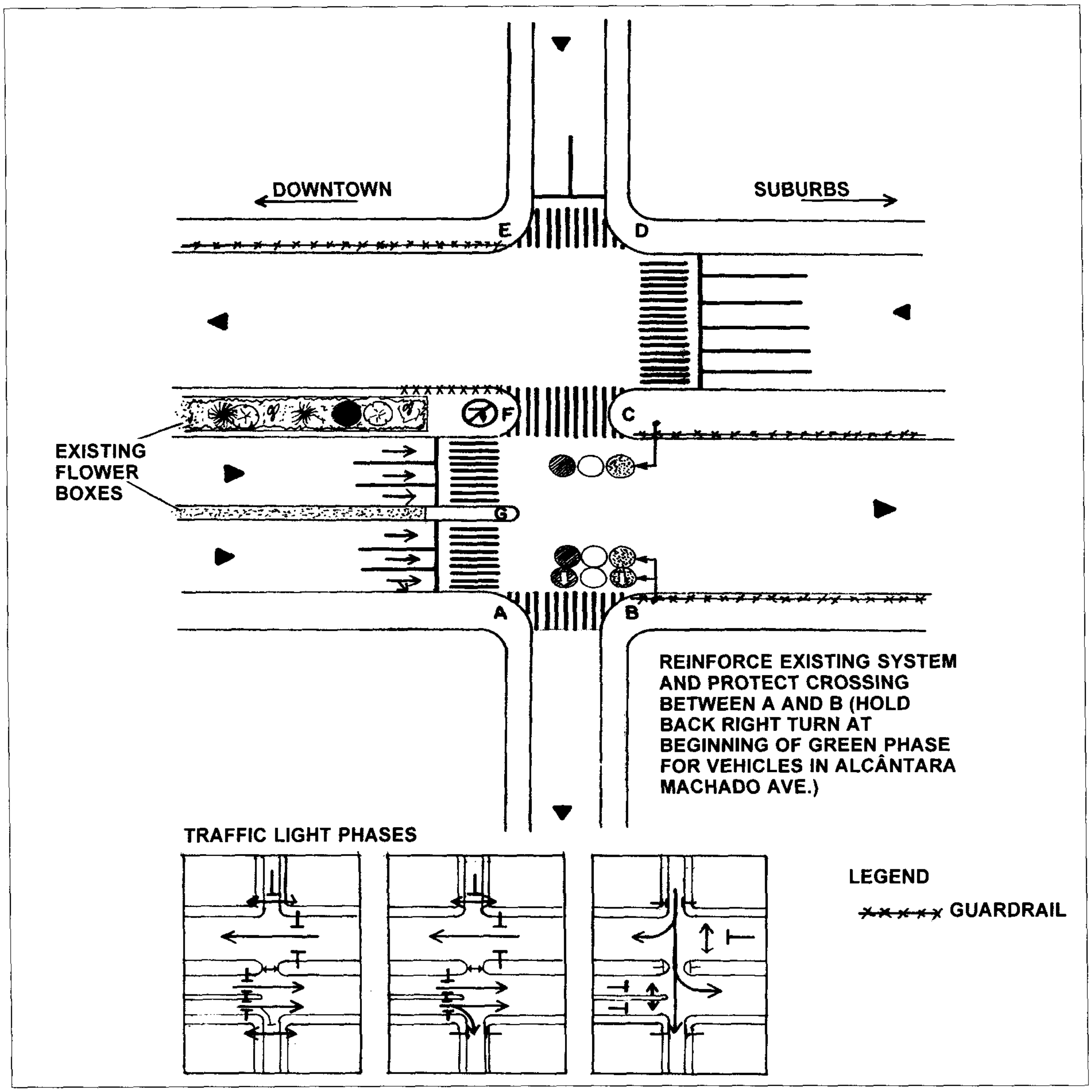
REINFORCE EXISTING SCHEME AND CREATE A PROTECTED CROSSING BETWEEN A AND B.

This alternative represents the minimum change needed to complete the protected pedestrian crossing network:

- eliminate crossing BC
- eliminate the remnants of crossing EF
- modify the program for traffic lights, holding back right turning vehicles, to leave sufficient time for pedestrians to make protected crossings AB and BA, at the start of the green phase for traffic in Alcântara Machado Avenue.
- prohibit right turns from FG (Alcântara Machado Avenue) to AB (Carneiro Leão Street); and
- introduce guardrails to avoid pedestrians crossing BC and EF.

This alternative does not solve the problem of the excessively long time sometimes spent by pedestrians crossing Alcântara Machado Avenue. It eliminates the crossing movements made along the most desired paths, which are also the most dangerous (AE and BD).

FIGURE 9.30
ALTERNATIVE I
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET



Source: CET

Alternative II (Figure 9.31)

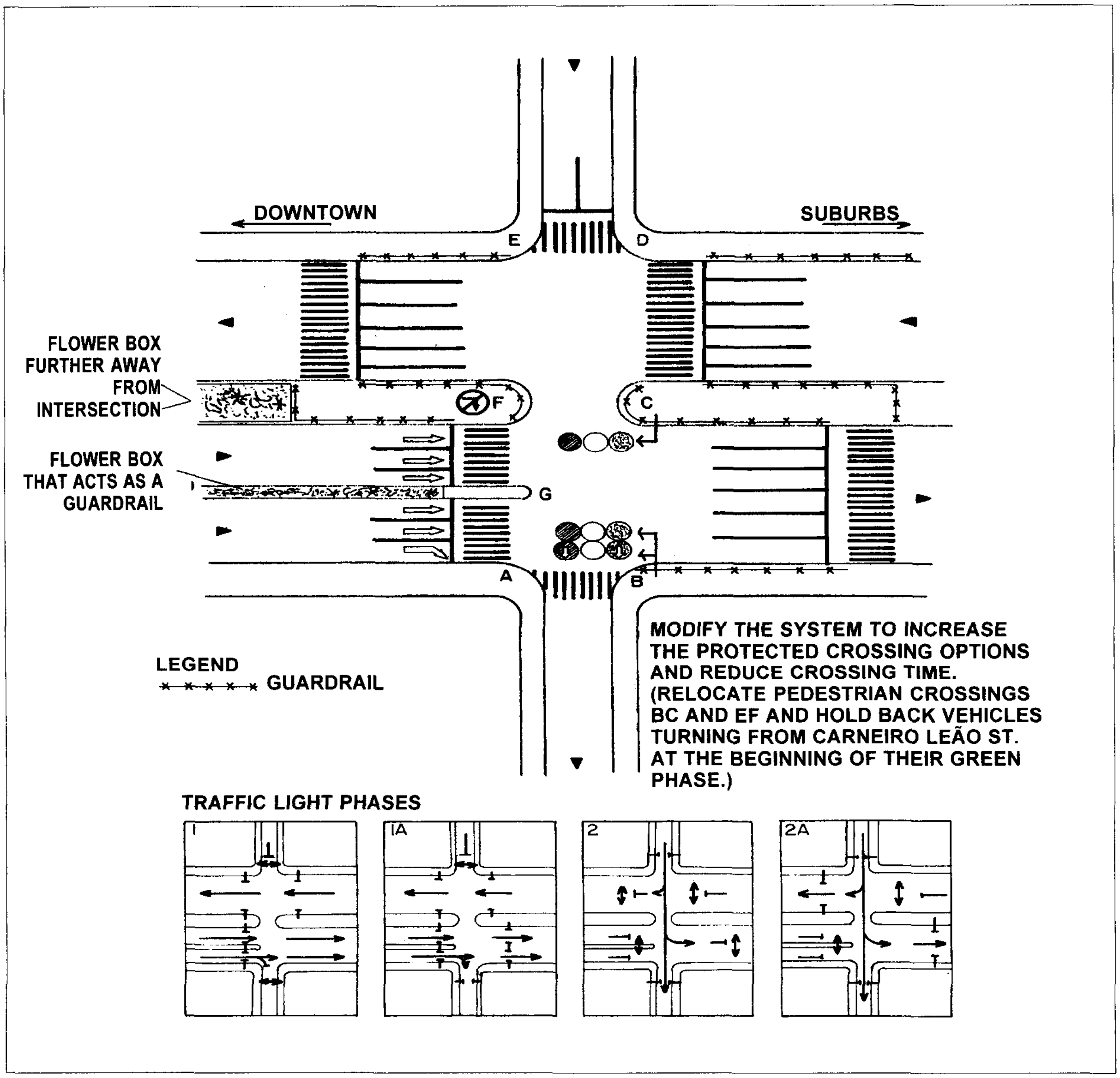
MODIFY THE EXISTING SCHEME, TO INCREASE THE OPTIONS FOR PROTECTED CROSSINGS AND TO REDUCE CROSSING TIME

This alternative increases the options for pedestrians. It moves two crossings back from the intersection, and protects crossings BC and EF at the start of the green phase for vehicles approaching from Carneiro Leão Street.

- Crossing AB has the same scheme described for Alternative I and the same prohibition of the dangerous right turn.
- New crossings BC and EF are placed back from the intersection; existing crossing BC and the remnants of old crossing EF are eliminated.
- Guardrails are used to avoid pedestrians crossing outside the marked areas; crossing FC is eliminated, as it has no function in this scheme.

Alcântara Machado Avenue could be crossed in one traffic light cycle with this alternative, and via the most desired paths, with a small deviation caused by the new location of the crossings. However, the fluidity of traffic from Carneiro Leão Street could be impaired, especially at peak hours.

FIGURE 9.31
ALTERNATIVE II
ALÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET



Source: CET

Alternative III (Figures 9.32 and 9.33)

NEW SCHEME INTEGRATED WITH ITAPIRA STREET

This alternative changes the local traffic circulation scheme to:

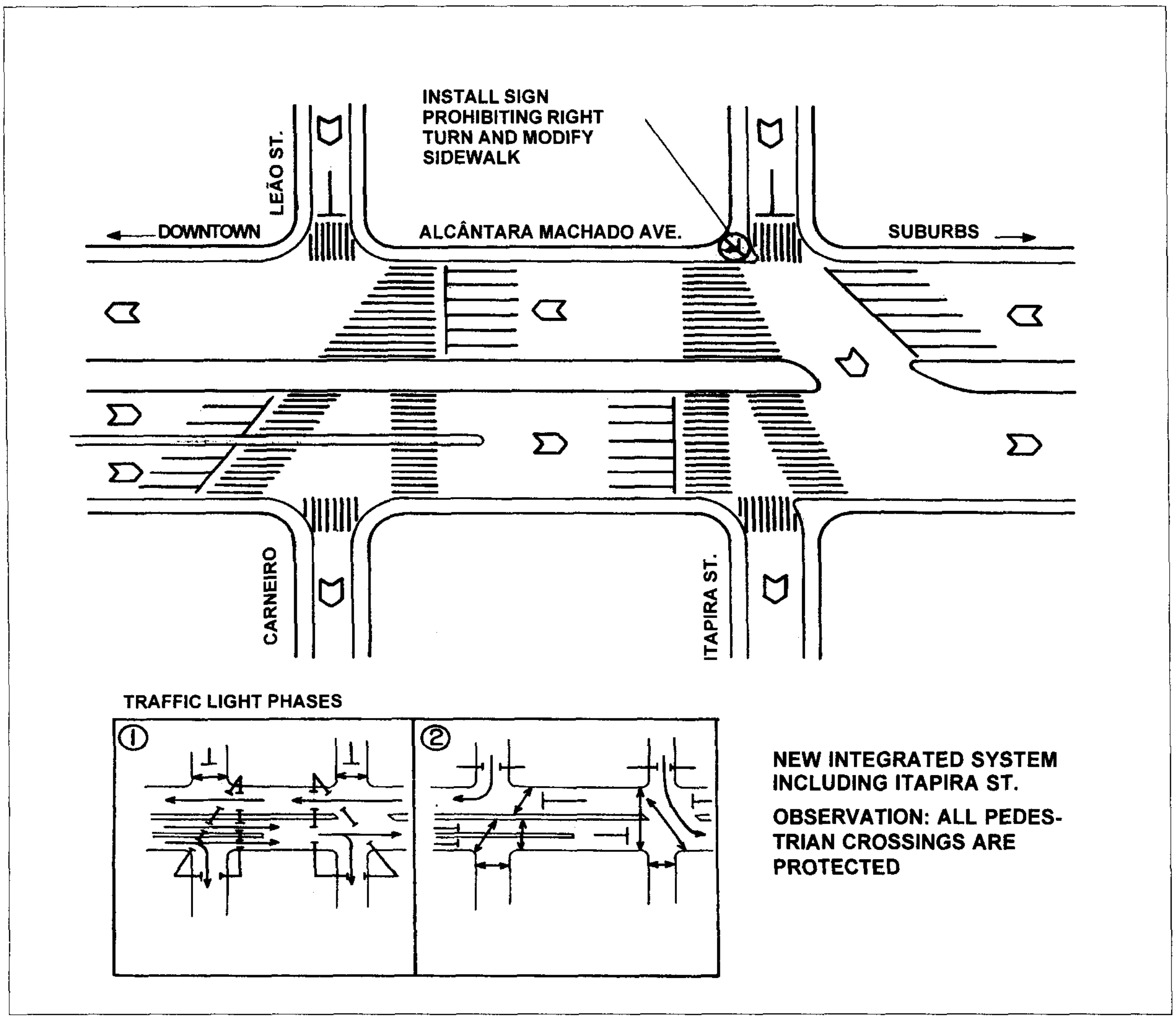
- avoid vehicular traffic crossing Alcântara Machado Avenue, just after the descent of the two bridges (downtown-suburbs direction), to reduce vehicle-vehicle accidents;
- avoid impairing traffic flow in general; and
- maintain only protected pedestrian crossings.

Summary of the scheme:

- reverse the direction of traffic on Visconde de Parnaíba Street;
- close the median strip at Carneiro Leão Street; and
- open the median strip for left turns from Itapira Street (north).
- prohibit right turns from Itapira Street (north), using signs and modifying the sidewalk;
- extend the median strip between the two parallel approaches, to eliminate the dangerous right turns from the East-West Connection to Carneiro Leão Street, and to avoid vehicle weaving movements on the pedestrian crossing, just after Carneiro Leão Street;
- modify pedestrian crossings at the two intersections;
- introduce guardrails, to avoid pedestrians crossing outside the marked areas; and
- modify the traffic lights, in accord with the needs of the scheme.

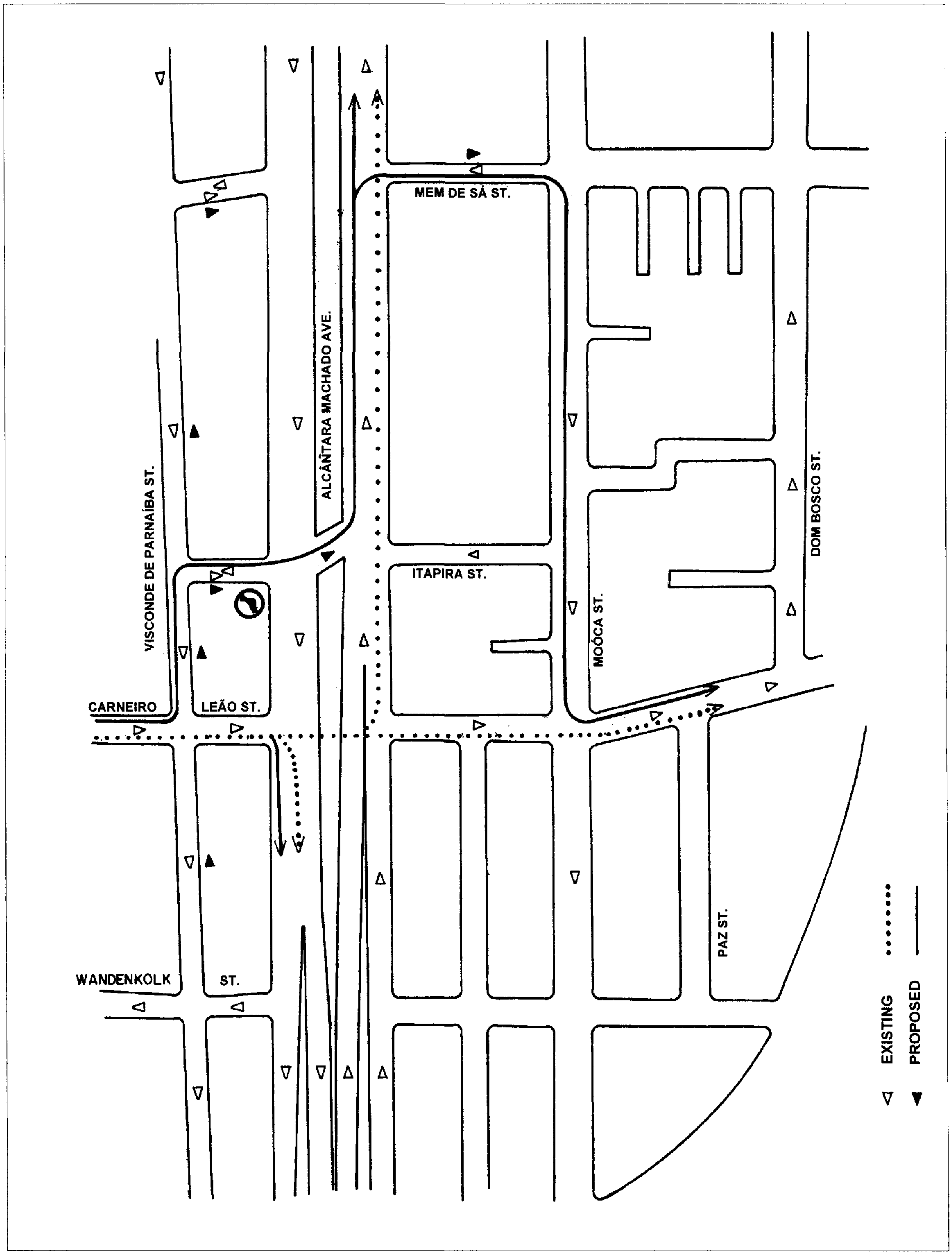
This alternative provides protected crossings for pedestrians, for all possible direct or indirect routes, without excessive delays; it also eliminates or separates conflicting vehicle movements, without modifying the traffic light cycle or impairing the flow of traffic.

FIGURE 9.32
ALTERNATIVE III
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET



Source: CET

FIGURE 9.33
ALTERNATIVE III
ALTERATION OF CIRCULATION SCHEME



Source: CET

A disadvantage is that an existing direct crossing of Alcântara Machado Avenue would be replaced by an indirect one. In compensation, at Itapira Street both north and south crossings become protected.

Alternative III is the best of the three, followed by II and, lastly, by I.

Other alternatives considered

- Moving crossing AB (Carneiro Leão Street) back from the intersection. This would not be feasible because of the entrances of the car repair workshop and the parking lot, severing the continuity of the guardrails that are required.
- Introduction of a U-turn at Figueira Street, allowing closure of the median strip at Carneiro Leão Street.
  This would be difficult or impossible, due to: (i) the low height of the bridge at this point; and (ii) the difficulty of weaving movements involving u-turning vehicles and those approaching at high-speed from the Exterior Avenue bridge (see Figure 9.5).
- Construction of a pedestrian footbridge over Alcântara Machado Avenue.
  This would be a partial solution, because the preferred routes for pedestrians crossing Alcântara Machado Avenue, at Carneiro Leão Street and at Itapira Street, were different and non-converging.

E – RECOMMENDATIONS MADE AT THE TIME OF THE STUDY

- The study recommended implementation of Alternative III, to reduce vehicle-vehicle and vehicle-pedestrian accidents and to improve crossing conditions for pedestrians without impairing traffic flow.
- Independently of whether this alternative was implemented or not, the study also recommended corrective measures to improve driver visibility and perception of the intersection, to alter undesirable driver behaviour and to improve driver-pedestrian visibility.

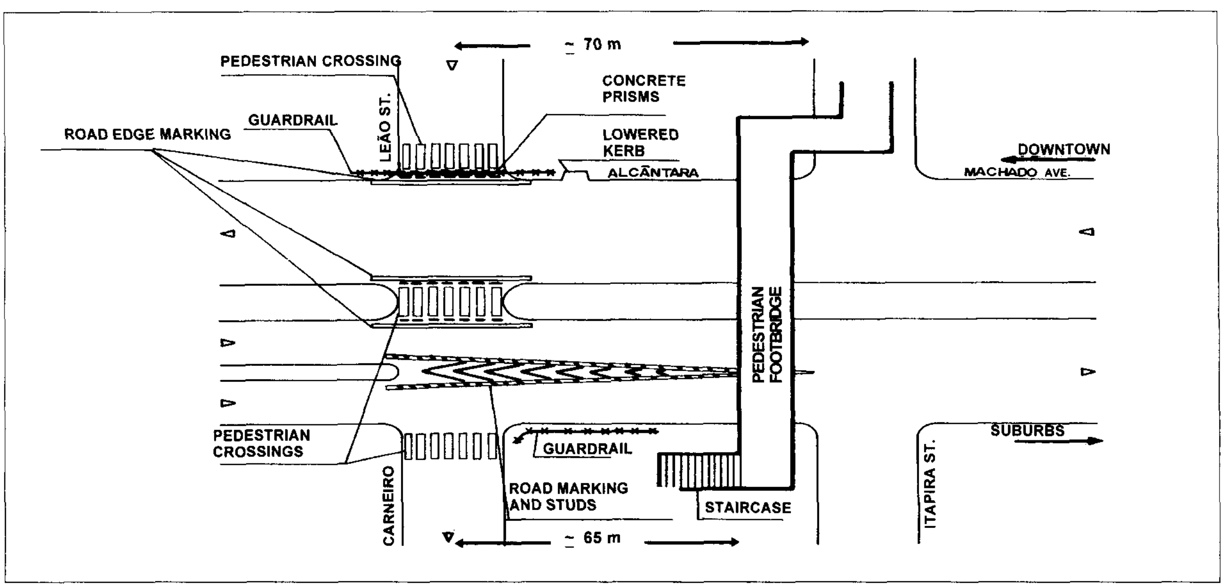
F – MODIFICATIONS EVENTUALLY CARRIED OUT

The study was undertaken in the early 1980s. No modifications were made since the decision-makers did not go ahead with proposed project (Alternative III). Some years later, in 1985, a pedestrian footbridge was constructed over Alcântara Machado Avenue at Itapira Street, eliminating the existing pedestrian crossing and traffic lights at this location. Later yet, the project shown in Figure 9.34 was implemented at the intersection with Carneiro Leão Street.

This project consisted of the following modifications:

- elimination of the intersection of Alcântara Machado Avenue with Carneiro Leão Street, by closing the median strip with concrete prisms, without eliminating the road markings of the existing pedestrian crossing parallel to the median strip, but adding the painting of a carriageway border line;
- closure of Carneiro Leão Street, north side, with concrete prisms, double metal chain guardrails and border line;
- elimination of all traffic lights;
- elimination of marked pedestrian crossings on Alcântara Machado Avenue;
- introduction of a painted triangle, reinforced with large studs, to avoid prohibited vehicle movements;
- introduction of a double metal chain guardrail on Alcântara Machado Avenue, between Carneiro Leão Street, south side, and the pedestrian footbridge; and
- alterations in the circulation scheme in the area influenced by the intersection, to create alternative routes for the vehicle movements eliminated by the project.

FIGURE 9.34
ALTERATIONS MADE AT THE LOCATION



Source: CET

Impact of the Alterations

To illustrate the impact of the implemented project, accident indices for 1979 (before implementation) were compared with those of 1986 (after implementation). See Table 9.8.

Before examining the results, some observations are necessary:

- between 1979 and 1986, the police changed their policy on the registration of property damage only accidents, greatly decreasing their registration; consequently the apparent reduction of 79% is probably fictitious. There was no corresponding change in criteria for registering personal injury accidents (pedestrian and non-pedestrian), so the data for both years should be reliable;
- it was not possible to analyse the possible effects of transfer of accidents to other locations, due to the rerouting of vehicles caused by the project. Vehicles may have been rerouted to less problematical intersections, but it is possible that, at these locations, accidents may have increased, after project implementation.

The project drastically reduced personal injury (non-pedestrian) accidents (62%). This was a direct consequence of the elimination of orthogonal conflicting vehicle flows and traffic lights with phase differences. However, pedestrian accidents at Carneiro Leão Street were not reduced (9 per year). Considering the elimination of all marked pedestrian crossings in Alcântara Machado Avenue, the project assumed that all pedestrians would use the footbridge. However, this footbridge was located about 65 m from Carneiro Leão Street, far removed from the desired path of pedestrians crossing at this street. The result, observed during site inspections, was that these pedestrians continued crossing Alcântara Machado Avenue at the intersection, in extremely dangerous conditions, as there were no traffic lights.

On the other hand, almost all pedestrians crossing the Avenue at Itapira Street were using the footbridge, even though there was no physical barrier to keep them from crossing the road under the footbridge. At that point pedestrian accidents were virtually eliminated, even though, before construction of the footbridge, the frequency of pedestrian accidents there had been similar to that at the intersection with Carneiro Leão Street. This success occurred, even though elements normally considered as essential for this type of situation were not systematically introduced, such as guardrails and warning signs or educational signs for pedestrians.

Effectiveness of the Solution

The implemented project diminished the problems with vehicle movements, but pedestrian crossing movements were not adequately treated:

- the location of the footbridge did not correspond to the path desired by the pedestrians, even though it solved the crossing problem at the location where it was built; and
- the actions needed to keep pedestrians from crossing at Carneiro Leão Street were not taken.

No vehicle and pedestrian counts were carried out in 1979 and 1986, before or after project implementation. With the pedestrian accident frequency unaltered, we do not know if the project diminished or increased the accident risks for pedestrians (in the cases of more or less pedestrians crossing, respectively), or if it diminished or increased the risk of driver involvement in pedestrian accidents (in the cases of increased or reduced vehicle flows). The existence of these doubts emphasises the importance of carrying out traffic counts.

Comments

Alternative III could have been implemented immediately. It was technically superior to alternatives I and II, and all had similar low costs. It covered driver and pedestrian safety, obliging drivers to wait during the seconds necessary for the protected crossing of pedestrians.

The alterations carried out demonstrate the failures of the traffic engineering courses being given at the time, which were giving priority only to vehicular traffic. The solution eliminated the intersection, the traffic lights, and the crossing routes used by pedestrians, obliging them to walk an extra 135 m and to climb a lengthy staircase to safely reach their destinations. Some may argue that the vehicle flows were more important at this location, but that would not justify the absence of physical measures to prevent pedestrians continuing to cross at their preferred location, which was made even more dangerous by the project implemented.

TABLE 9.1
SUMMARY OF ACCIDENTS (STICK DIAGRAM)

LOCATION: MAMORÉ ST. x NEWTON PRADO ST.

Implementation Date: 01/23/79
Monitoring Period: 07/22/78 to 07/23/79

Before: accidents 1–12 | After: accidents 13–15

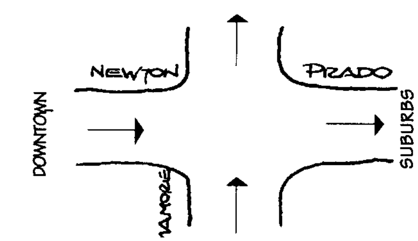
ACCIDENT NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15			
DATE	8/23	9/10	9/22	10/10	10/12	10/26	11/9	11/10	11/16	11/24	12/7	12/18	3/24	4/24	6/26			
DAY OF WEEK	WED	SUN	FRI	TUE	THU	THU	FRI	THU	FRI	THU	FRI	MON	SAT	TUE	TUE			
TIME	7:10 - am	12:45 pm	03:40 pm	05:30 pm	09:50 am	01:13 am	12:15 pm	04:40 pm	05:30 pm	10:50 pm	03:30 pm	07:30 pm	01:54 pm	01:20 pm	11:11 pm			
ACCIDENT TYPE	DO	DO	DO	DO	PI	PI	DO	DO	DO	DO	DO	DO	DO	DO	DO			
ROAD SURFACE CONDITION* WET/DRY	-	-	Dry	-	Dry	-	-	Dry	-	-	Wet	Dry	-	Dry	Dry			
ILUMINATION DAY/NIGHT	D	D	D	D	D	D	D	D	D	N	D	N	D	D	D			
ACCIDENT DIAGRAM*	-	-		-		-	-		-	-			-					

N° of accidents before and after implementation								
6 MONTHS BEFORE				6 MONTHS AFTER				Reduction %
DO	PI	PE	Total	DO	PI	PE	Total	
10	2	-	12	3	-	-	3	75%

MOST FREQUENT ACCIDENT TYPE

FOR ACCIDENTS WITH DIAGRAMS: RIGHT-ANGLE COLLISIONS. FOR ACCIDENTS WITHOUT DIAGRAMS, FRONT-TO-REAR COLLISIONS ARE ALSO LIKELY.

Sketch of location



Source: CET

* The police reports were not located in the cases of accidents with missing data. The only information was a form filled out by the telephone operator on duty.

DO- Property damage only
PI-Personal injury
PE-Pedestrian accident

D- Day
N- Night

TABLE 9.2
MAMORÉ STREET x NEWTON PRADO STREET
MONTHLY ACCIDENT FREQUENCY BEFORE
PROJECT IMPLEMENTATION

MONTH	NUMBER OF ACCIDENTS
July	–
August	1
September	2
October	3
November	4
December	2
TOTAL	**12**

Source: CET

TABLE 9.3
ACCIDENT DISTRIBUTION BY HOUR OF DAY AND DAY OF WEEK
BEFORE PROJECT IMPLEMENTATION
MAMORÉ STREET X NEWTON PRADO STREET

TIME / DAY OF WEEK	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	TOTAL
MON													○				1
TUE											○						1
WED	○																1
THU			●			○	●		○		○						5
FRI									○	○						○	3
SAT																	-
SUN						○											1
TOTAL	1	-	1	-	-	2	1	-	2	1	2	-	1	-	-	1	12

○ - PROPERTY DAMAGE ONLY
● - PERSONAL INJURY

Source: CET

TABLE 9.4

ACCIDENT DISTRIBUTION BY HOUR OF DAY AND DAY OF WEEK
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET

DAY OF WEEK \ TIME	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	TOTAL	PI	PE
MON	⬮●							●			⬮	●●	●●●	⬮●	⬮	●●	● △	●●	●●●●	●●	⬮●	⬮			27	6	1
TUE							⬮		●●●●● △	⬮●	●●	●●●	⬮●	●	⬮●●●	●●●	●● △	●●●●	●	●●●		⬮		●	37	5	2
WED	●						⬮ △	● △	⬮	●●	●	●●●●	⬮ △		⬮● △	●					△		●		21	4	5
THU										⬮		●	●●	●	●●	●●	●	●●	●●	●	●				16	1	
FRI		●					●	●	●		●●	⬮●●●	●	⬮	⬮⬮	●		●	●●	●			⬮●	●	22	5	
SAT	⬮ △				●			⬮●			⬮●	⬮● △		⬮●●●	●●●●		●	●●	⬮●●		●	⬮	●	●● △	30	7	3
SUN	⬮●	●●				●		⬮						⬮●●	●●●	⬮●●		⬮●●●●		●●	△				23	5	1
TOTAL	7	3			1	1	4	7	8	5	8	17	10	12	19	12	7	16	12	9	6	3	4	5	176		
PI	3						2	2	2	2	1	2	2	4	5	1		1	1		1	3	1			33	
PE	1						1	1	1			1	1		1		2				2			1			12

LEGEND: PROPERTY DAMAGE ONLY ● NON-PEDESTRIAN PERSONAL INJURY (PI) ⬮ PEDESTRIAN ACCIDENT (PE) △

Source: CET

TABLE 9.5
REGISTERED ACCIDENTS
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET

Situation	ACCIDENT TYPE			
	NON-PEDESTRIAN INJURY	PROPERTY DAMAGE ONLY	PEDESTRIAN	**TOTAL**
w/PR, w/AD	18	70	3	91 (52%)
w/PR, n/AD	4	17	6	27 (15%)
n/PR	11	44	3	58 (33%)
TOTAL	33	131	12	176 (100%)

Source: CET

Note:

w/ – with　　PR – Police Report
n/ – not available　　AD – Accident Diagram

TABLE 9.8
ACCIDENTS BEFORE AND AFTER PROJECT IMPLEMENTATION
ALCÂNTARA MACHADO AVENUE x CARNEIRO LEÃO STREET

ACCIDENT TYPE	1979	1986	REDUCTION
DO	106	22	79%*
PI	21	8	62%
PE	9	9	0%
TOTAL	**136**	**39**	**71%**

Source: CET

* Probably over-estimated

CHAPTER 10

A SURVEY OF ENGINEERING TECHNIQUES FOR REDUCING ACCIDENTS

This chapter presents many of the most utilised and effective traffic engineering techniques for reducing accidents and discusses their advantages and disadvantages. The techniques range from small, easily implementable, low-cost projects to others that require medium investments, such as the treatment of intersections with traffic lights, street markings, and vertical signs.

The choice of technique depends on the analysis and diagnosis of the causes of accidents at the location, and on the resources available to correct the problems found there. Generally, a well-designed project results in social savings considerably larger than its cost of implementation and maintenance. *The social benefit or savings* refers to all expenditure avoided as a result of accident reduction, including medical costs, vehicle repairs, police and judicial resources, and loss of production.

The evaluation of the results of projects is essential to continue improving an accident reduction program. Chapter 12 presents a methodology for the economic evaluation of these projects.

This chapter includes numerous measures to improve pedestrian safety, since pedestrians are frequently the victims of traffic accidents in Latin America and the Caribbean. These measures are doubly important for people with mobility, auditory, and visual handicaps that, in mild to severe forms, affect a substantial part of the population.[1] Proper design will benefit the general population along with the disabled.

The techniques may be enhanced by lowering kerbs at intersections (transforming them into smooth ramps, suitable for wheelchairs) and by installing sound-emitting devices in traffic lights and special paving materials on sidewalks at intersections. These devices warn pedestrians of the proximity of the end of the sidewalk and of the start of the area for vehicle circulation, an element especially important for the visually handicapped (see Rickert, 1998).

10.1 Speed Reduction

Excess speed causes many serious accidents in urban areas, especially those involving pedestrians. Some speed control devices and equipment cause discomfort for occupants of vehicles travelling at excessively high-speeds; other devices detect and identify vehicles violating the speed limits.

Transverse Rows of Studs

These are formed by reflective studs, installed in continuous kerb-to-kerb rows (see Figure 10.1).

These should be used when obstacles such as speed humps (discussed below) are inconvenient, as on steep slopes and high-speed roads. Various layouts are used, including one, two or three parallel rows, with spacings that vary from a few centimetres to dozens of metres. Closely spaced rows (gaps of around 0.70 m) are very efficient, since they act as obstacles and produce sounds and vehicle vibration.

Effective signs and/or road markings are required to warn drivers of the presence of the studs, avoiding dangerous sudden braking.

Transverse stud projects implemented in São Paulo reduced ***average*** vehicle speeds from 25% to 65%, which reduced accident frequencies.

In many cases, a drastic reduction of average speed occurs during the first few days after installation of the studs, followed by a gradual increase of speeds, as the drivers become accustomed to them. Even so, the new average speed remains lower than before installation.

However, the studs did not reduce ***maximum*** vehicle speeds; in fact, maximum speeds increased in a few cases. Thus, studs should not be used in situations where, for example, unaccompanied small children cross the road.

The problems occur because studs cause less discomfort when crossed at higher than average speeds, especially when single rows are used, so that some drivers prefer to cross at higher speeds. This can be dangerous to both motorists and pedestrians, as some drivers brake when arriving at the studs, while some of those following them try to pass at high-speed.

Drivers, however, can pass the transverse rows of studs at high-speeds without losing control of their vehicles. This permits the use of studs on roadways to reduce speed or to warn drivers that they are nearing more substantial obstacles, such as speed humps.

The Brazilian traffic code (CTB) suggests stripes to encourage speed reduction. The stripes are painted on the road, parallel to the rows of studs, and spaced according to the operational speed of the road, as shown in Figure 10.2 (see CTB, Annex II, item 2.2).

Some precautions should be taken when installing the studs:

- Studs will loosen and/or break soon after installation if they are inadequately affixed to the pavement or made of material of inferior quality (Figure 10.3). The studs should be continuously maintained, with rapid replacement of loose or broken ones. If not, spaces appear and permit vehicle wheels to pass freely between the remaining fixed ones, eliminating the desired effect of driver and passenger discomfort. Double rows, with only a small space between them, can minimise this problem: when a stud in one row loosens or breaks, there is still another one in the same wheel track to maintain the speed-reducing effect.
- When roads are to be repaved, existing studs should be removed and replaced afterwards. Although many studs are broken when removed, this avoids burying studs under the new asphalt and reducing its durability.

FIGURE 10.1
EXAMPLE OF ROWS OF STUDS

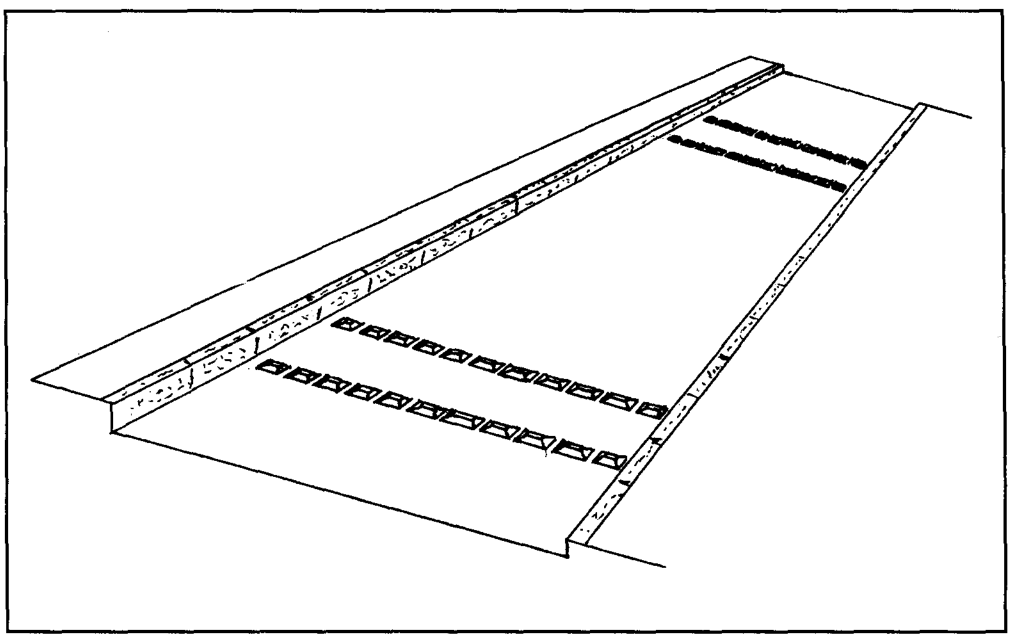


FIGURE 10.2
TRANSVERSE LINES TO ENCOURAGE SPEED REDUCTION

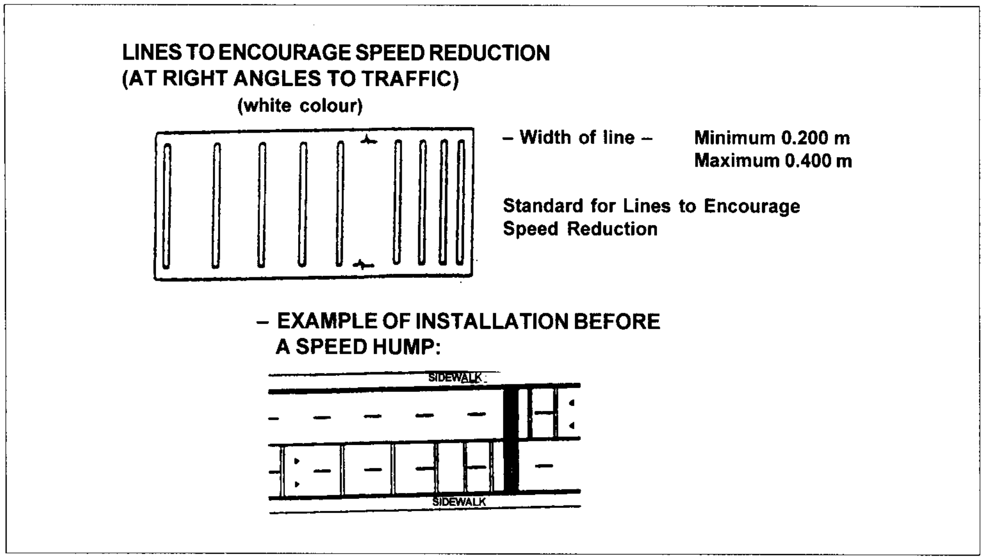


FIGURE 10.3
EXAMPLE OF LOCATION WITH STUDS DAMAGED OR WRENCHED OUT BY VEHICLES
SAPOPEMBA AVENUE – SÃO PAULO

Transverse stud obstacles have the disadvantage of transmitting noise and vibration beyond the drivers and vehicles that pass over them. They should be avoided in populated areas, since nearby residents may complain or petition for their removal.

Speed Humps

Speed humps are very effective speed reduction devices when built with an adequate cross section and installed with warning signs. Unlike the transverse rows of studs, speed humps reduce both average and maximum speeds. Since discomfort increases with speed, virtually all high vehicle speeds disappear immediately after installation of the humps.

Speed humps are normally restricted to local roads where low speeds are desired, but they are occasionally also used on important roads and avenues, on routes with heavy goods vehicles, and even in the interior of bus terminals.

Their installation usually increases safety, reducing accident frequencies and severity.

In all cases, effective warning signs and signals are necessary (see Annex II). On high-speed roads, the installation of studs or other types of rumble strips is essential to warn drivers of the speed humps ahead. This avoids both vehicle damage and loss of control by the driver, which could cause accidents. Rumble strips are normally made of rounded asphalt or concrete strips that rise about 1.25 cm above the rest of the pavement. They can also be used on shoulders to reduce fall-asleep accidents on intercity highways where drivers go off the road and hit trees or other obstacles. Rumble slots are used in lieu of strips on the shoulders of the New York Thruway and Pennsylvania Turnpikes, since the strips interfere with snowplow operations. The slots are ground into the shoulders and are credited with reducing fall-asleep accidents from 56% to 100% on the sections where they have been used (*Toll Road Newsletter* 4, June 1996, p.7-8).

When speed humps were first installed in a section of the Campo Limpo Road, a mixed local distributor and through traffic route in São Paulo, flashing yellow lights were installed, together with a warning sign SPEED HUMPS DURING THE NEXT 1,000 m, placed in a very visible position, alerting drivers of the proximity of the speed humps. On urban sections of the Cuiabá-Porto Velho Highway, warning signs and studs were also used very successfully (GEIPOT, 1987, p. 42-43).

The Brazilian CTB specifies two types of speed humps. Type I reduces average speeds to approximately 10 or 20 km/h, with maximum speeds of around 30 km/h. Type II produces average speeds between 20 and 25 km/h and maximum speeds of around 45 km/h. The use of Type I humps should be limited to local roads. On all others, the more expensive Type II should be used because they cause less discomfort to drivers and passengers. (See Appendix II for the technical specifications.) Strict use of the standardised cross sections is required to avoid making the humps dangerous or excessively uncomfortable at the design speeds. Non-standard obstacles can damage vehicles and cause accidents.

On Adelvira de Toledo Street, in São Paulo, transverse rows of studs were installed, and later replaced by speed humps, in the same positions. Average speed decreased from 40 km/h to 26 km/h with the studs and to 19 km/h with the humps. The maximum speed, previously over 100 km/h, continued the same with the studs, but fell to 50 km/h with the humps, and this speed was registered only in exceptional cases.

Precautions should be taken when installing speed humps:

- Place warning signs in very visible positions, positioned directly in front of the drivers' line of vision and at least 50 m before the humps.
- The warning signs should be installed before the humps. On a São Paulo street, a hump was installed without warning signs, resulting in a fatal accident when a driver lost control of his vehicle upon crossing the hump at high-speed.
- Humps should be painted with highly visible road markings, with diagonal yellow stripes, maximizing the contrast with the rest of the road surface. Special care should be taken to paint or otherwise differentiate the colour of humps built of material having the same colour as the general road surface.
- Some types of road markings require regular maintenance, since abrasion by vehicles quickly wears them away.
- Special illumination of speed humps is recommended, such as directional spotlights that highlight their presence at night (see sub-item 10.7). In Curitiba, Brazil, speed humps preceded by transverse rows of small reflective studs were successfully installed, greatly improving visibility.
- Speed humps are subjected to abrasion and shearing forces. Therefore, they should be built of compacted concrete asphalt or concrete cement with a high coefficient of resistance.
- Humps should not be built right up to the kerbs, as this will block drainage of rainwater. Space should be left for water to flow, but it should not be wide enough to allow a wheel to pass, as this would encourage some drivers to partially avoid the obstacle by passing so close to the kerb that they would put pedestrians at risk. This problem may be avoided by bridging the space between the hump and the kerb with a metal grill, leaving a channel for water (Figure 10.4).
- The distance between successive humps should be 50 m to 100 m when possible. This spacing allows vehicles to pass easily through the road section, without attaining excess speed.

In São Paulo city, during the 1980s, residents were allowed to install speed humps as long as the traffic authority (*Departamento do Sistema Viário* – DSV) defined the precise location, the signs, signals, and road markings, and checked the construction characteristics.[2]

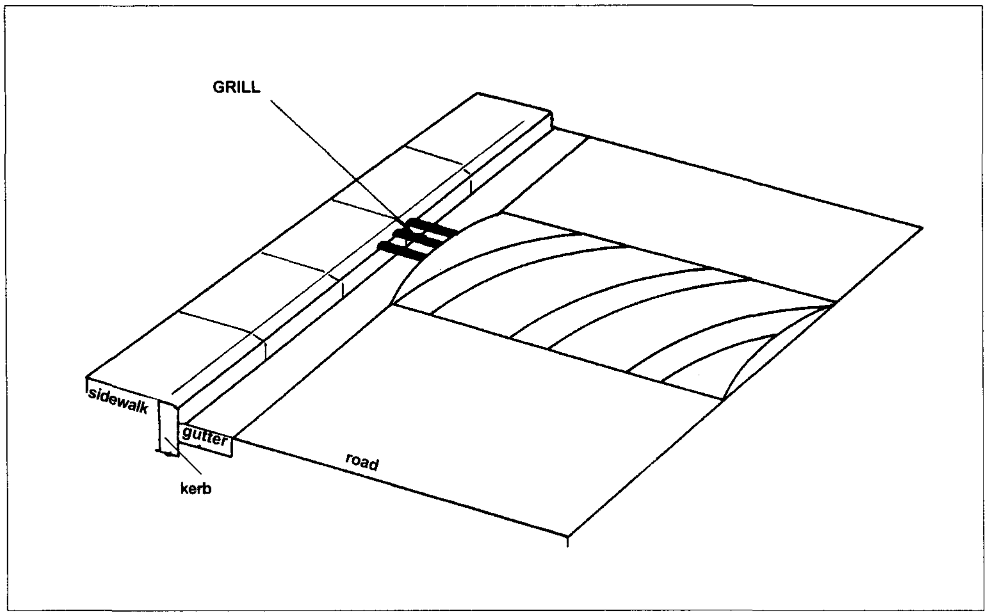
Electronic Speed Hump

This device is being used in certain situations in Brazil to avoid or replace the conventional, physical speed humps described in the previous subitem. Vehicle detector tubes or wires embedded in the road surface are connected to electronic equipment and measure the speed of each approaching vehicle. A display mounted on a totem shows the driver the maximum permitted speed and the measured speed of his or her vehicle. When a driver passes at a speed higher than the predetermined limit (the maximum permitted speed, or this maximum plus a small margin), a camera, also mounted in the column, takes a photograph of the vehicle, permitting its identification, the registration of the violation, and the emission of a fine.

The electronic speed hump has the advantages over the physical speed hump of:

- allowing the traffic authority to fix any maximum speed;
- permitting alteration of the maximum permitted speed, when necessary;
- avoiding interference with the movement of emergency vehicles; and
- being self-financing with the fines.

FIGURE 10.4
SPEED HUMP WITH EXTENSION TO KERB



The principal disadvantages are:

- the speed-reducing effect is limited to the areas immediately before and after the device;
- some high vehicle speeds may still occur; and
- higher maintenance costs, especially of the electrical and electronic parts.

Radar with Photography

These devices are being installed in a number of countries, including the United States and Brazil. Several Brazilian cities have had excellent results in decreasing accidents with them. They consist of small cameras mounted on posts by the roadside where they are almost invisible to drivers. They have protective shields, and are coupled to automatic speed-measuring equipment. Several of these cameras are installed along a section of highway or urban road, to control vehicle speeds along the whole stretch. In contrast to the electronic speed hump, designed to maximise its visibility, the exact location of the cameras should be hidden from drivers, obliging them to drive below the speed limit throughout the whole stretch. The license plates of violating vehicles are photographed.

Drivers that discover the locations of the cameras can accelerate on the intermediate sections. This can be avoided by installing more protective shields than cameras and randomly alternating the cameras between the shields, forcing drivers to obey the speed limits along the entire stretch.

Speed Control Channels

Transverse or diagonal channels serve as inverted speed humps and produce similar effects, reducing both average and maximum speeds. Few if any countries have traffic design standards for these channels. They tend to have dimensions similar to those of drainage channels and are often designed for this function, with speed control being an unintended benefit. In São Paulo, channels with widths of 2.1 m and depths of 0.08 m were tested. Drivers may accept channels more willingly than speed humps, seeing them as a drainage system for rainwater rather than a speed-reduction device. Channels may be built at street corners to reduce speeds at intersections.

Both transverse and diagonal channels were tested simultaneously in different sections of Nina Stocco Street, an arterial road on the outskirts of São Paulo. The transverse channel reduced the average speed from 43 to 22 km/h, and the maximum speed from 90 to 45 km/h. The diagonal channel was less effective, reducing average speed from 48 to 28 km/h and maximum speed from 90 to 64 km/h.

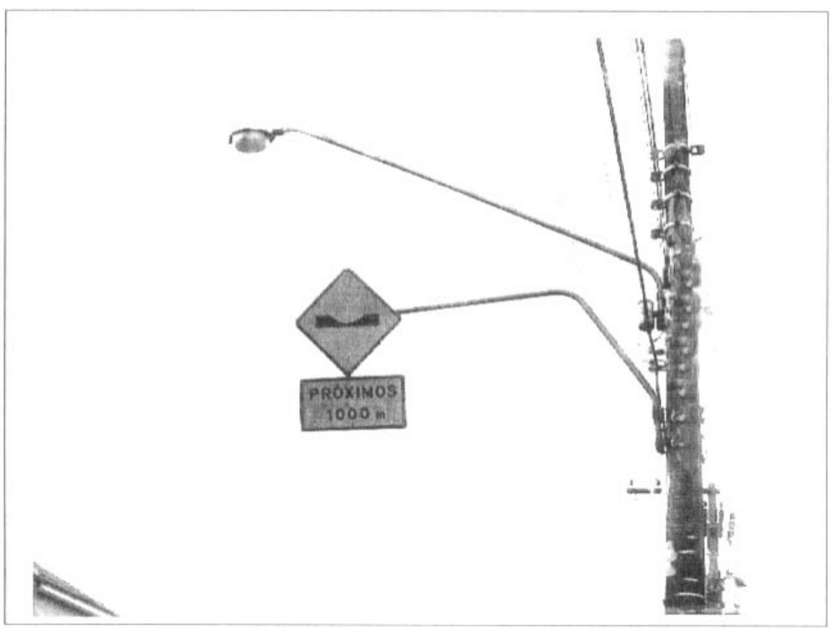
The channel is less effective at reducing speeds than the physical hump, and is less damaging to vehicles that eventually pass at high-speed. The effects of channels thus fall between physical humps and rows of studs in reducing average and maximum speeds. Channels are subject to great mechanical wear (Figure 10.5) and must be made of high resistance concrete, with a sufficiently resistant base to guarantee durability. One of the disadvantages of the channel is that its cost is four times that of a similar sized hump.

Some precautions should be taken when installing and maintaining channels:

- As with the speed hump, the channel requires efficient warning signs and signals, including special illumination at night, and signs projected over the road (Figure 10.6).

FIGURE 10.5
EXAMPLE OF CHANNEL BUILT OF CONCRETE WITH INSUFFICIENT RESISTANCE
SAPOPEMBA AVENUE – SÃO PAULO

FIGURE 10.6
SIGN MOUNTED ON PROJECTING ARM, ADVISING OF THE EXISTENCE
OF CHANNELS DURING THE NEXT 1,000 m
INCONFIDÊNCIA MINEIRA AVENUE – SÃO PAULO



- When repaving roads, these channels should not be filled in or left with excess depth.
- The channel should be self-draining to avoid the accumulation of dirt and water.

10.2 Geometric Design for Pedestrian Safety

This item presents measures for improving pedestrian safety. It features small public works, such as safety islands or refuges for pedestrians crossing the road, and special paving on streets reserved for the exclusive use of pedestrians.

Widening the Sidewalk

This measure reduces the crossing distance and time for pedestrians. It also reduces vehicle speeds by narrowing the carriageway (Figure 10.7), and improves the visibility for both drivers and pedestrians.

Sidewalks can be widened at street corners or mid-block. In commercial areas where parking is allowed, the scheme shown in Figure 10.8 improves pedestrian safety and comfort, without penalizing the flow of motorised traffic.

Based on tests in São Paulo, sidewalks should be widened in the following situations:

- at intersections with very narrow sidewalks that result in partial occupation of the carriageway by pedestrians and the attendant risk of pedestrian accidents, especially when there are traffic lights with long cycle times;
- at locations where vehicles are parked illegally on street corners (violations virtually disappear after sidewalk widening without the need for policing);
- at locations with poor visibility between drivers and pedestrians; widening reduces the effects of existing interferences on the sidewalk, as pedestrians are provided with an area free of other activities and obstacles that offers a head-on view of the vehicles (public authorities should see that these areas are kept clear of street vendors); and
- at intersections that have traffic lights but not a specific pedestrian phase, where pedestrians cross the street and vehicles make right or left turns at speeds incompatible with pedestrian safety; widening the sidewalk makes drivers reduce speed and shortens the distance of the crossing where the pedestrian is exposed to risk.

Design of sidewalk-widening projects (Figure 10.9) should include a gradual narrowing of the street. This avoids creating a frontal obstacle for vehicles approaching the intersection. Sidewalks should be widened by 2.0 m to 2.5 m, corresponding to the width of the space occupied by one parked vehicle and, consequently, maintaining the vehicle flow capacity of the roadway.

Kerbs may be moulded on-site to minimise installation cost. Concrete prisms should not be used to delineate the area, except when the widening is carried out to channel the flow of vehicles. The prisms do not transmit the effect of an extension of the sidewalk to drivers and thus fail to guarantee pedestrian safety.

FIGURE 10.7
ENLARGEMENT OF SIDEWALK AT A CORNER
SILVA BUENO STREET x COMANDANTE TAYLOR STREET– SÃO PAULO

FIGURE 10.8
WIDENING OF SIDEWALK IN A STREET WITH LARGE
PEDESTRIAN FLOWS ALONG ITS WHOLE LENGTH

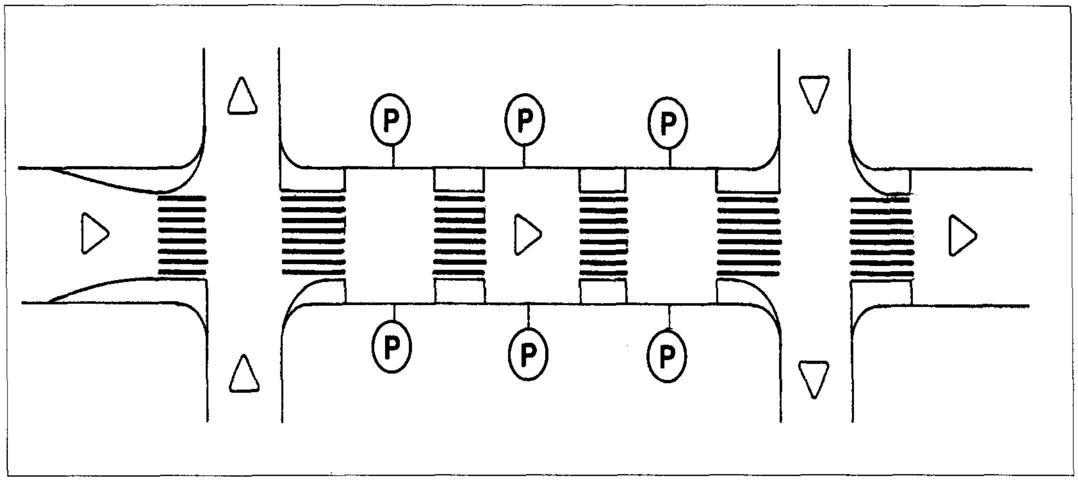


FIGURE 10.9
EXAMPLE OF GRADUAL NARROWING OF CARRIAGEWAY
SILVA BUENO STREET x COMANDANTE TAYLOR STREET – SÃO PAULO

Refuges (Safety Islands)

Pedestrians can cross a street in two stages with lower risk if they have the use of islands, or pairs of islands, in the middle of the roadway (Figure 10.10).

Islands are recommended for two-way streets of 12.0 m width or more, at locations where many pedestrians cross the road, such as schools, hospitals, supermarkets, bus stops, and road junctions. When crossing these streets before the installation of islands, pedestrians encounter vehicles travelling in both directions. There is also always a risk of a vehicle encroaching on the wrong side of the road, during overtaking. The pedestrian may also have to stop and wait in the middle of the road, until a convenient gap appears between successive vehicles or groups of vehicles. The characteristics of the gaps in the traffic flow constitute the criterion for the choice of a such a refuge, rather than other measures, such as traffic lights or pedestrian footbridges.

A refuge has the following advantages:

- it does not have to be installed together with traffic lights;
- it permits better utilisation of gaps when crossing, as the pedestrian needs gaps in only one vehicle direction at a time;
- it only slightly reduces the vehicle flow capacity of the roadway by maintaining the number of traffic lanes in each direction, even though the effective road width is reduced;
- it is a relatively low cost measure, especially if built using on-site kerb moulding, and it offers a much more economical alternative to the installation of a continuous median strip, along streets where pedestrians' desired crossing locations are scattered. Successive refuges may be installed, conveniently spaced (for example every 100 m), with continuous road markings between the refuges, reinforced with studs to help reserve the areas between the refuges for pedestrian use. This measure was installed in Conselheiro Carrão Avenue in São Paulo (Figure 10.11).

The minimum recommended width for a refuge is 1.00 m, plus a painted borderline, leaving a safety margin of 0.30 m on each side, between the refuge and the borderline.

Median Strip

The use of a median strip in a street results in the physical separation of opposing vehicle flows, keeping vehicles from encroaching on the wrong side of the road during overtaking. Like a refuge, the median strip permits pedestrians to cross the road in two stages (see Figure 10.12).

This measure is recommended when pedestrian crossing requirements are scattered along the street, as occurs with streets in commercial areas. The roadway should be 14.0 m wide or more, although it can be used on roadways only 12.0 m wide when other circumstances warrant. The minimum recommended width for a median strip is 1.0 m, the same as for refuges.

Other advantages of a median strip are:

- it impedes undesirable vehicle movements, such as U-turns and right or left turns at locations other than intersections; and

FIGURE 10.10
EXAMPLE OF CONCRETE REFUGE
SAPOPEMBA AVENUE – SÃO PAULO

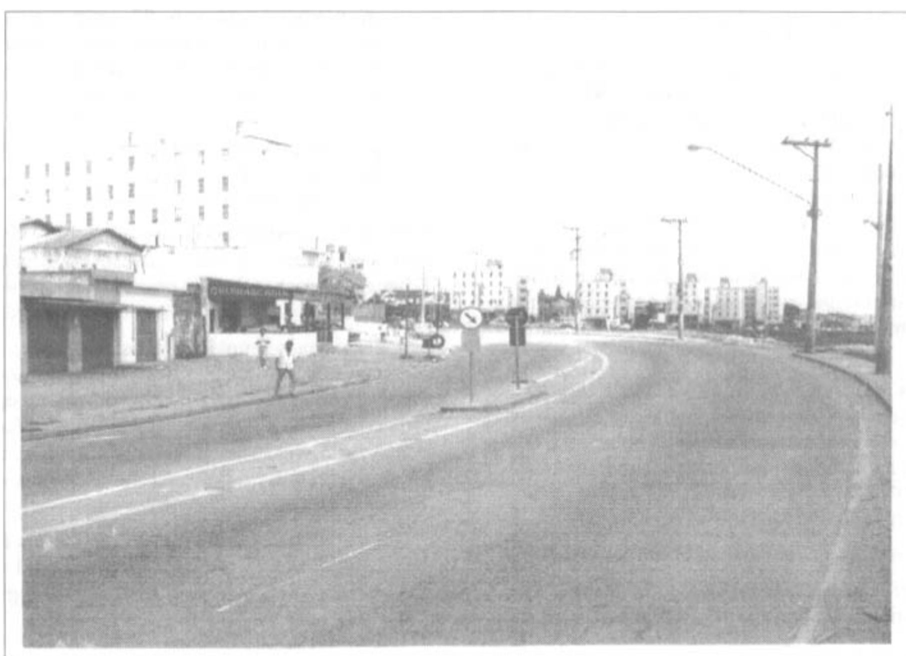
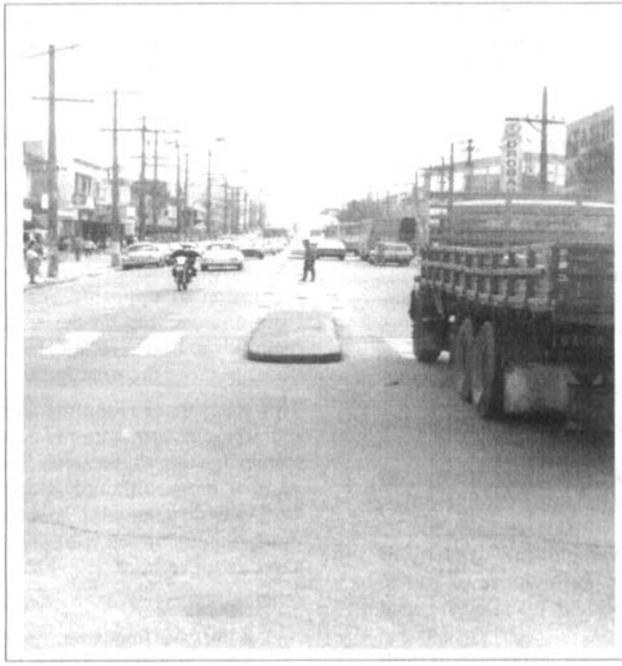


FIGURE 10.11
REFUGES COMPLEMENTED BY STUDS, ACTING AS MEDIAN STRIP
CONSELHEIRO CARRÃO AVENUE – SÃO PAULO



- it is a continuous element, parallel to the road, so it can be installed with concrete prisms, substantially reducing the cost.

Pedestrian Streets and Pedestrian Areas

These areas are often created for other reasons than traffic safety. They increase the capacity of narrow downtown streets to transport people by a factor of 30 or more where the streets were previously devoted to congested automobile traffic. This occurs as cars – the lowest capacity mode – are replaced by buses and pedestrians, which are high capacity modes in relation to the space they require. Vehicle flow is greatly reduced, along with noise and visual and atmospheric pollution. The entire area becomes more attractive to shoppers, municipal authorities, and investors, and this encourages movements to preserve historical buildings.

Pedestrian streets and areas also improve traffic safety by eliminating pedestrian-vehicle conflicts. Before treatment, pedestrians may often be seen walking in the carriageway, generating high risk of pedestrian accidents and traffic congestion. Figure 10.13 shows a street in the centre of São Paulo, from which vehicular traffic was eliminated.

Pedestrian areas have other important components:

- selective traffic streets: these should be streets near the pedestrian streets and their function is to guarantee access to the pedestrian area by public transport (e.g., trams, buses, or taxis);
- service roads: these should be streets with fewer restrictions on vehicle traffic, with special times of day for loading and unloading goods, and with continuous access for public service vehicles (fire brigade, ambulances, armoured vehicles for transport of money, etc.);
- parking places to meet the needs of private automobile users; and
- passenger and goods terminals.

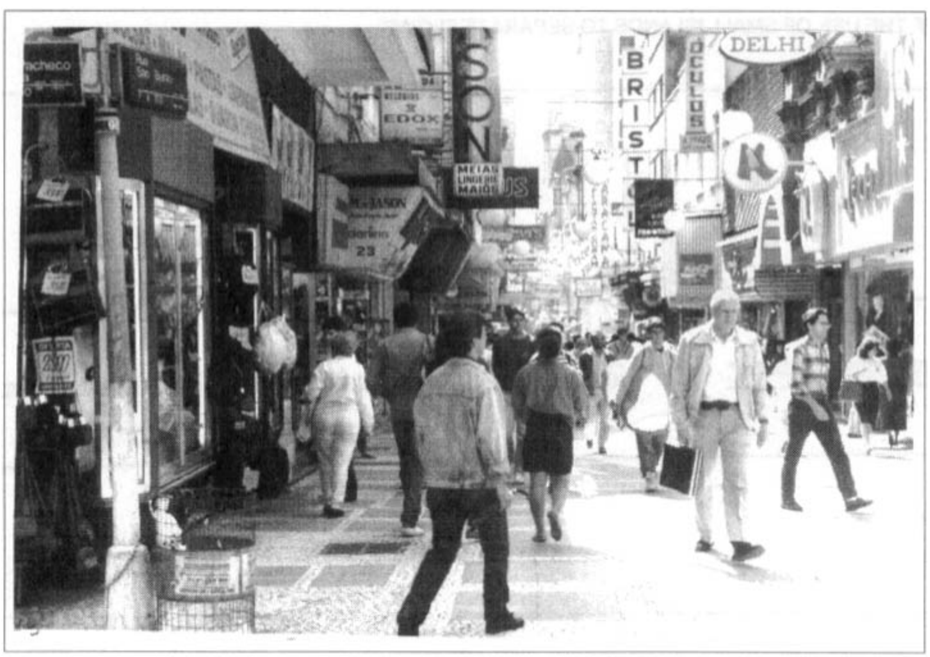
The smaller pedestrian areas (especially those in peripheral zones) usually have pedestrian streets without the other components. In this case, service vehicle access and general safety of the area must be guaranteed.

The only disadvantages of pedestrian areas and streets are the high costs of project design and implementation, including replacing the asphalt with more suitable paving (such as bricks or stones), and the costs of other urban revitalisation measures. In the medium term, tax collections often increase with commercial activities, compensating for the high costs.

Vehicles excluded from pedestrian streets and areas must be rerouted, and the traffic engineer should avoid directing the traffic to neighbouring streets with high accident po-

FIGURE 10.12
MEDIAN STRIP, SEPARATING VEHICLE FLOWS
SALIM MALUF AVENUE – SÃO PAULO

FIGURE 10.13
STREET WITH EXCLUSIVE USE BY PEDESTRIANS
SÃO BENTO STREET – SÃO PAULO



tential. This would transfer accidents to other streets, rather than reduce them. In some cases vehicular traffic may be temporarily excluded from the street to be converted to the exclusive use of pedestrians, to evaluate the consequences of the planned change for motorised traffic, before implementing the project.

10.3 Gemometric Projects for Channelising Vehicles

Islands

Islands are well-defined areas, situated between traffic lanes, designed to guide vehicle movements and to serve as pedestrian refuges. They are used to:

- control the angles of conflict;
- reduce the area of conflict;
- create refuge zones;
- order the traffic flows;
- avoid prohibited vehicle movements;
- provide space for the installation and protection of traffic control equipment; and
- aid pedestrians in crossing the road.

These islands may be classified as dividing or directional. *Dividing islands* separate traffic flows that are moving in the same or opposing directions. They are used on approaches to intersections on secondary roads to organise turning movements and to provide waiting lanes for left-turning vehicles (in countries where traffic circulates on the right). *Directional islands* are used to maintain vehicles in adequate alignments, so that turning movements at intersections occur within the appropriate areas and with the most convenient angles and speeds.

Conflicting movements in very spacious paved areas may be eliminated by the construction of islands in the least utilised parts of the areas, reducing vehicle dispersion.

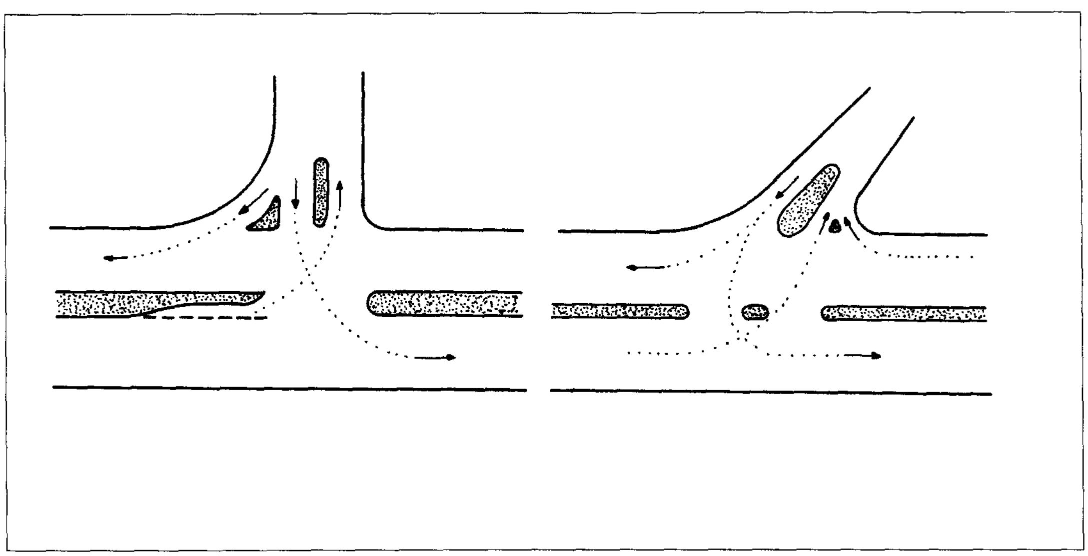
Islands may have various shapes and sizes, depending on the conditions and dimensions of the intersection (Figure 10.14).

The basic format of islands may be deduced using standard templates of vehicle swept paths, prepared by registering the paths of the front left wheel and the back right wheel of different types of vehicles, when carrying out different turning movements. For the majority of cases (principal connections within urban areas, commercial- and mixed-use areas, and goods transport terminals), use of the template corresponding to the movement of a medium-sized truck is sufficient and safe.

Figures 10.15 to 10.17 show an example of geometric configuration of a channelisation scheme, based on islands designed using reproduction of the templates printed on transparent paper.

The islands should be designed so as not to confuse drivers. Channelisation solutions should have a small number of large islands rather than a large number of small islands. The islands should be of sufficient size to attract the attention of drivers, and should have rounded corners. The minimum recommended area for an island is 4.5 m^2 and preferably 7.0 m^2 or more. Islands with the form of a drop of water should have a minimum width of 1.0 m and a length between 3.5 m and 6.0 m, although in some cases a width of 0.5 m may be acceptable. The length of all sides of triangular islands should be at least 2.4 m (preferably 3.0 m or more).

FIGURE 10.14
EXAMPLES OF THE USE OF SMALL ISLANDS TO SEPARATE FLOWS



Acceleration and Deceleration Lanes

These lanes are essential for traffic safety and are used on freeway carriageways, expressways, and principal arterial roads. They permit drivers to alter the speed of their vehicles as necessary to enter a secondary road or to merge with the traffic on the main road. They have two sections, one of transition, with constant width, and the other with varying width.

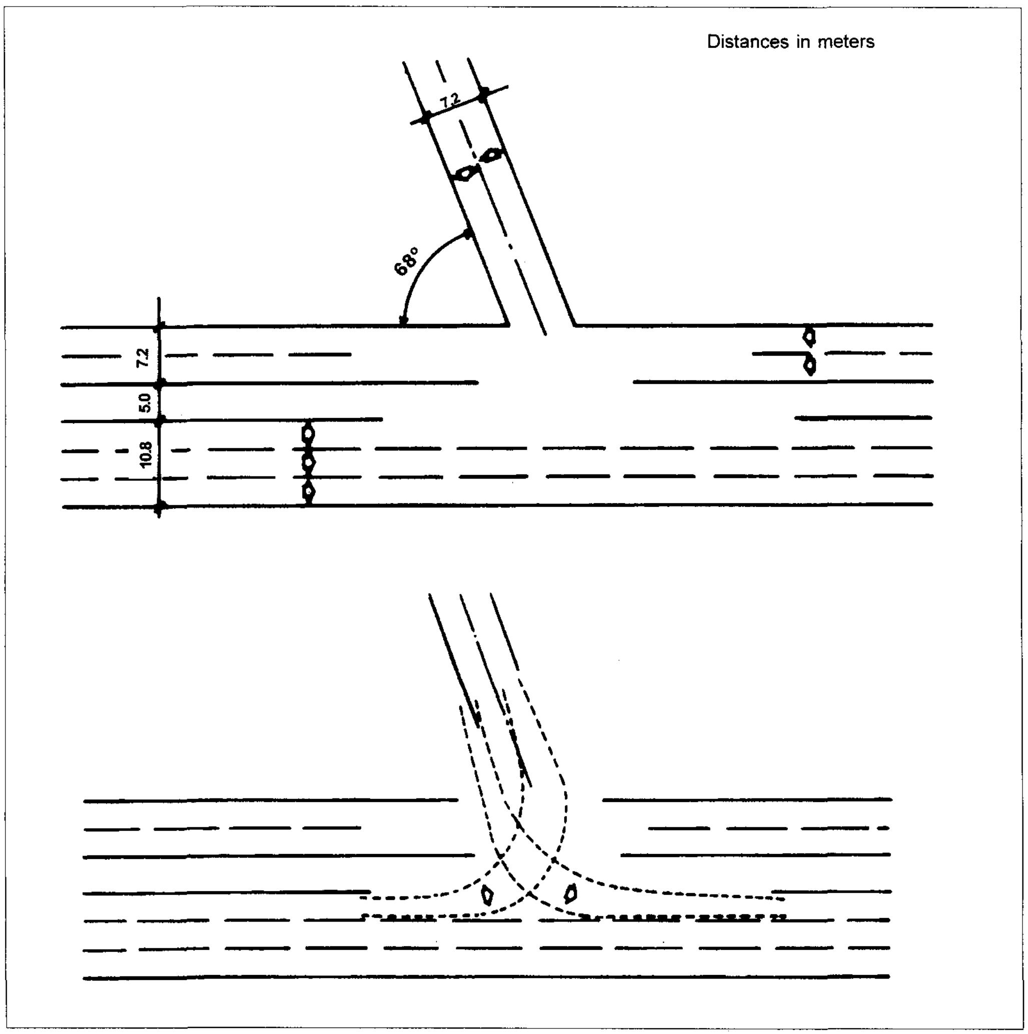
The section with varying width is designed on the basis of vehicle speed of 1.0 m/seg for lateral movement of a vehicle. Thus, adopting a width of 3.0 m to 3.5 m for the transition lane (where speed change should occur), a vehicle would take 3.0 to 3.5 seconds to travel the length of the variable width section.

Table 10.1 presents transition lane lengths for different vehicle speeds, using the following formulas:

Min. transition length= 15 + 0.5 x (Highway design speed)

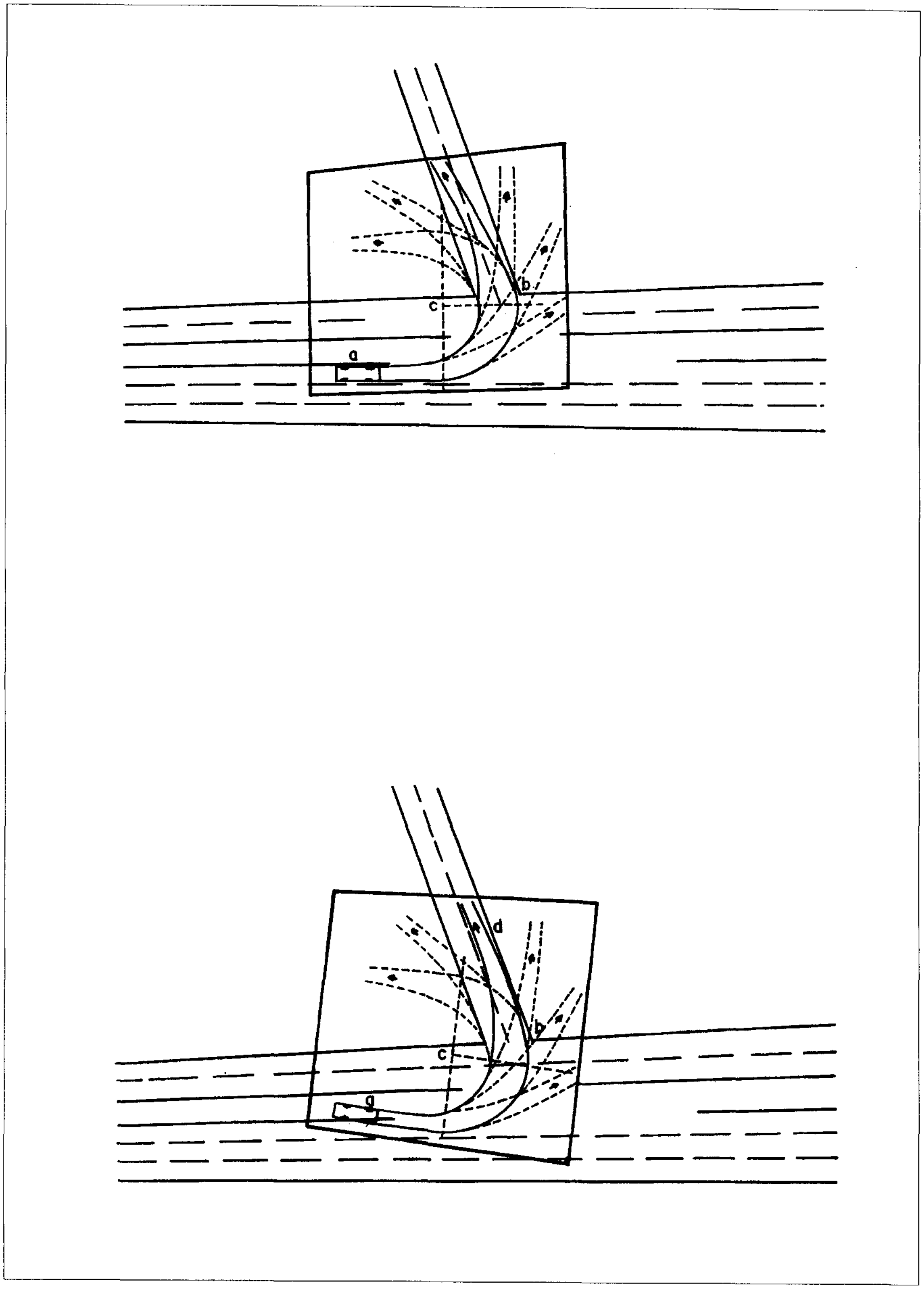
Preferred length = 10 + 0.75 x (Higway design speed)

FIGURE 10.15
DESIGNING ISLANDS (1):
TRANSFERING STANDARD VEHICLE SWEPT PATHS DURING CURVES, FROM THE TEMPLATE TO THE BLUEPRINT



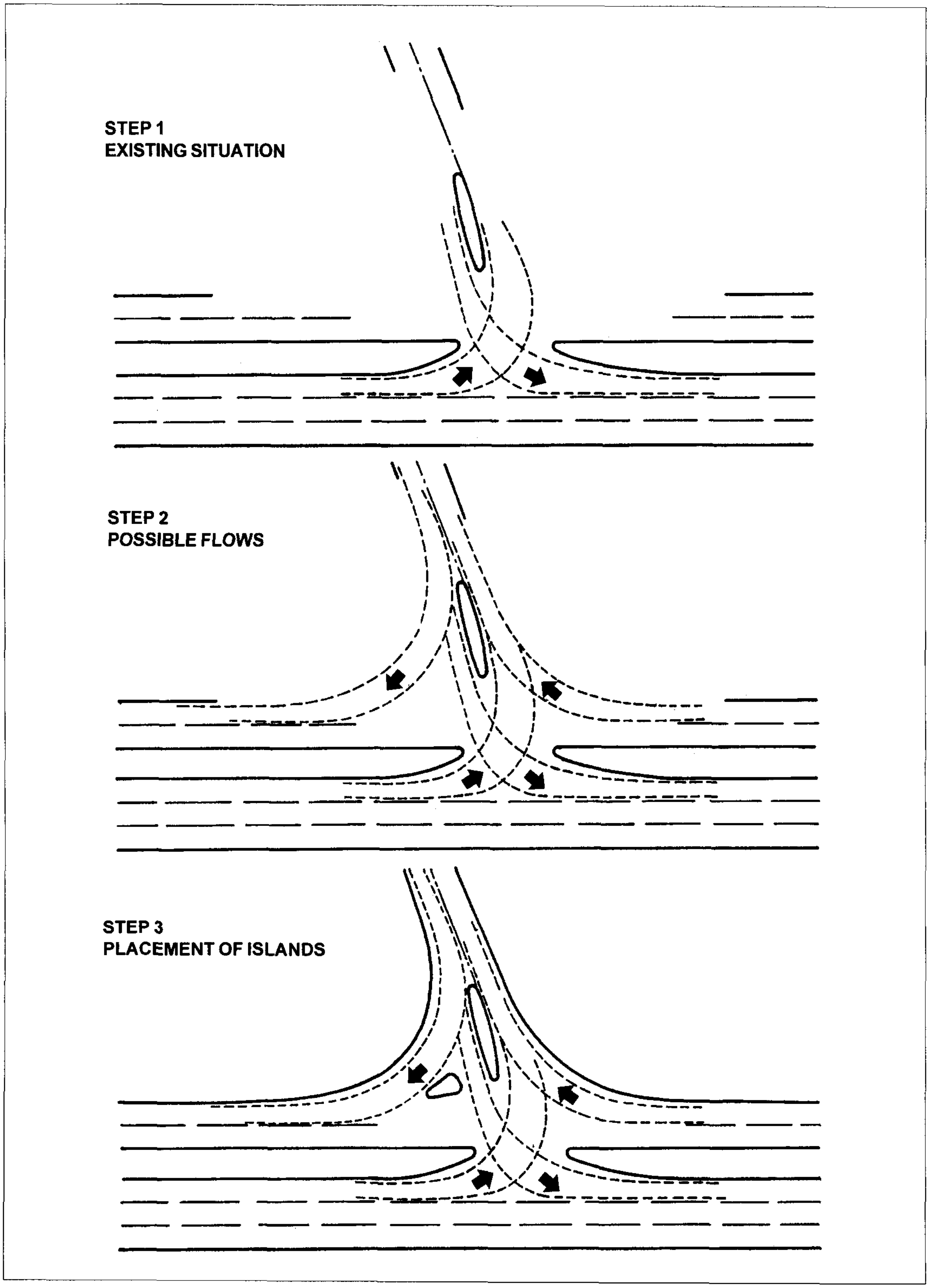
Source: CET, Technical Bulletin No. 15, p.66.

FIGURE 10.16
DESIGNING ISLANDS (2):
USE OF TEMPLATES FOR "BROKEN" ANGLES



Source: CET, Technical Bulletin No. 15, p.67.

FIGURE 10.17
DESIGNING ISLANDS (3):
DEVELOPMENT OF CHANNELISATION TO ADJUST FOR SWEPT PATHS



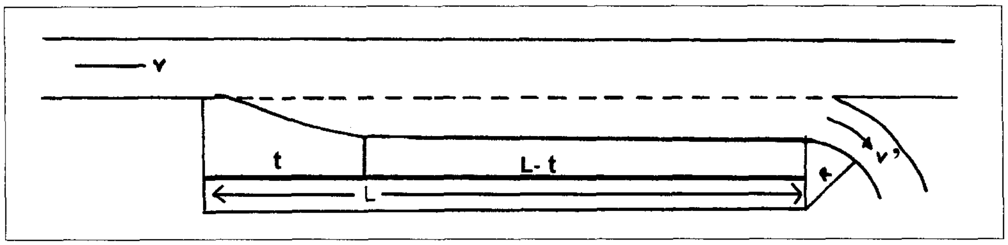
Source: CET, Technical Bulletin No. 15, p.68.

TABLE 10.1
ACCELERATION AND DECELERATION LANES:
RELATIONSHIP BETWEEN SPEED AND LENGTH OF TRANSITION LANE

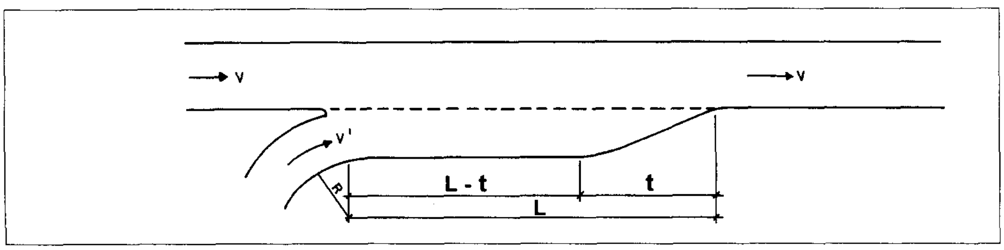
Highway design speed (km/h)	40	50	60	70	80	90	100	110	120
Minimum transition length (m)	35	40	45	50	55	60	65	70	75
Preferred length (m)	40	47.5	55	62.5	70	77.5	85	92.5	100

Source: Campos (1979), p.126. Adapted by author.

The following diagram shows the design characteristics of deceleration lanes:



Similarly, the next diagram shows the design characteristics of acceleration lanes.



Where:

V = operating speed of the highway

V'= operating speed of curve with radius R

L = total length of the acceleration/deceleration lane

R = radius of the turning curve

t = length of section with variable width

L-t = length of transition lane

Another variable that may be used in calculating the acceleration lane is the volume of through traffic. If this volume is very high, a longer lane may be necessary to permit vehicles to merge from the secondary road without stopping or suddenly reducing speed. It is assumed that entry speed V' should be equal to the highway operating speed V.

Table 10.2 presents acceleration and deceleration lane lengths for different project speeds.

Superelevation

Superelevation refers to the transverse inclination of highways, introduced to avoid acumulation of rainwater on the carriageway and loss of control of vehicles at curves. Superelevation at curves provides equilibrium between centripetal and centrifugal forces.

The minimum acceptable rate of superelevation, according to Brazilian standards, is 2%, which is applied on straight sections for drainage of rainwater. The maximum rate for use at curves depends on the class of road, being 10% for special class roads and 8% for the remainder. For urban sections, a maximum rate of 6% is applied, and for rural areas 8% (possibly reaching up to 12% in exceptional cases).

A problem found in Brazilian cities is the use of transverse inclination of roads, from the centre to the kerb, (Figure 10.18). This type of cross section is acceptable in straight road stretches. However, it is also sometimes used at curves, resulting in negative superelevation, that is, the external edge of the curve is lower, instead of higher, than the internal edge. This causes accidents on roads with fast moving traffic. The correct percent of superelevation depends directly on the radius of the curve. Figure 10.19 gives superelevation as a function of curve radius and operating speed.

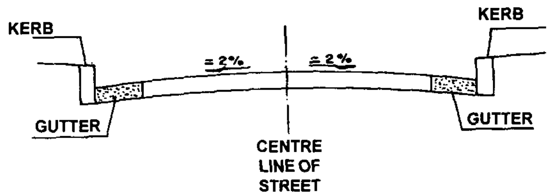
The variation of superelevation is also an important element of the project. It starts at the straight stretch and passes to the curved section, to the spiral section (if there is one), and back to a straight section. This calculation involves some concepts outside the scope of this book. The interested reader should consult the Institution of Highways and Transportation's publication, *Roads and Traffic in Urban Areas* (1987), which also presents other preventive safety aspects related to geometric design, with criteria for determining when spiral curves are necessary, carriageway widening at curves, and visibility distances.

TABELA 10.2
DESIGN LENGTH OF SPEED CHANGE LANES
FOR SMOOTH DOWNWARD SLOPES OF 2% OR LESS

Design speed of conversion curve (km/h)		Stationary	20	30	40	50	60	70	80
Minimum radius of conversion curve (m)		–	10	25	45	80	110	150	200
Highway design speed (km/h)	Length of section with variable width (m)	Total length of deceleration lane, including the section with variable width, for all primary highways (m)							
40	40	60	40	–	–	–	–	–	–
50	45	80	50	45	–	–	–	–	–
60	55	90	70	65	55	–	–	–	–
70	60	110	90	85	75	60	–	–	–
80	70	120	100	95	80	70	–	–	–
90	75	130	120	110	100	85	75	–	–
100	85	140	130	125	115	100	85	–	–
110	*90*	*150*	*140*	*135*	*125*	*110*	*100*	*90*	–
120	100	160	150	140	130	115	110	105	100
Highway design speed (km/h)	Length of section with variable width (m)	Total length of acceleration lane, including the section with variable width (m)							
Case I – Highways with intense traffic									
40	40	60	40	–	–	–	–	–	–
50	45	90	70	60	45	–	–	–	–
60	55	130	110	100	70	55	–	–	–
70	60	180	150	140	120	90	60	–	–
80	70	230	210	200	180	140	100	70	–
90	75	280	250	240	220	190	140	100	75
100	85	340	310	290	280	240	200	170	110
110	*90*	*390*	*360*	*350*	*320*	*290*	*250*	*200*	*160*
120	100	430	400	390	360	330	290	240	200
Case II – Highways with less-than-intense traffic									
40	40	40	–	–	–	–	–	–	–
50	45	50	45	–	–	–	–	–	–
60	55	80	60	55	–	–	–	–	–
70	60	120	100	90	60	–	–	–	–
80	70	160	140	130	110	70	–	–	–
90	75	200	180	170	140	100	75	–	–
100	85	250	220	210	190	180	120	85	–
110	90	300	260	250	230	200	150	100	90
120	100	330	300	290	260	240	190	140	100

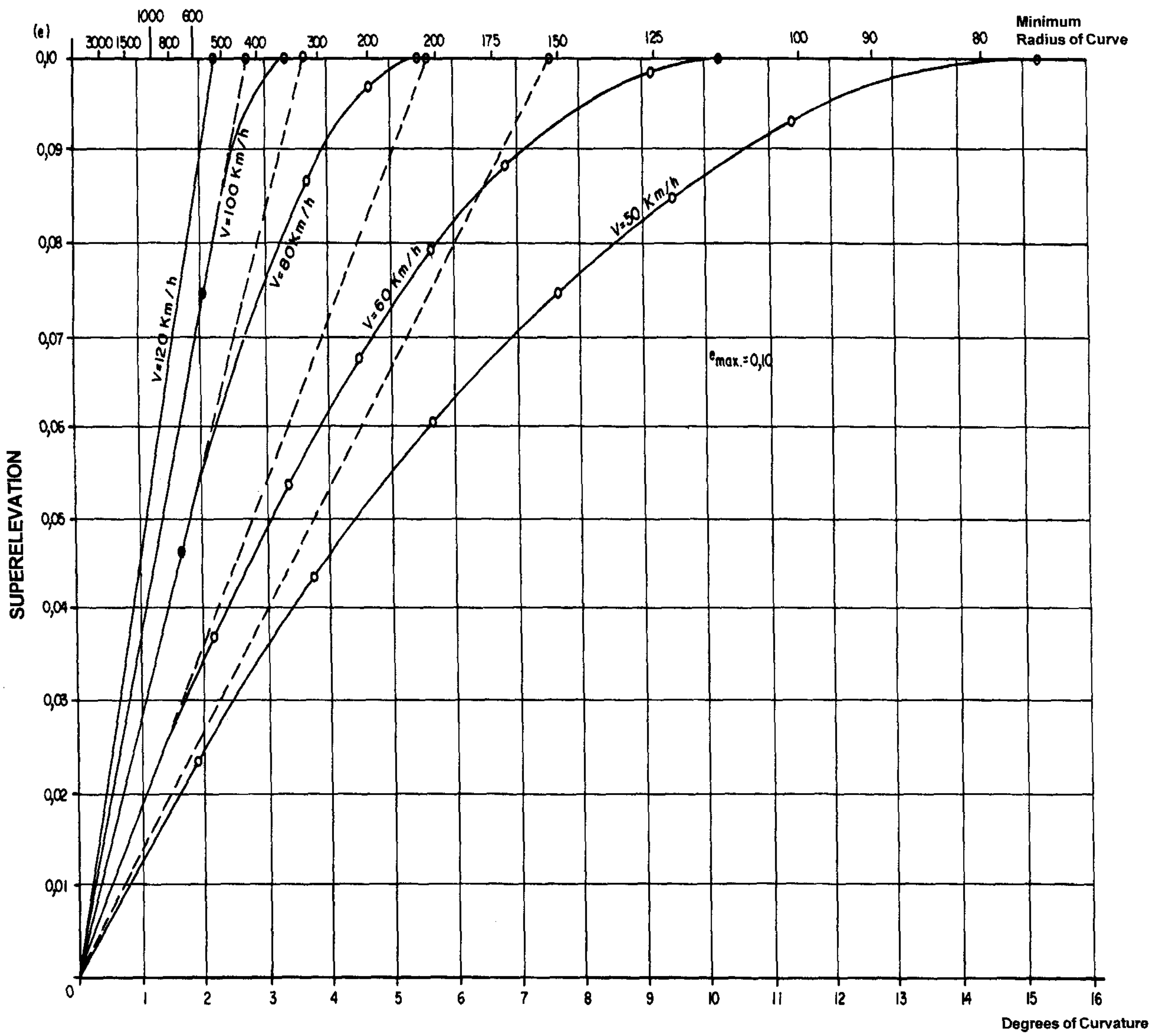
Source: Campos (1979), p.134.

FIGURE 10.18
TRANSVERSAL INCLINATION OF THE ROAD



Source: Campos (1979), p. 97.

FIGURE 10.19
HORIZONTAL CURVE RADIUS AND
SUPERELEVATION



Source: Campos (1979), p. 98.

10.4 Reorganisation of Vehicle Movements

This item covers the following measures to minimise or eliminate conflicting vehicle movements: definition of priorities at intersections; traffic lights; flashing lights; one-way streets; prohibited turning movements; narrowing the roadway; and mini-roundabouts.

Definition of Priority at Intersections

At intersections, accidents may occur due to the absence of signs, signals, and road markings to define priority.

The criteria to determine which approach(es) will be preferential are listed below, and should be analysed together as a group.

- vehicle volume in each approach (larger volume = priority street);
- knowledge of the area;
- topographical aspects (visibility, upward and downward slopes);
- presence of rain water drainage channels between corners of the intersection; and
- streets that are part of established bus or truck routes.

Once the priority street has been defined, the other approaches should be appropriately signed and signalled. A STOP sign (code R1 in Brazil) is usually the first item installed in the secondary, non-priority, streets, except when vehicle volumes warrant the installation of traffic lights. If the intersection has irregular geometry, the word STOP may be painted on the road, with a stop line and/or a double yellow centre line, and approach lines, as shown in Figure 10.20 (see also item 8.5).

Normally, the STOP sign is placed at the street corner, mounted on a simple post, at a height of 2.80 m from the ground. If there are visual interferences at the intersection, such as trees, signs, newsstands, posts, telephone boxes, or letter boxes, the STOP sign should be mounted on a projecting support arm, connected to a simple post or to one of the concrete posts that carry electricity cables, at a height of 4.50 m from the ground. This STOP (PARE) sign position has been used in São Paulo city with good results (see Figure 10.21).

Section 8.5 analyses possible problems with the use of STOP signs to define priority.

FIGURE 10.20
ROAD MARKING REINFORCING THE
MESSAGE OF THE STOP SIGN

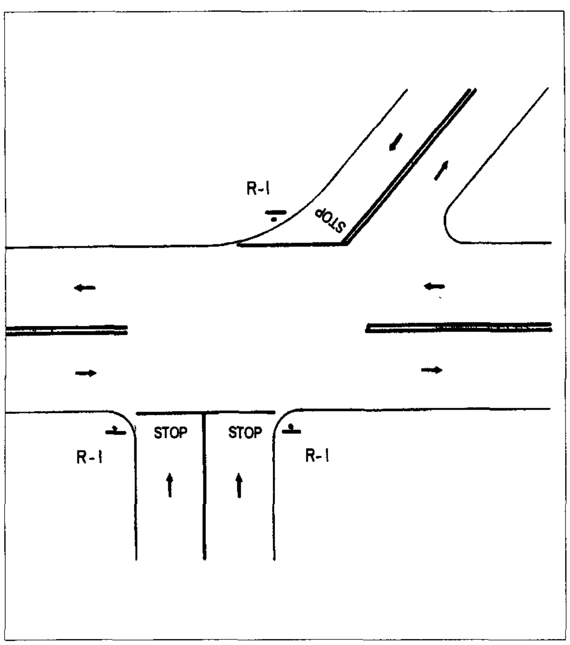
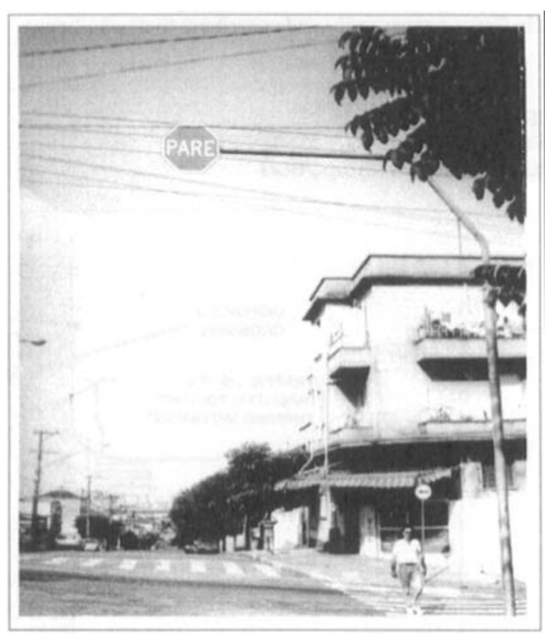


FIGURE 10.21
STOP SIGN MOUNTED ON PROJECTING ARM
LINO COUTINHO STREET x LIMA E SILVA STREET



If the accident frequency continues to be significant, despite the installation of a STOP sign, and with no change in the volume of vehicles, the installation of other measures, such as a mini-roundabout (described later), may be required.

In certain intersections, secondary roads may approach main roads at angles and with visibility conditions that permit drivers to observe the speed and proximity of approaching vehicles in the main road and to take a decision to stop before entering the main road, or to enter at a reasonable speed without stopping. In these cases, the installation of a YIELD sign is recommended. In Brazil and some other countries, this sign is an inverted triangle with no words; in the United States, the word YIELD is written on the sign. If there are no words and drivers do not understand the symbol, another sign with the word YIELD may be placed under the triangle on the same support, a solution used by the DNER and the CET in Brazil.

This type of signing (STOP and YIELD) may be supplemented by the implementation of the Vision-Project described later.

Traffic Lights

A – Pedestrian traffic lights

Installation criteria

These lights should only be installed when a careful evaluation shows that they are needed and will be useful. Pedestrian traffic lights normally should not be installed in locations with low vehicle traffic volumes, or with fixed traffic light cycles where pedestrians cross only at certain fixed times of the day. In such situations, the lights will stop the vehicle flow unnecessarily and contribute to disobedience of traffic lights by drivers, eventually putting pedestrians at risk.

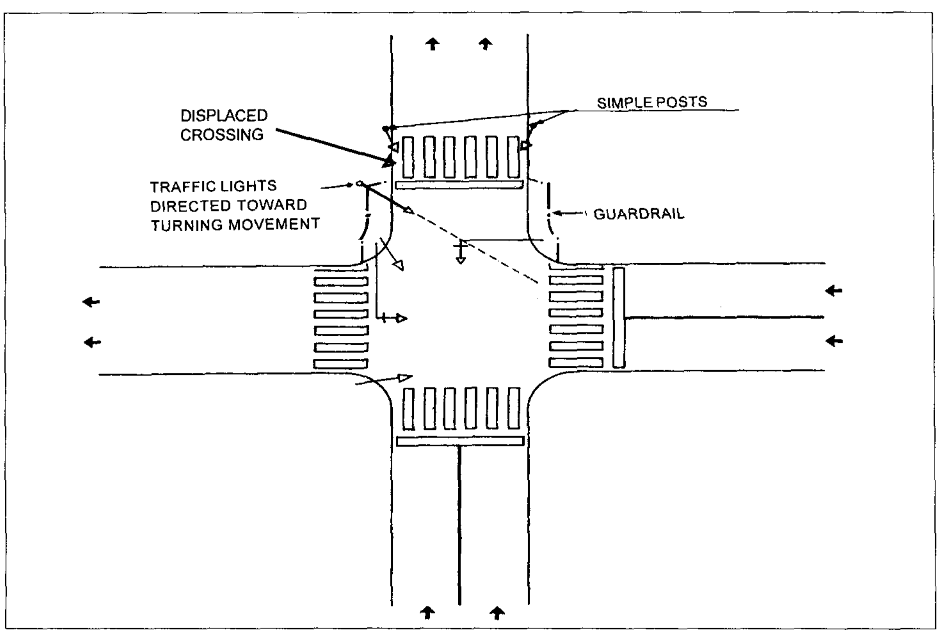
The following minimum volumes may justify traffic lights at pedestrian crossings (CET/CONTRAN/DENATRAN, 1978): 250 pedestrians per hour in both crossing directions and 600 vehicles per hour, on a two-way road without a median strip; or 1,000 vehicles per hour when there is a median strip with a width of 1.0 m or more. Exceptional cases may require the installation of traffic lights at smaller vehicle volumes, for example, when the traffic flow is continuous and gaps are insufficient for pedestrians to cross freely and in safety. In these cases pedestrian traffic lights, with a button for activation by the pedestrians themselves, are recommended.

Position of the traffic lights

Whenever possible, pedestrian traffic lights should be placed on the path that pedestrians want to use to cross the street. Pedestrians are naturally reluctant to accept an increase in walking distance to use a crossing that traffic engineers consider safe, if this location is off their desired route. Unless crossing the road is difficult or impossible, many pedestrians will cross by the shortest path, rather than walking 50 m or 100 m to a traffic light.

A special case of the use of traffic lights is to set the pedestrian crossing back a short distance from an intersection that has a high volume of turning vehicles. This solution is often useful when the flow of vehicles is such that unacceptable delays would occur if an exclusive pedestrian phase were implemented, stopping all vehicle flows. To work well, the pedestrian crossing must be correctly positioned in relation to the intersection (Figures 9.31 and 10.22).

FIGURE 10.22
PEDESTRIAN CROSSING SLIGHTLY DISPLACED FROM INTERSECTION



The correct position of the crossing will vary with the volume of vehicle turning movements, the road capacity, the geometric layout, and other factors. The traffic light should be placed far enough from the intersection to leave enough space for turning vehicles to stop after turning as they approach the pedestrian crossing, without forming a queue that would block the intersection for non-turning traffic (Figure 10.22). Around 15 m is often acceptable.

The reluctance of pedestrians to cross far from their desired path is illustrated by the Radial Leste Avenue in São Paulo, which has several of these setback pedestrian crossings. At the junction with Hipódromo Street, pedestrians tend not to use the crossing which is 23 m from the intersection. The next intersection, at the junction with Almirante Brasil Avenue, has similar characteristics but much higher pedestrian use, since it is only 14 m from the intersection.

Traffic lights set back from the intersection should be positioned so that drivers of turning vehicles can see them when turning in time to make a decision to stop. A second traffic light may be installed, before the pedestrian crossing, directed towards these drivers (Figure 10.22).

Some drivers on the road with the set-back crossing may become confused at the beginning and ending of their green phase, since their traffic lights are close to other traffic lights that are directed to drivers turning from the orthogonal street. They may erroneously follow the traffic lights at the pedestrian crossing, provoking dangerous situations. This occurs in the normal situation when the opening and closing of the green phases of the two locations are not simultaneous. One solution for these situations, tested successfully in São Paulo on one-way streets, is to make the traffic lights at the intersection very visible, with two lens groups projected over the road and two repeat groups, while at the pedestrian crossing only two lens groups are installed at the sides of the road, with sufficient visibility for drivers already close to the crossing and those turning from the orthogonal street.

Guardrails or flower boxes should be used to channelise pedestrians towards the pedestrian crossing and crossing supervisors should be used when possible. These people should stay at the intersection, supervising pedestrians as to the utilisation of the set-back crossing. In São Paulo, students were employed part-time as supervisors with satisfactory results. In other cases, police, volunteers, or employees of local schools perform this function.

Traffic light programming

This section describes the methodology used to program pedestrian traffic lights in São Paulo. Variations on this methodology exist in Brazil and in other countries (Cannel, 1996). The times and principles are a subject of debate among traffic engineers. Drivers cannot be subject to excessive stop time at pedestrian crossings, since this generates disobedience of traffic lights unless enforcement is omnipresent and rigorous. The minimum crossing time depends on the width of the street and the type of pedestrian. The DNER uses the following pedestrian speeds:

- average speed (normal adults) 1.3 m/sec
- minimum speed (children and the elderly) 1.1 m/sec

Two seconds should be added for pedestrian reaction time and another 2 seconds when many pedestrians are crossing.

The green phase for pedestrians is followed by a flashing red phase[3] that warns pedestrians on the sidewalk that it is too late to begin crossing, similar to the yellow phase for drivers. The calculation of the flashing red phase assumes that pedestrians will begin walking faster in this phase, at 1.6 m/sec. Despite its wide use, this assumption is questionable, as it requires pedestrians, including children and the elderly, to increase their speed and perhaps even run to avoid being in the road at the start of the green phase for vehicles. The following example shows the calculation of the green and flashing red phases for pedestrians (adults) crossing a 10 m wide road, with a large volume of pedestrians.

GREEN PHASE

Reaction time..2.0 seconds

Normal crossing time: 10 m/1.3 m/sec.............7.7 seconds

Additional time for large volume.....................2.0 seconds

Subtotal..11.7 seconds

FLASHING RED PHASE

Subtotal with fast-walking assumption:

10m/1.6m/sec..6.2 seconds

Subtotal without that assumption:

10 m/1.3 m/sec...7.7 seconds

TOTAL CROSSING TIME

Green for

11.7 sec + flashing red for 6.2 sec = 17.9 seconds, or

green for

11.7 sec + flashing red for 7.7 sec = 19.4 seconds

For crossings at mid-block, when at least one of the two successive intersections has traffic lights, the traffic engineer should verify if the pedestrian traffic lights can be synchronised with the other lights to avoid unnecessary interruptions of vehicle flow.

At intersections that require a special phase for pedestrians (red for all vehicle approaches), the traffic lights should be positioned so that drivers cannot see the traffic lights on the orthogonal street. When this recommendation is not followed and enforcement is weak, drivers often see the start of the red phase on the orthogonal street and move before their own light changes to green, effectively ignoring the pedestrian traffic light. This can be avoided by positioning the traffic lights immediately before the area of the intersection, eliminating the view from the orthogonal street. Special shields may also be placed over the lenses, and the angles for the traffic lights carefully chosen to make them visible only to those drivers who should be seeing them.

Pedestrian-activated traffic lights

This equipment has the advantage of interrupting the vehicle flow only when really necessary: when a pedestrian wishes to cross the street. This type of traffic light is normally more respected by drivers when pedestrian volume is low and crossings are at mid-block. It should be used where pedestrians cross the street at certain specific times of day in places where crossing would be difficult without traffic lights.

Pedestrian-activated lights have a disadvantage, however, when vehicular traffic is light, gaps frequent, and pedestrians try to activate them at short intervals. The traffic light stays open for vehicles for a minimum period in each cycle. This creates lengthy delays before showing green for some pedestrians, who become impatient and cross without waiting for their phase. When the pedestrian-activated red-for-vehicle/green-for-pedestrian phase begins, there are no longer any pedestrians waiting to cross, which irritates drivers and can lead them to disobey the red light.

Automatic mid-block pedestrian traffic lights

This type of equipment is justified only when a substantial number of pedestrians are crossing throughout the day, so that the traffic light is seldom red for vehicles when no pedestrians are crossing, a situation that would lead to disrespect for the red light.

B - Traffic lights for vehicles at intersections

Installation criteria

The following three criteria deserve special attention when deciding whether to install traffic lights at an intersection (CET/CONTRAN/DENATRAN, 1978).

1 - Minimum values for vehicle volumes for installation of traffic lights (Table 10.3).

These volumes refer to the average of the 8 hours of greatest vehicle volume at the intersection.

2 - Interruption of continuous traffic (Table 10.4).

Under this criterion, although the volume on the secondary street does not reach the minimum values stipulated under Criterion 1 (minimum vehicle volumes), the volume on the principal street reaches values that make crossing difficult by vehicles on the secondary street. The equivalent minimum volumes for this situation are shown in Table 10.4.

TABLE 10.3
MINIMUM FLOWS FOR IMPLEMENTATION OF TRAFFIC LIGHTS - NORMAL SITUATION

Number of traffic lanes per approaching flow		Vehicles/hour in preferential road: sum of both directions	Vehicles/hour in secondary road: direction with highest flow
Preferential Road	Secondary Road		
1	1	500	150
2 or more	1	600	150
2 or more	2 or more	600	200
1	2 or more	500	200

Source: CET/CONTRAN/DENATRAN, 1978, p.42

TABLE 10.4
MINIMUM FLOWS FOR IMPLEMENTATION OF TRAFFIC LIGHTS – HEAVY FLOWS IN PREFERENTIAL ROAD

Number of traffic lanes per approaching flow		Vehicles/hour in preferential road:sum of both directions	Vehicles/hour in secondary road: direction with highest flow
Preferential	Secondary		
1	1	750	75
2 or more	1	900	75
2 or more	2 or more	900	100
1	2 or more	750	100

Source: CET/CONTRAN/DENATRAN, 1978, p.44

3 - Accident index

The existence of a high accident index may justify the installation of traffic lights in intersections with lower traffic volumes than those stipulated under the first two criteria. The types of accidents should be examined to determine if they are likely to be reduced by traffic lights or by other, less radical, measures with lower costs, such as speed reducing devices, mini-roundabouts, or flashing warning lights.

Traffic light programming

The following precautions should be taken when programming traffic lights, to ensure that traffic safety will in fact occur:

- avoid long cycle times, which generate unnecessarily long waiting times, leading to red light violations;
- utilise, whenever possible, controllers with variable cycle times, adjustable with demand or with preestablished periods of the day;
- synchronise successive traffic lights to minimise interruption of the vehicle flow;
- on high speed streets, synchronise so that the vehicle platoon receives the new green phase only when it is nearing the approach, to diminish speed when arriving at the intersection; and
- check yellow times and all-red times at intersections where many accidents occur, or where accident potential is high, utilizing Tables 10.5 and 10.6.

TABLE 10.5
YELLOW TIMES

Road type	Real speed (km/h)	Yellow time (seconds)
Secondary	40	3
Primary (Avenue)	60	4
Rapid/Express	80	5

Source: Ejzenberg, 1997.

TABLE 10.6
ALL-RED SAFETY TIME

Type of orthogonal street	Approach speed (km/h)	All-red safety time (seconds)
Secondary	40-60-80	0
Avenue	40	2
Avenue	60	1
Express	60	1
Avenue	80	0.4
Express	80	0.4

Source: Ejzenberg, 1997.

Positioning the traffic lights

Good visibility of traffic lights is essential, considering the following criteria and precautions:

- On streets with medium traffic volumes (600 -1,000 vehicles/day/lane) and speeds below 60km/h, widths of up to 10.5 m: use at least 2 traffic light groups, 1 projected over the road and 1 repeat group.
- When the width exceeds 10.5 m and/or volumes and speeds are high, 4 groups should be used, 2 projected and 2 repeat groups.
- An excessive number of groups is preferable to an insufficient number (do not exaggerate).
- All traffic lights projected over the road should have surrounding black screens to help them stand out from the background, and to be visible even in strong sunlight, when in an east-west direction.
- Maintain light units constantly, clean them, replace rubber waterproofing gaskets when needed, verify the voltage, etc. Deficient luminosity of the lights may cause accidents, especially during days of intense sunlight. The shields around the lenses are also fundamental for adequate luminosity.
- Traffic lights should not be positioned near vegetation that will grow enough to cover them, or near other lights, especially those associated with advertising that might hide the lights or confuse drivers.

Positioning the traffic lights before or after the intersection

Most Latin American cities follow the U.S. system for positioning traffic lights, placing them after the intersection. However, it may be preferable to place the lights before the intersection, as standardised in various European countries, if precautions are taken to ensure adequate visibility for vehicles waiting at the stop line. There is no worldwide agreement on the best location, but there are arguments for considering the "before" location in certain situations. The advantages and disadvantages/special care required for the before position are described below.

Advantages of positioning *before:*

- Drivers stopped on one street are unable to see the traffic lights on the orthogonal street, eliminating the danger of drivers on one road advancing upon seeing the yellow light on the other road. Traffic lights placed before the intersection, associated with a short all-red phase when necessary, clear the intersection, strongly reducing the risk of conflicts at the changes of phases.
- To be able to see the traffic light, drivers are obliged to stop behind the stop line and, therefore, do not encroach upon the pedestrian crossing areas.
- Drivers have an early view of the traffic lights, which is especially advantageous at wide, complex intersections where, under the U.S. practice, traffic lights may be installed as far as 40 m after the stop line.

Disadvantages:

- Pedestrians crossing the road "after" the intersection, on one-way streets, will only be able to see a traffic light if one is installed especially for pedestrians.

Special care is needed to ensure that drivers of vehicles at the stop line can see the "before" traffic lights. This may be achieved by installing repeater groups lower down (2.0 m) and turned slightly towards the centre of the carriageway, for the first vehicles in the queue. This system is utilised in France, Spain, and some other European countries, where the repeater groups are smaller and mounted on the same posts as the main groups, but lower down.

Flashing Yellow Lights

Priority at intersections without traffic lights is usually defined by STOP signs. However, accidents may occur despite the existence of the STOP sign where vehicle volumes alone do not justify the installation of conventional traffic lights, due to driver disobedience and/or to poor visibility of the sign. One solution for this problem, developed by the CET in São Paulo, is to install continuously flashing yellow lights in addition to the STOP sign, on the non-preferential approaches, as shown in Figure 10.23.

The objective of this blinking yellow light is to reinforce the message of the STOP sign (which should remain), alerting drivers that they must yield. Additionally, a warning sign with the words "Proceed with Caution" reinforces the message from the blinking yellow light. This traffic light may also be used in other situations, when drivers should be alerted about an imminent situation that requires more attention than they would normally give it. An example in São Paulo is found at the intersection of Abrão de Morães Avenue (suburbs-centre direction) x Fagundes Filho Street x Miguel Stéfano Avenue. The traffic flow from Fagundes Filho Street enters Abrão de Morães Avenue, together with that from Miguel Stéfano Avenue, as shown in Figure 10.24.

A traffic light composed of a red lens and a yellow flashing lens was installed in the Miguel Stéfano Avenue approach. The red lens acts as a conventional traffic light, and the flashing yellow one warns of the existence of conflicting movements. The flashing yellow light comes into action when vehicles from Miguel Stéfano Avenue should enter Abrão de Morães Avenue. A warning sign "Proceed with Caution on Flashing Yellow" was mounted on the traffic light post as an explanation for drivers. When drivers on Miguel Stéfano Avenue must stop for the green phase for Abrão de Morães Avenue, the yellow light stops flashing but stays alight for 3 seconds and, when it switches off, the red light is switched on (Figure 10.25).

Recent investigations (1994-96) carried out in São Paulo, have led to doubts about the effectiveness of flashing yellow with the "Proceed with Caution" sign in reducing accidents. More recently, (1998) the "Proceed with Caution" sign has been replaced by one that includes the word STOP in red letters and the words "Proceed with Caution". Direct night-time illumination of these signs is also being developed.

FIGURE 10.23
FLASHING YELLOW SIGNAL AND MESSAGE "PROCEED WITH CAUTION" (*CRUZE COM CUIDADO*)

FIGURE 10.24
EXAMPLE OF USE OF FLASHING SIGNAL
TO ALERT DRIVERS TO DANGEROUS INTERSECTION
(PROCEED WITH CAUTION ON FLASHING YELLOW -
ENTRE COM CUIDADO NO AMARELO PISCANTE)

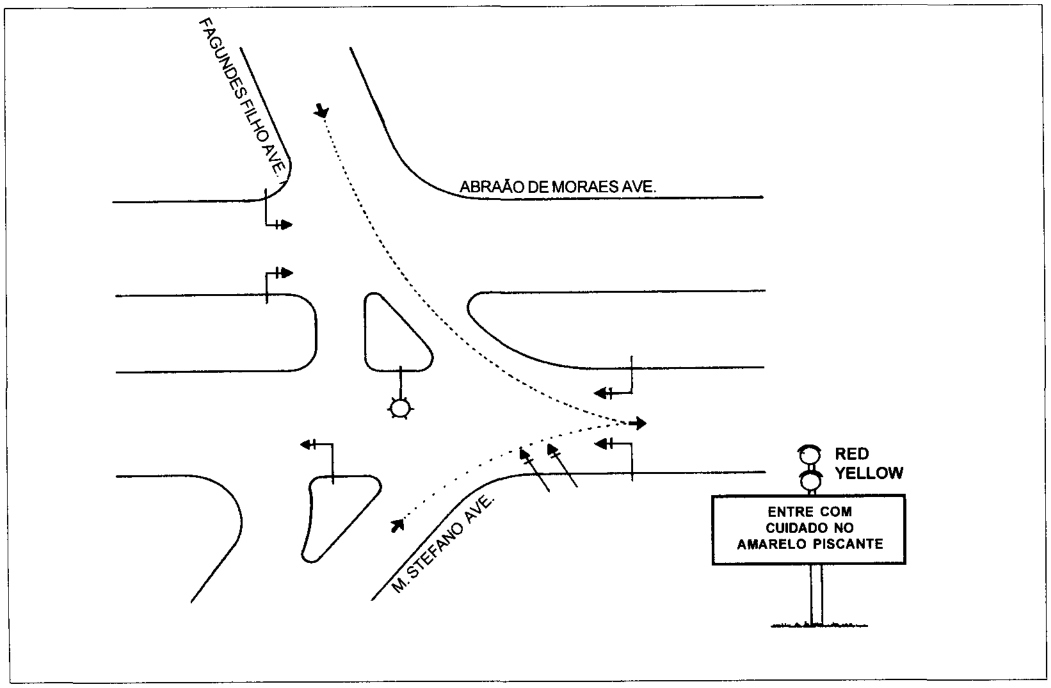


FIGURE 10.25
COMBINATION OF YELLOW FLASHING AND CONVENTIONAL SIGNALS
ABRAÃO DE MORAES AVENUE x MIGUEL STÉFANO AVENUE
(PROCEED WITH CAUTION ON FLASHING YELLOW –
ENTRE COM CUIDADO NO AMARELO PISCANTE)

Restricting Vehicle Movements

One way traffic

One-way traffic is frequently utilised to organise traffic within a street network. The benefits may be observed at intersections and along the streets. Intersections with four approaches and two-way traffic on all approaches have 28 points of conflict, that is, 28 different possibilities for collisions between vehicles from different approaches (see Figure 10.26).

With the introduction of one-way traffic on just one of the roads, the conflicts are reduced to 10 points (see Figure 10.27).

With one-way traffic on both streets, there are only 3 points of conflict (see Figure 10.28).

FIGURE 10.26
TWENTY EIGHT POINTS OF CONFLICT AT THE INTERSECTION OF TWO TWO-WAY STREETS

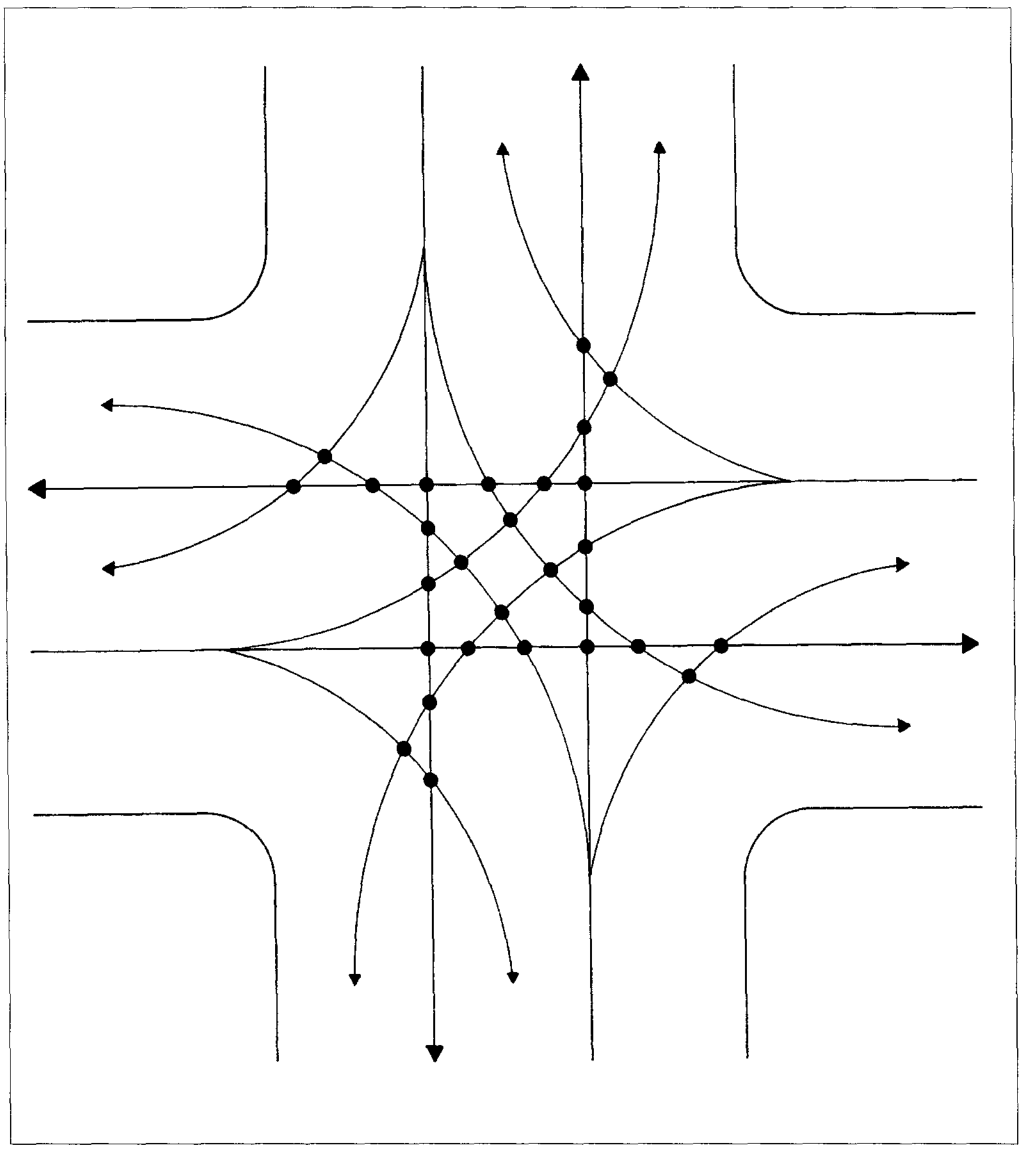


FIGURE 10.27
TEN POINTS OF CONFLICT AT THE INTERSECTION OF
A ONE-WAY STREET WITH A TWO-WAY STREET

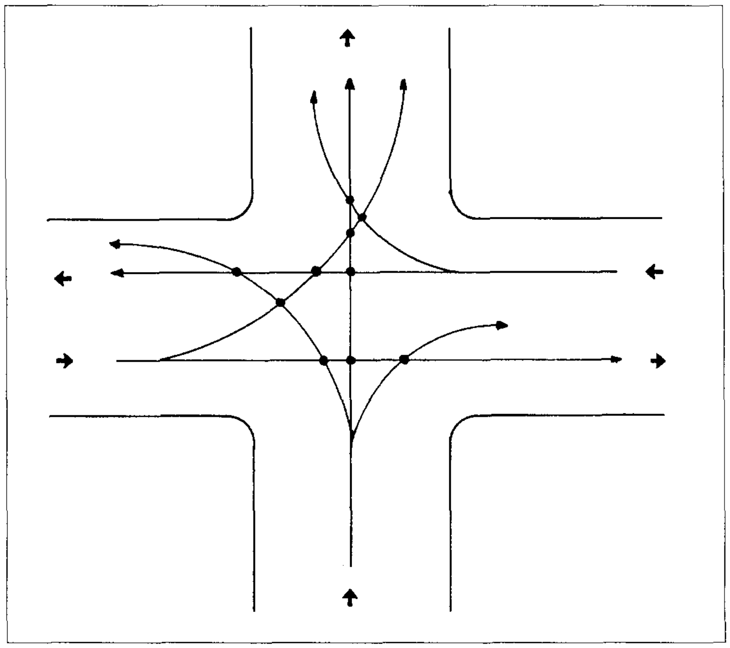
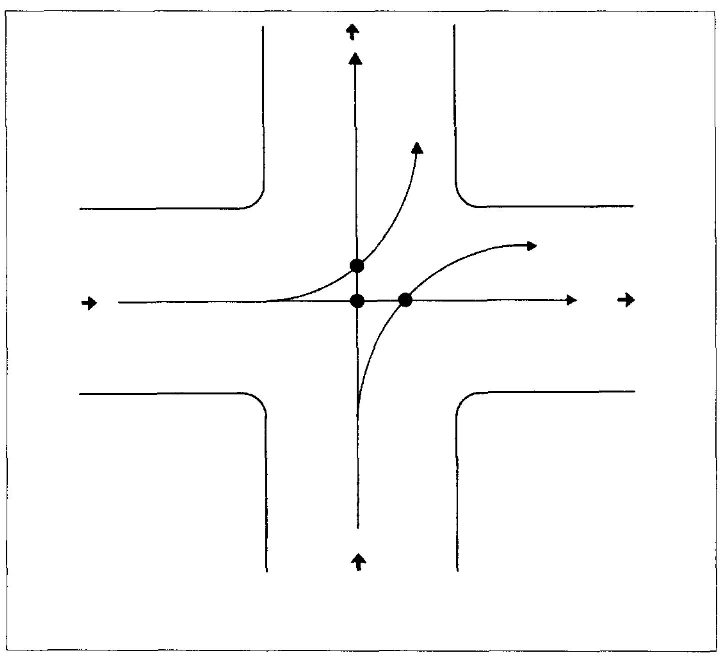


FIGURE 10.28
ONLY THREE POINTS OF CONFLICT AT THE
INTERSECTION OF TWO ONE-WAY STREETS



Thus, the introduction of one-way traffic simplifies an intersection and improves its operation and safety, reducing the potential for conflicts between vehicles.

It is also easier for pedestrians to cross a one-way street. They need to pay attention to only one direction of vehicle movement at a time, there are fewer vehicle turning movements, and they can more correctly evaluate the gaps in approaching vehicle flows.

One-way operation is almost always necessary to avoid introducing three or more traffic light phases in complex intersections that have four or more approaches controlled by traffic lights.

One-way traffic operation also has advantages on long road or street sections:

- pedestrians are safer since they do not need to look in both directions and may cross the street directly, in one stage, without stopping in the middle, as on two-way streets;
- there are longer gaps between vehicles;
- overtaking is easier and safer, with no risk of head-on collisions;
- more space is available per vehicle, reducing the probability of involvement in unexpected dangerous situations;
- there is more capacity for vehicles and better use of streets with an uneven number of traffic lanes; and
- better coordination is possible between successive traffic lights, permitting vehicle platoons to form that spend less time stopped at traffic lights and provide a greater frequency of gaps suitable for pedestrians to cross the street.

One-way operation also has disadvantages:

- increased vehicle speeds, as drivers feel more free and safe;
- increased travelling distances, as drivers are obliged to use indirect routes for some parts of their trips; and
- nearby parallel roads are needed to absorb traffic in the opposite direction and may become congested.

Prohibition of Turning Movements

Prohibition of turning movements reduces vehicle/vehicle and vehicle/pedestrian conflicts.

This type of restriction is transmitted to drivers by a circular prohibition sign with an arrow indicating the prohibited movement (to the left or right) and a diagonal red stripe (prohibition symbol).

These signs seldom please drivers, as they prohibit movements that are convenient and used. Thus the prohibition may not be respected if there is no physical barrier or effective, constant enforcement. At intersections with intense pedestrian crossing movements in the secondary road, conflicts occur with right-turning vehicles (in countries where driving is on the right). If capacity limitations

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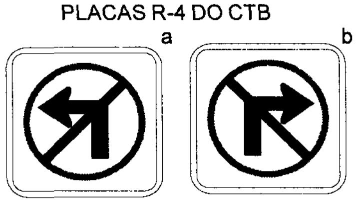


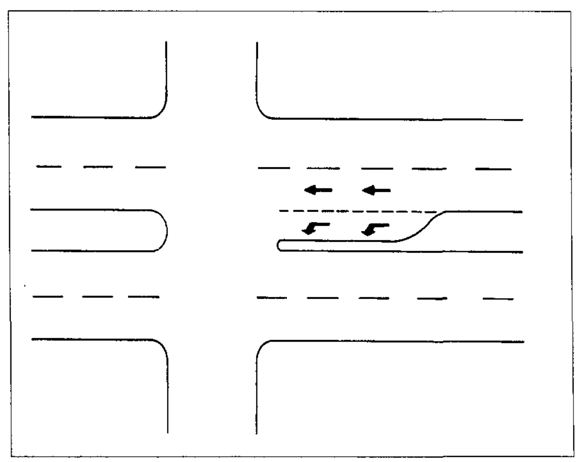
impede the utilisation of an all red vehicle traffic lights phase, as a means of introducing a pedestrian phase, then creating safe crossing conditions for pedestrians will require prohibiting right turns, using the appropriate signs, and effective enforcement.

In the extreme cases that require prohibiting right turns, the following precautions should be taken:

- place the sign on the right side of the road, in a highly visible position, preferentially using a sign with a diameter of 80 cm, mounted on a projecting arm;
- inform drivers of the alternative routes in the vicinity;
- guarantee effective, constant enforcement, to avoid systematic disobedience.

The prohibition of left turns is applicable whenever these movements would significantly reduce road capacity to intolerable levels, or cause accidents. Before prohibiting a turning movement, the engineer should verify if the geometric characteristics of the location can be improved to hold turning vehicles in a special, safe, lane and/or to create a special traffic light phase for these turning vehicles (Figure 10.29).

FIGURE 10.29
LEFT TURN WITH
ADDITIONAL WAITING LANE



The traffic engineer should assess the need to maintain the restriction during the whole day, or if turning movements could be permitted outside peak hours. Whenever a turning movement is prohibited, the best alternative route should be identified and drivers should be informed, so that they can follow the new route, obeying the signs and signals. The options for left turns include:

- transfer the turning movement to a less dangerous location;
- turn right one or two blocks before and carry out the left turn via less problematic roads, crossing the road in which the driver was originally travelling (see Figure 10.30); and
- turn right after the intersection and, via more right turns, in less saturated streets, cross the road in which the driver was originally travelling (Figure 10.31).

These prohibitions are only respected when there is continuous enforcement, except where or when the vehicle flow is so intense that it naturally limits turns.

FIGURE 10.30
ALTERNATIVE ROUTE
FOR LEFT TURNS

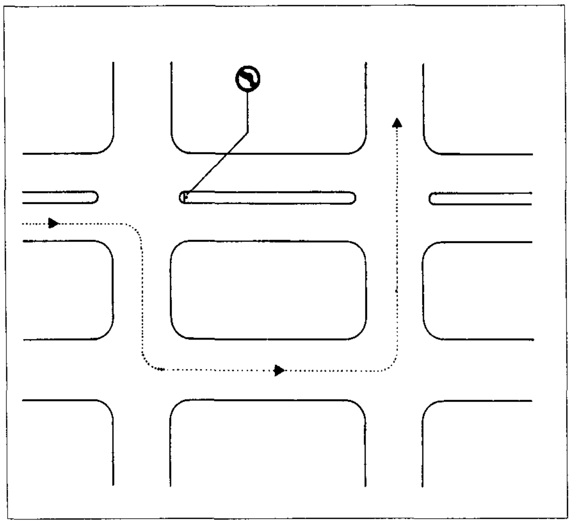
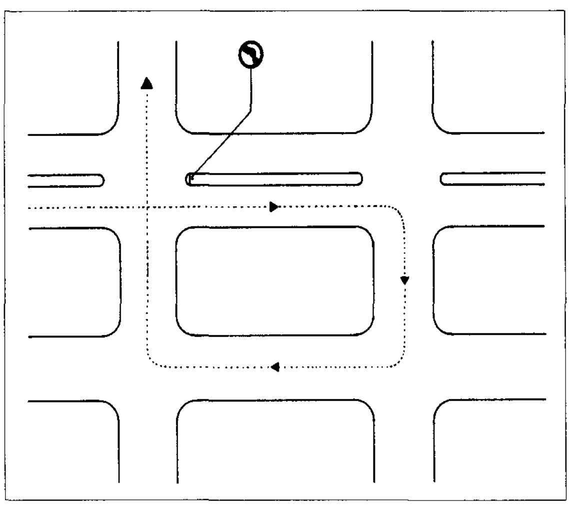


FIGURE 10.31
ALTERNATIVE ROUTE
FOR LEFT TURNS



Road Narrowing

This technique is sometimes considered as a speed reducer. When tested in São Paulo, however, no significant reductions were registered, except in cases where the narrowing of the street restricted capacity to the point of impairing the flow of traffic.

Narrowing does have the advantages of organizing the vehicle flow and having an effect similar to widening the sidewalks. The creation of an area for pedestrian use makes crossing easier (because the width of the roadway is reduced and the vehicle flow is channelised) and improves visibility between the two streets that meet at the intersection. The street should be narrowed using a concrete extension of the sidewalk, whenever possible, to maximise visibility for drivers and safety for pedestrians.

The use of studs instead of concrete does not exclude the parking of vehicles within the area reserved for pedestrians (see Figure 10.32). When built of concrete prisms, nighttime visibility is precarious. Some vehicles knock into these barriers, partly breaking them. The narrowing should be gradual, to ensure safe transition of vehicles between the different street widths.

Mini-Roundabouts

Mini-roundabouts were initially developed in England and later adopted by cities in other countries. They significantly reduce the frequency of vehicle conflicts at intersections where accident indices are high, priority is not well defined, and all vehicle approach volumes are small. They work by forcing the reduction of approach speeds and by organizing turning movements.

FIGURE 10.32
USE OF STUDS FOR
ROAD NARROWING

Mini-roundabouts are recommended for intersections where priority signs are not effective and the traffic volume does not justify installing traffic lights. When these devices are in operation, drivers "negotiate" the right of way at lower speeds; usually, the vehicle already in the roundabout has priority, which is the rule in Brazil (CTB, Chapter III, Clause 29).

The model developed by the CET and used in hundreds of intersections in São Paulo has a yellow circle as its principal element, painted in the centre of the intersection. Its diameter is between 1 m and 8 m, and it has a second circle of unidirectional reflective studs, just inside the painted circle (Figure 10.33).

The following recommendations apply to the use of mini-roundabouts:

- They should not be installed on regular bus or truck routes; they create problems for turning movements of large vehicles, which encroach upon the circle, cancelling its function. (Sometimes this is advantageous, permitting necessary truck turning movements, with the installation of mini-roundabouts at junctions where rigid obstacles would impede these movements).
- The location should be flat to permit good visibility of the painted circle and the studs from a distance of at least 50 m for drivers approaching the junction.
- The diameter of the mini-roundabout should be 0.35 of the diameter of the largest circle that may be inscribed within the area of the intersection, without passing the limits defined by the kerbs.[4]
- The circles should be accompanied by: (i) vertical warning and regulatory signs; (ii) road markings to channelise traffic along the approaches and arrows around the outside of the circle; and (iii) a "vision-project" (see section 10.7), to guarantee the effectiveness of this device.
- Concrete prisms may be used in very wide intersections to produce a configuration similar to that of conventional roundabouts, but with a much lower installation cost (Figure 10.34).

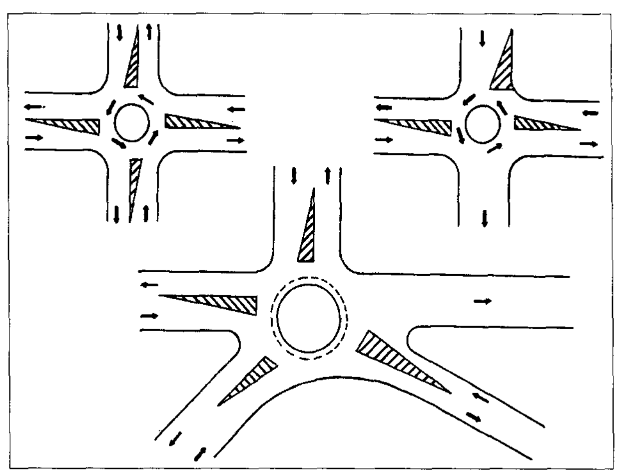
The first 22 mini-roundabouts installed in São Paulo reduced approach speeds 20 to 30%. Comparing the last year before implementation with the first year after, accidents were reduced from 142 before (108 DO, 27 PI and 7 PE) to 24 after (20 DO, 1 PI and 3 PE), with outstanding results for personal injury accidents, which were reduced from 27 to only 1.

Figure 10.35 shows several different schemes for mini-roundabouts.

FIGURE 10.33
MINIROUNDABOUT WITH STUDS IN SÃO PAULO

FIGURE 10.34
MINIROUNDABOUT WITH CONCRETE PRISMS

FIGURE 35
EXEMPLES OF MINIROUNDABOUTS



10.5 Channelisation of Pedestrian Traffic Flows

Guardrails

Guardrails guide pedestrians to cross the street in safer places than the ones they would otherwise choose. These new locations may be intersections or points along a roadway section, with or without traffic lights and marked pedestrian crossings. Sometimes there is nothing more than the guardrail, which serves simply to indicate a safer crossing location. Important recommendations for the use of guardrails are:

- Channelisation, using guardrails, should always have associated vertical orientation signs for pedestrians, to alleviate the aggressive impression that may result from obliging them to leave their preferred path.
- At street corners, guardrails should be extended to "join" the pedestrian as he or she approaches the corner, to avoid a choice of crossing on the wrong side or walking in the roadway, near the kerb, and crossing in an inappropriate place. Figure 10.36 indicates the channelisation scheme normally recommended.
- Guardrails should not be installed on streets with many vehicle accesses to buildings that must be kept open. Since the guardrails would have to be discontinuous to avoid blocking the accesses, pedestrians would continue to cross at inadequate locations.
- Channelisation with guardrails should always be installed on both sides of the street (Figure 10.36). If installed on only one side, pedestrians may cross from the other side and then encounter the guardrail, an obstacle that may prevent them from leaving the roadway.
- Guardrails should not be installed very close to kerbs because some pedestrians may cross diagonally and be trapped in the roadway, with risk of being squashed against the guardrail by vehicles. The guardrail should be set back about 0.50 m from the kerb, leaving only the extremities near the kerbs. The half-metre is sufficient to accommodate a pedestrian on the sidewalk, yet in a position that will discourage the repetition of improper crossings (Figure 10.37).
- Applying the two previous criteria, guardrails are not recommended on median strips less than 1.50 m wide.
- Guardrails should be at least 1.1 m high, sufficient to avoid pedestrians jumping or climbing over them.

FIGURE 10.36
USE OF GUARDRAIL TO CHANNELIZE PEDESTRIANS

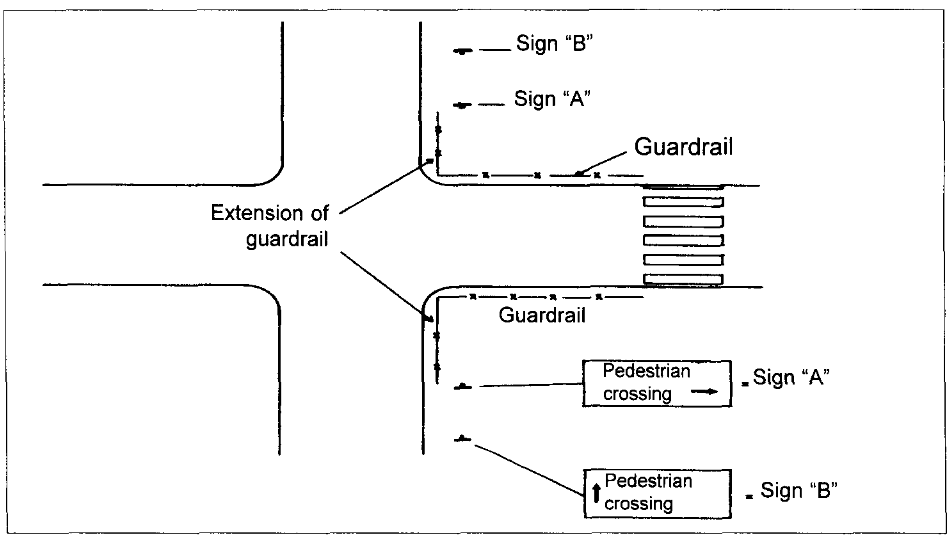
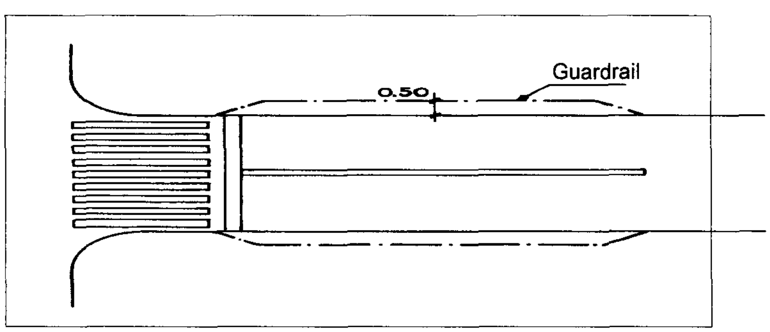


FIGURE 10.37
GUARDRAILS LOCATED AWAY FROM KERB



The guardrail may be flexible or rigid. Rigid guardrails are more effective and should be used unless budget limits rule them out or the installation is temporary (for example, during public works). Many types of guardrail are available. Acceptable guardrails, when near pedestrian crossings, must not block visibility between drivers and pedestrians, especially small children.

Flower Boxes

Flower boxes have the same objective as guardrails: to channelise pedestrians toward safer crossings. They are a natural, decorative, and non-aggressive element that may be easily integrated into the urban scene (Figure 10.38). Flower boxes should be used whenever possible, especially in areas with wide streets and median strips. The observations concerning guardrails are also applicable to flower boxes, except the last one–height.

The vegetation has to be kept at an acceptable height, meaning the set of concrete plus plants should not exceed 1.0 m, to avoid blocking mutual visibility between pedestrians and drivers. Small plants, with little or slow growth, are preferred. Frequent pruning and other upkeep are required.

***Pedestrian Footbridges and Underpasses* (Grade-separated pedestrian crossings)**

This type of equipment, when well designed, offers total physical separation of pedestrian and vehicle movements and eliminates the risk of accidents for the pedestrians who use it. By removing vehicle-pedestrian conflicts, they also maximise the vehicle flow capacity of the carriageway.

Footbridges are built over streets and roads. There are two types of underpasses: (i) those where pedestrians cross at street level under an elevated section of road; and (ii) underground passages, with stairs or ramps.

Of the three options, the ground level underpass is the only one that requires no additional physical exertion by pedestrians. It may, however, leave them in conflict with some vehicle traffic flows, which continue at ground level. Footbridges and underground passages require physical effort of pedestrians but totally eliminate accident risk for those who use them.

Footbridges have several advantages when compared to underground passages:

- they do not interfere with underground public service networks;
- they are cleaner and more aesthetically acceptable for pedestrians (there are exceptions where the underground passage has been transformed into a small shopping mall);
- they offer less possibilities of mugging;
- they usually have lower building costs (sometimes as little as 10% of the cost of an equivalent underground underpass).

Pedestrian underground passages have the following advantages, when compared with footbridges:

- a smaller change of level for pedestrians, requiring less time and exertion; between 3.0 m and 3.5 m instead of 5.0 m to 5.5 m for footbridges;
- fewer aesthetic objections from an urbanistic point of view. (However, footbridges in Salvador, Brazil, have a uniquely aesthetic design, which may invert this idea); and
- more comfort in adverse weather conditions.

In general, underground passages are used more in and around city centres, while footbridges are located away from the centre where more space is available for the access stairs and ramps (there are, however, exceptions). Both may be introduced in existing street networks. Ground level underpasses normally require decisions at the planning stage for the construction of new roads.

A fundamental problem of underground passages is the need to remodel underground public service networks, which leads to very high construction costs.

FIGURE 10.38
USE OF FLOWER-BOXES
TO CHANNELISE PEDESTRIANS

The minimum acceptable internal height for underground (or enclosed) passages is 2.5 m, of which 2.2 m should be entirely free of obstacles. When access is via ramps, the slope should not exceed 10%.

The maximum concentration of pedestrians for all bridges and passages is usually considered 1.4 pedestrians/m^2, with a speed of 3 to 4 km/h. This results in a capacity of 60 pedestrians/minute (or 3.600 pedestrians/hour) per metre of width. Higher flows have been registered for a full hour, such as 4,900 pedestrians/hour in the Port Authority bus terminal in New York, and for short periods, such as the equivalent of 7,700 pedestrians/hour registered in a 5-minute period in the CY Stephens Auditorium in the U.S. State of Iowa (Transportation Research Board, 1985, p. 13-2).

Footbridges and underground passages require additional physical effort of pedestrians to change level and span the extra walking distance. Both factors discourage use of this type of equipment. For footbridges and underground passages to be successful, they should be located close to the paths chosen by pedestrians. Whenever possible, they should be fully integrated within the urban design, naturally attracting pedestrians to use them or even guiding pedestrians to their entrances and blocking or hiding unsafe alternative crossings. It may be necessary to install guardrails/barriers to channelise the pedestrians. Where there are large numbers of users and financial resources permit, escalators (moving staircases) are recommended – such situations are likely to occur in areas surrounding major bus and train terminals.

In Madrid, in 1972, observations were made of pedestrians using underground passages to cross roads with 6 lanes of traffic and flows of 40.000 to 100.000 vehicles/day. Crossing via the underground passage added, on average, one minute to crossing time, compared to crossing at street level, so that only 50% of pedestrians chose the underground passage. However, during peak hours, when high traffic flow resulted in equal crossing times, 90% of pedestrians used the underground passage. The United Kingdom's Department of the Environment found that if the time to cross via a footbridge was not more than 75% of the time to cross at street level, almost all pedestrians would use the footbridge.

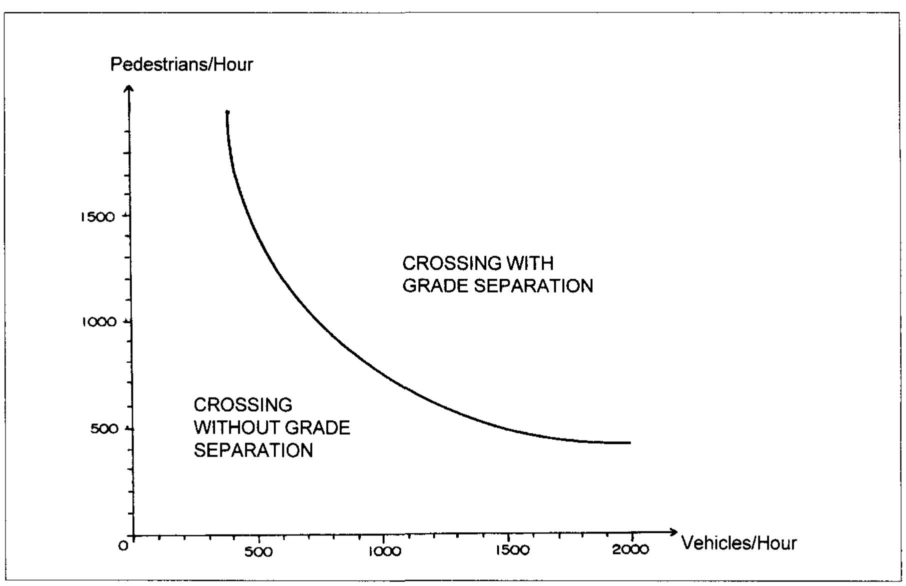
Figure 10.39 shows a general criterion to evaluate when a grade separated crossing should be provided, for vehicle speeds of up to 60 km/h. The particular characteristics of each place should also be considered.

10.6 Safety Barriers

The objectives of safety barriers are to (OECD, 1975):

- prevent any out-of-control vehicle from causing injury or damage to people or property outside the vehicle;
- prevent light vehicles and--financial resources permitting--heavy vehicles from unintentionally entering dangerous zones;
- redirect vehicles that come into contact with the barrier, giving them a direction approximately parallel to the barrier alignment;
- keep impacts received by occupants of out-of-control vehicles within supportable limits;
- minimise total damage costs; and
- absorb the impact when a vehicle crashes into the barrier, preventing the vehicle and the barrier from being transformed into a threat to the safety of other traffic.

FIGURE 10.39
CRITERIA FOR IMPLEMENTATION
OF PEDESTRIAN FOOTBRIDGES



Source: DIRECTION DES PONTS ET DE LA CIRCULATION ROUTIÈRE - PARIS.

The concept of redirecting out of control vehicles is used to prevent vehicles from passing the barrier, which acts on the vehicle at a height near its centre of gravity. This results in the profiles of the most commonly used barriers.

Safety barriers are classified as flexible or rigid.

Flexible Metallic Barriers

Flexible metallic barriers are installed near rivers, streams, embankments, etc. They are also used to divide carriageways, and as protection near columns of bridges, transitions from highways to narrow bridges, sign-supporting porticos, and typical locations where uncontrolled vehicles leave the roadway, such as curves.

The following recommendations apply to barriers:

- Barriers should not be installed where an area exists by the roadside where vehicles can gradually reduce their speed.
- On highways with kerbs, the part of the barrier designed to make contact with the vehicle should be on the same vertical plane as the kerb, or in front of it, to avoid vehicles crashing into the kerb and then bouncing over the barrier or falling on top of it. If water drainage needs permit, it is preferable to lower the kerb and move the barrier further back.
- The ends of flexible metallic barriers should be anchored to some structural element of the highway, if a convenient one exists, or in the ground, to avoid the "guillotine" effect, when the barrier cuts through the vehicle longitudinally (Figure 10.40).
- When necessary, openings should be left for pedestrians and cyclists to cross the road, as shown in Figures 10.41a to 10.41e. Whenever possible, the openings should be arranged to place approaching pedestrians and cyclists always looking towards oncoming vehicles.

Depending on their capacity to absorb kinetic energy, metallic barriers are classified as:

- *semi-flexible barrier:* with malleable elements connecting the main beam of the barrier to the rigid (wooden or metallic) supporting posts. This is the most common type.
- *flexible barrier:* installed with supporting posts that offer little resistance, and which become anatomically deformed when hit by an out-of-control vehicle.

Rigid Barrier (Concrete barrier)

This type of barrier is usually made of reinforced concrete and is characterised by being undeformable under impact. Its principal uses are to separate opposing traffic flows on two-way roads with no median strip, to protect sign-supporting porticos and bridge columns, and to contain traffic during transition from highways to narrow bridges. They are also installed to intentionally block vehicle or pedestrian movements, for example, on a median strip to oblige pedestrians to use a footbridge.

Some recommendations concerning rigid barriers follow.

- The New Jersey profile is the most highly recommended in general, and the most adequate for small vehicles.
- The profile should be constant, with no alterations in dimensions or angles, to avoid reducing the efficiency of the barrier.
- The barriers should be continuous, with their extremities designed to provide smooth transitions, eliminating all possibility of frontal impact of vehicles with parts exposed to the traffic.
- Prefabricated barriers are preferable to those built on site. The prefabricated ones may be rapidly put in position, without interfering with traffic flow, and usually have a more uniform surface.
- On highways with opposing traffic flows separated by wide, horizontal median strips, the barrier should be installed along the centre of the median strip, making use of the strip as an escape area for out-of-control vehicles that leave the carriageway.

When compared with metallic barriers, rigid barriers have advantages and disadvantages:

Advantages

- they last longer (greatest advantage);
- they have almost no maintenance costs;
- they fit more easily in the urban context; and
- theoretically, it is impossible to pass through or over them.

Disadvantages

- They are not recommended for places where the angle of approaching vehicles is more than 20/25°; at greater angles, rigid barriers do not absorb strong impacts.
- They require precautions for drainage of rainwater.
- Only prefabricated barriers may be easily removed.

FIGURE 10.40
SCHEME FOR ANCHORING METAL
BARRIER IN THE GROUND

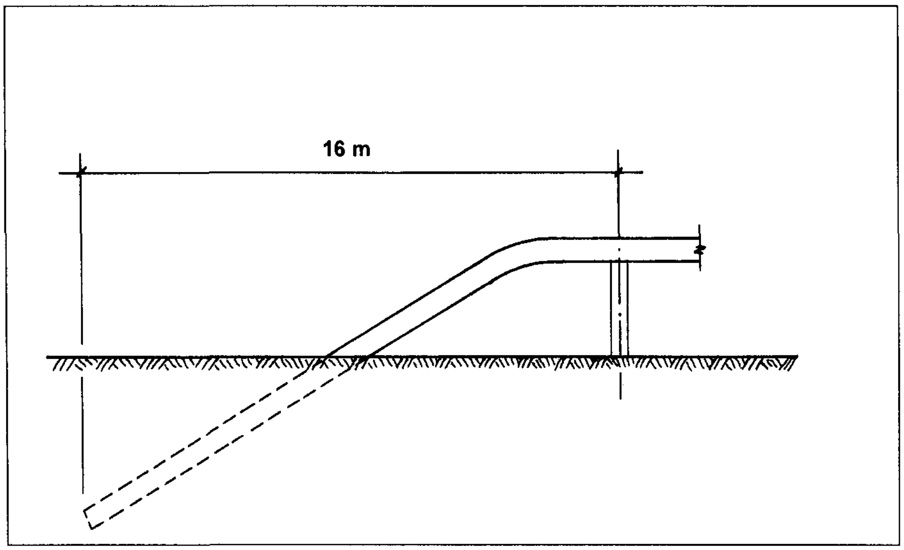


FIGURE 10.41a
TWO-WAY HIGHWAY WITH
MEDIAN AREA OF INSUFFICIENT WIDTH

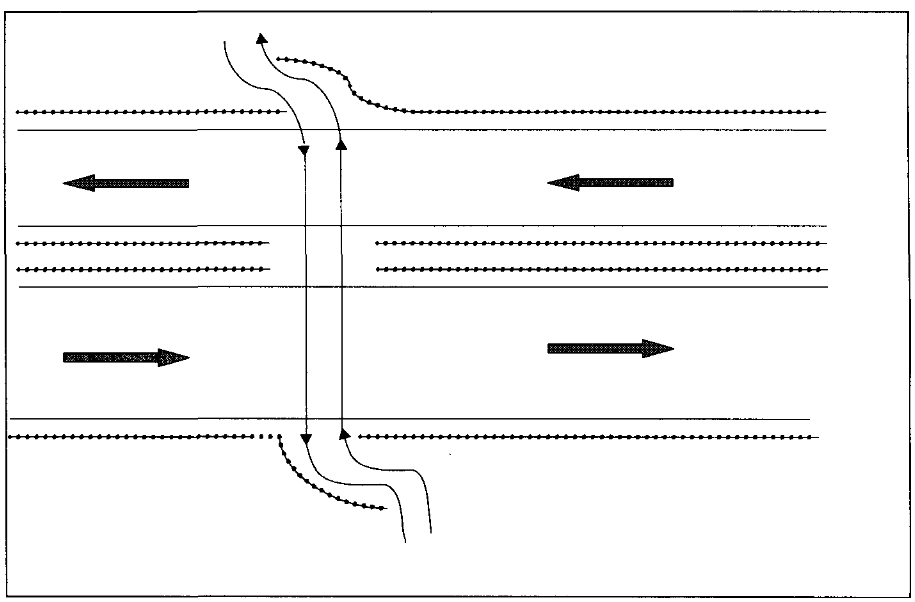


FIGURE 10.41b
TWO-WAY HIGHWAY WITHOUT
MEDIAN SEPARATOR

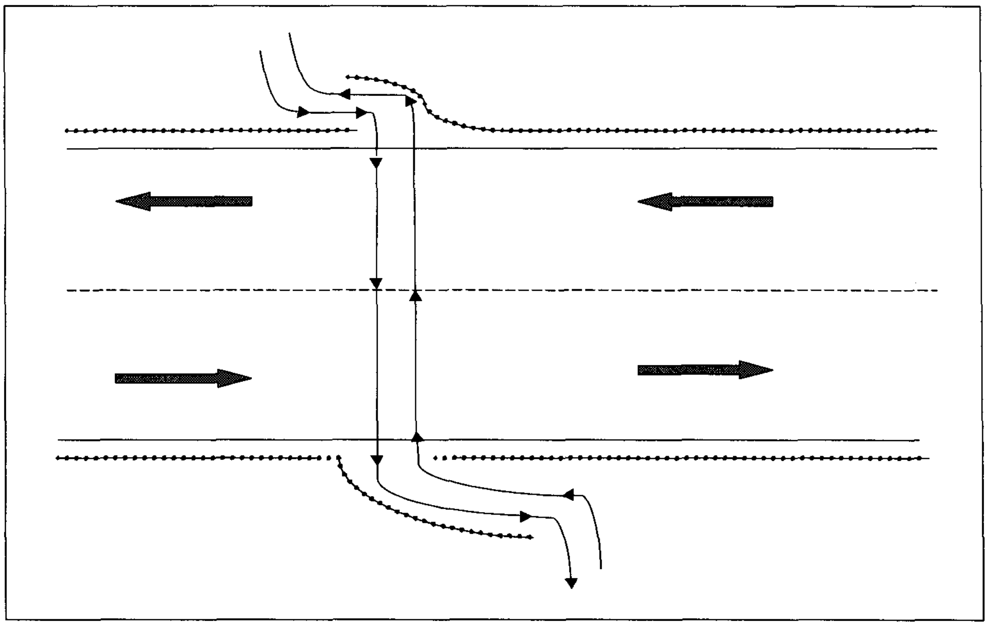


FIGURE 10.41c
TWO-WAY HIGHWAY WITH MEDIAN AREA OF
INSUFFICIENT WIDTH FOR OPENING THE BARRIERS
BUT WITH SUFFICIENT DISTANCE BETWEEN THE
BARRIERS FOR PEDESTRIAN AND BICYCLE MOVEMENTS

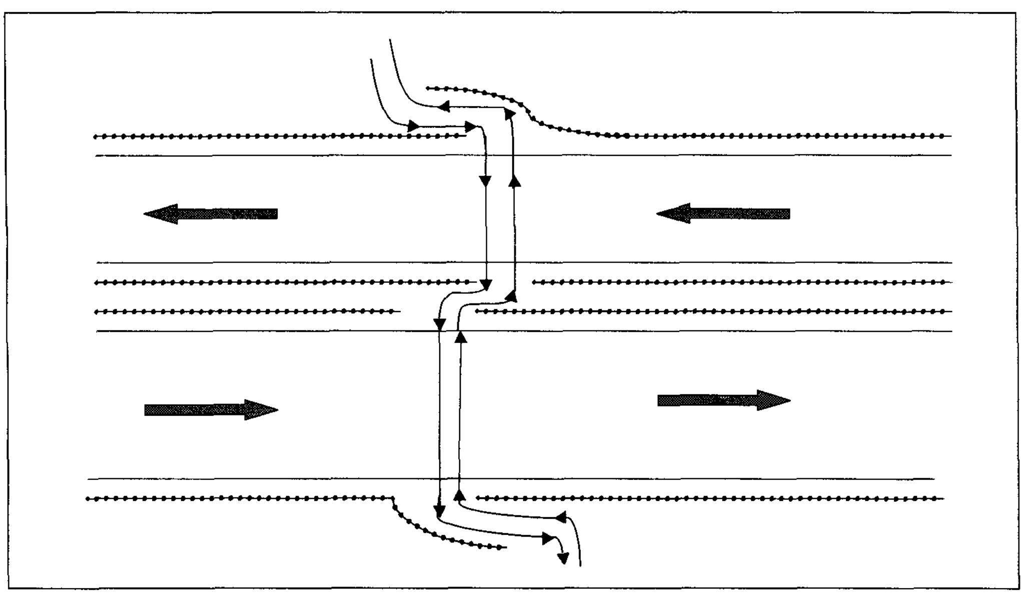


FIGURE 10.41d
TWO-WAY HIGHWAY WITH MEDIAN AREA
WIDE ENOUGH FOR OPENING BARRIERS

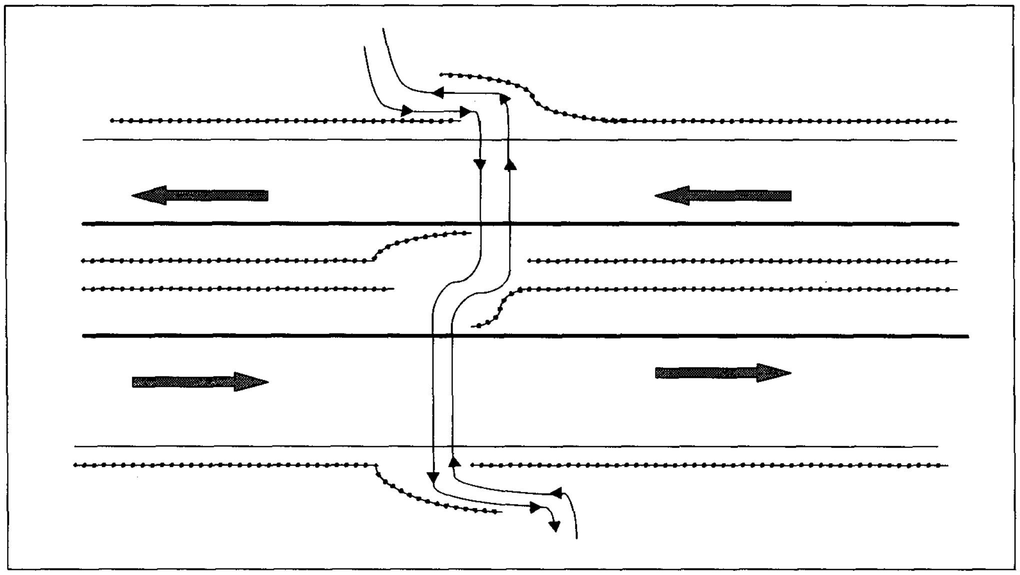


FIGURE 10.41e
ONE-WAY HIGHWAY

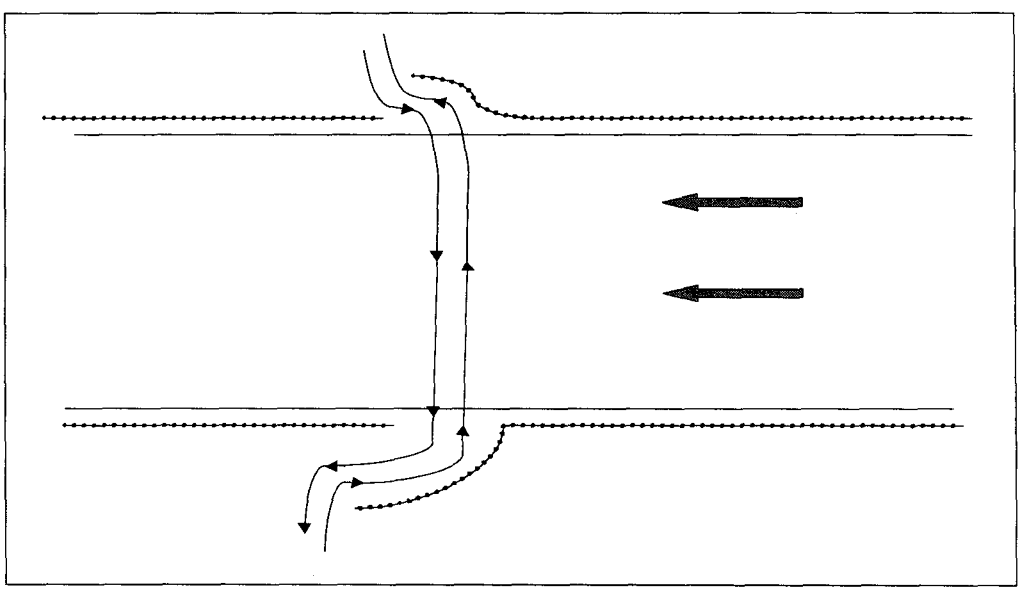


Table 10.7 shows the criteria for choosing between flexible and rigid barriers, resulting from a study of the influence of the width of the median strip over the probable impact angle.

Figure 10.42 presents criteria for deciding if central safety barriers are needed, using the correlation between Average Daily Traffic (ADT) and the width of the median strip.

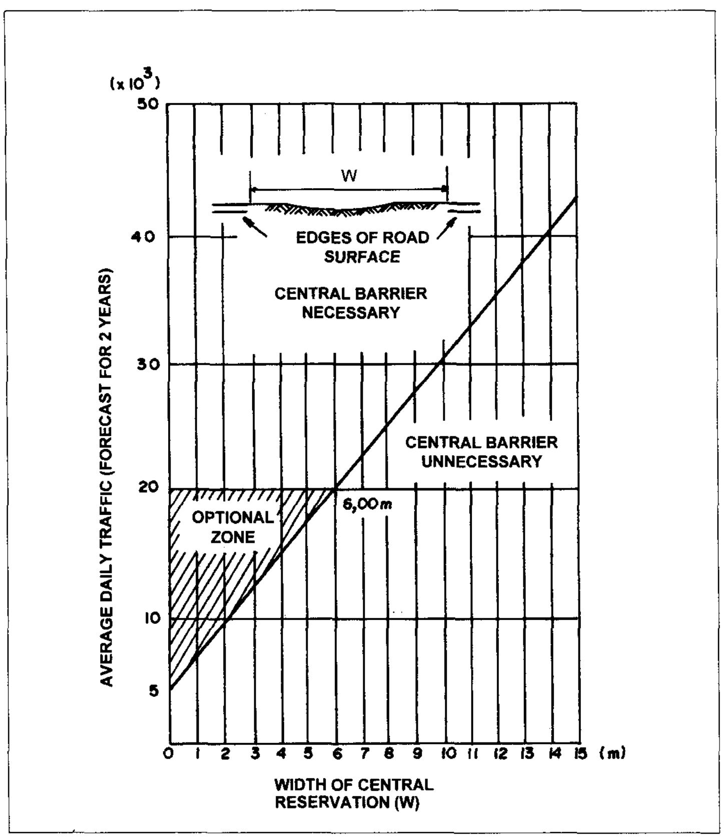
Figure 10.43 presents proposals by OECD to determine the necessity for safety barriers at the roadside for roads built adjacent to embankments, depending on the height and slope of the embankment.

TABLE 10.7
RECOMMENDED BARRIER TYPES
FOR DIFFERENT MEDIAN WIDTHS

WIDTH OF MEDIAN AREA	TYPE OF BARRIER
UP TO 5.40m	rigid
5.40 a 7.20m	rigid or flexible
7.20 a 9.00m	flexible

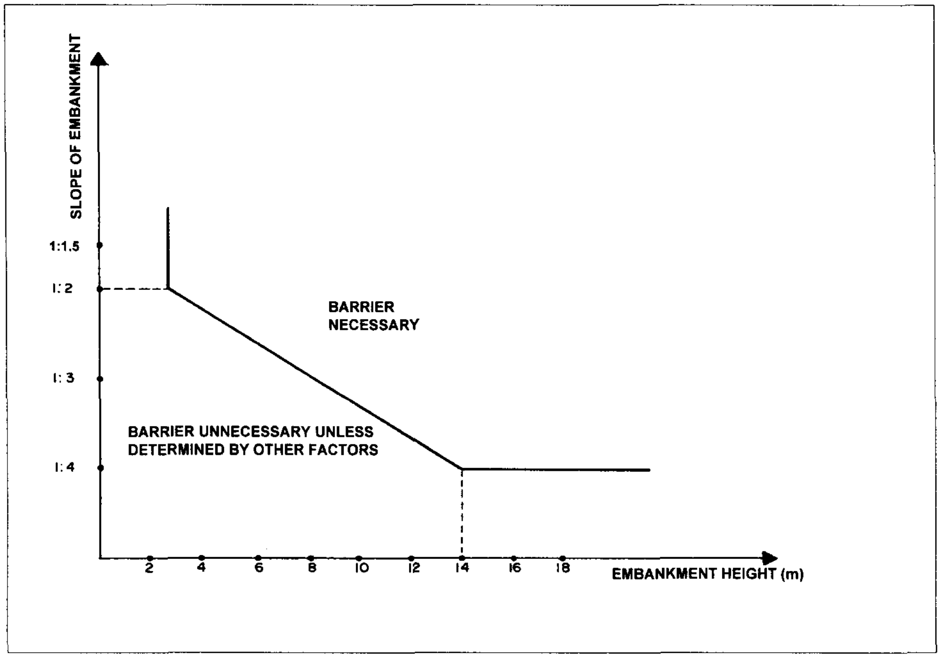
Source: Giamusso,1992, p.19.

FIGURE 10.42
NEED FOR CENTRAL BARRIER AS A FUNCTION OF AVERAGE DAILY TRAFFIC AND WIDTH OF CENTRAL RESERVATION (ADOPTED BY THE BRAZILIAN NATIONAL ROADS ADMINISTRATION – DNER)



Source: Giamusso, 1992, p.19.

FIGURE 10.43
NEED FOR LATERAL BARRIER AS A
FUNCTION OF EMBANKMENT HEIGHT



Source: CET (1978), v.7, p.35.

10.7 Illumination and Visibility

Darkness increases the danger for drivers and pedestrians. In São Paulo, for example, 40% of serious traffic accidents occur at night, when only 20% of vehicle trips occur. Many of the nocturnal accident victims are pedestrians.

The low intensity of street lighting makes it difficult for drivers to see pedestrians. Pedestrians may still see vehicles (or at least their headlights) at night, but it is much more difficult for them to judge vehicle distances and speeds at night than during daylight. Thus pedestrians frequently make incorrect evaluations, especially as many drivers use only parking lights instead of the low-beam headlights required by law.

Consequently, improvements in street lighting usually result in reduction of nocturnal accidents, particularly those involving pedestrians. Studies carried out in England, at locations where street lighting was improved, demonstrated a reduction of 43% in nocturnal pedestrian accidents and 10% in other types of nocturnal accidents. Fatal nocturnal accidents were reduced by 46% and serious non-fatal nocturnal accidents were reduced by 27%. This occurred despite an increase in daylight accidents, on the same streets. A summary of the data obtained in these studies is presented in Table 10.8.

Typical urban street lighting is sufficient to provide comfort and a certain degree of personal safety for pedestrians, discouraging the action of muggers. However, the intensity of street lighting is normally insufficient to guarantee traffic safety or to make traffic signs visible to drivers travelling within the speed limits. Many signs are reflective and designed to become visible under the action of car headlights. However, others are non-reflective or are positioned outside the area illuminated by headlights and pass unnoticed by drivers at night.

TABLE 10.8
NUMBERS OF INJURY ACCIDENTS BEFORE AND AFTER INTRODUCTION OF PUBLIC LIGHTING IMPROVEMENTS (ENGLAND)

PERIOD		PEDESTRIANS	OTHERS	TOTAL
Day	before	319	929	1.248
	after	334	1.091	1.425
Night	before	159	346	505
	after	91	312	403
Accidents after/before				
Day		1.05	1.17	1.14
Night		0.57	0.90	0.80
PERIOD		Fatal Injury	Serious Injury	Minor Injury
Day	before	16	224	1.008
	after	17	244	1.164
Night	before	28	123	354
	after	15	90	298
Accidents after/before				
Day		1.06	1,09	1.16
Night		0.54	0.73	0.84

Source: CET, Technical Bulletin No. 27, p.79.

Use of Low-beam Headlights

The Brazilian Traffic Code (Chapter III, Clause 40) requires the use of low-beam headlights at night. Many drivers in Brazilian cities, however, drive with only their parking lights on.

Traffic signs and road markings should normally be made using reflective materials. Signs are made with paint or reflective film; microspheres of reflective glass should be added to paint used in road markings and studs should contain a retro-reflective element.

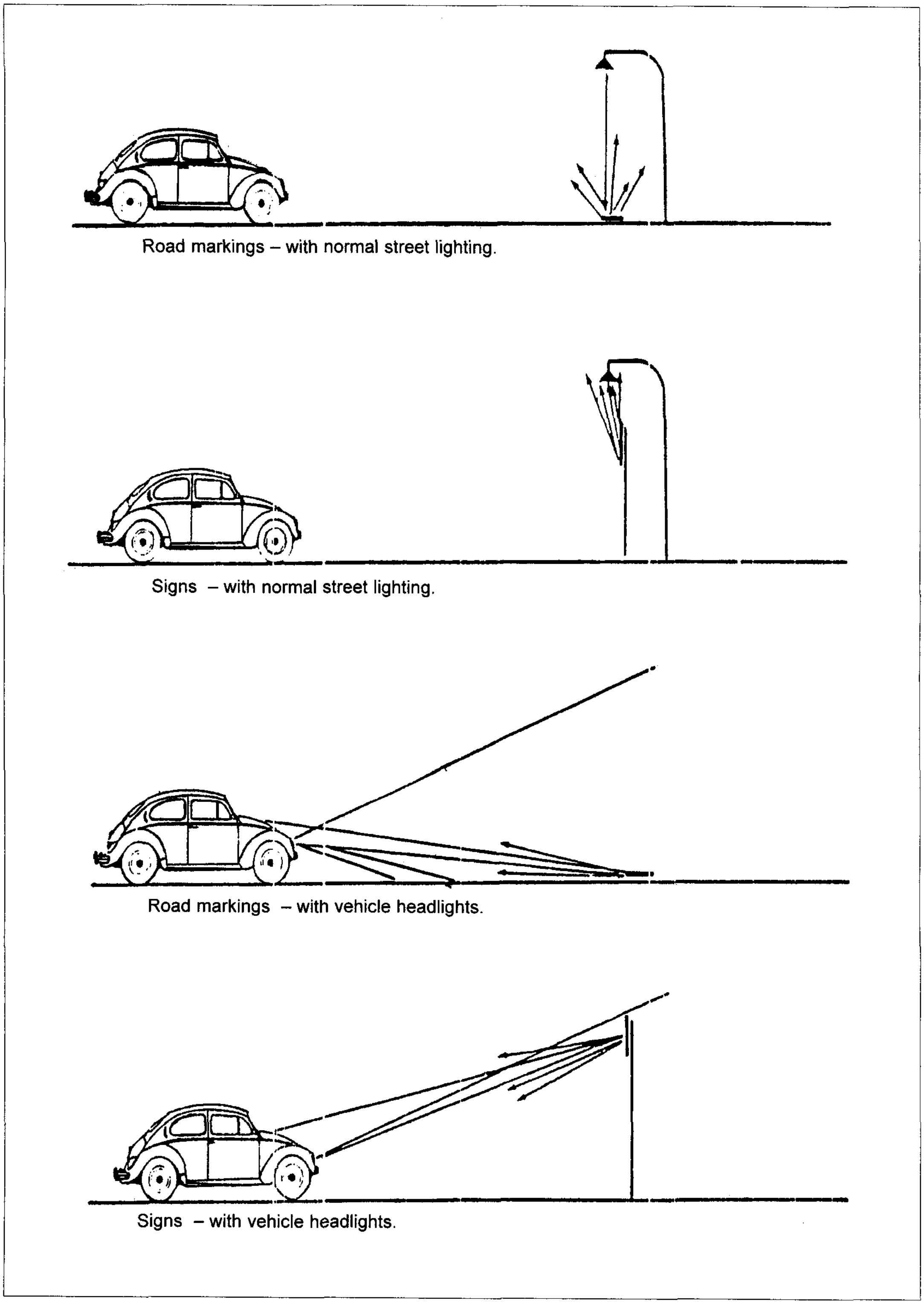
This type of material has the property of reflecting incident light directly back to the source. Thus light emitted from vehicle headlights is reflected towards drivers, while street lighting is not. Figure 10.44 illustrates this concept.

Some of the principal advantages of the use of low-beam headlights in urban areas are as follows:

- they improve vision of pedestrians by drivers and of vehicles by pedestrians and help pedestrians to evaluate vehicle speeds and distances;
- at intersections, low-beam headlights act as an extension of the vehicle, since the light they emit may be seen by drivers of vehicles on the other approach, well before arrival at the intersection, effectively increasing the distance and time available for braking (Figure 10.45);
- the vehicle with low-beam headlights is more visible to other drivers, facilitating their perception of the position of the vehicle in the roadway.
- better illumination: the driver is less hampered by variations of street lighting that occur during typical urban trips, and has better vision of any obstacles that may appear; and
- improved visibility and legibility of signs and road markings.

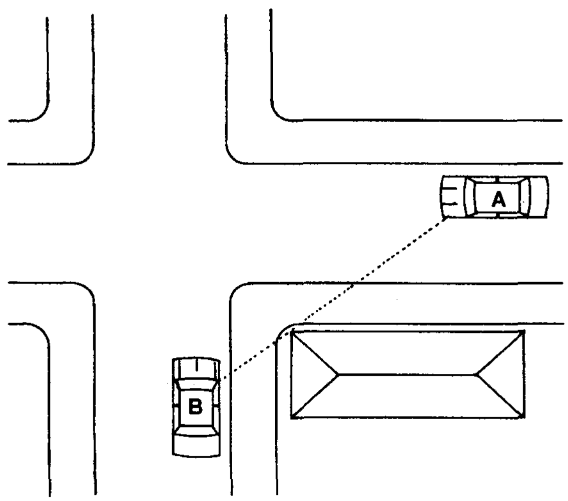
The use of low-beam headlights should therefore be encouraged through media campaigns, signs, and posters that explain their importance, and by police enforcement.

FIGURA 10.44
REFLECTIVE SIGNS AND ROAD MARKINGS WORK
ADEQUATELY ONLY WHEN ILLUMINATED BY VEHICLE HEADLIGHTS

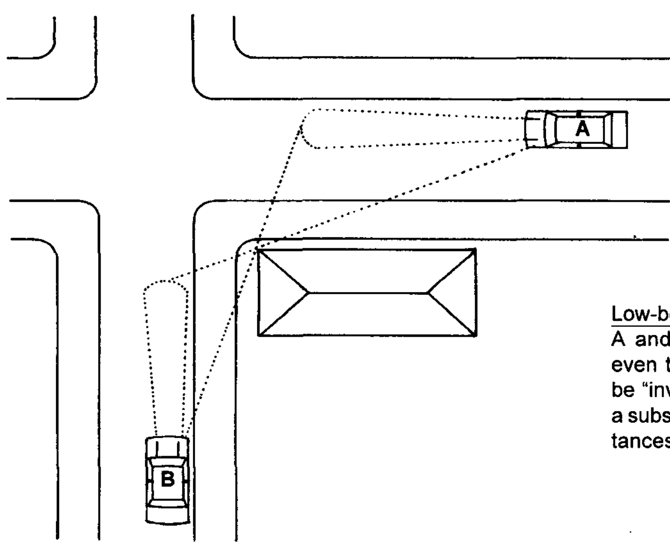


Source: CET, Technical Bulletin Nº 27, p.67.

FIGURE 10.45
INCREASE OF INTERVISIBILITY WITH
THE USE OF LOW-BEAM HEADLIGHTS



Headlights off
A and B only perceive the presence of the other when their vehicles enter the direct visibility area. Braking distances are insufficient for speeds greater than 20 km/h in typical intersections.



<u>Low-beam headlights on</u>
A and B see the headlight beams even though the drivers continue to be "invisible" to each other. There is a substancial increase in braking distances.

Source: CET, Technical Bulletin Nº 27, p. 70.

In São Paulo, a somewhat sporadic television and radio campaign produced a gradual increase in use of headlights, from 7.7% of automobiles with low-beam headlights on in 1984, to 21.5% in 1987, without any increase in police enforcement. Further campaigns during the last 15 years and the introduction of stiffer penalties in the 1998 Brazilian traffic code have resulted in a much higher use of headlights in the city.

Headlights must be well regulated to correctly illuminate the roadway yet avoid blinding drivers in oncoming traffic. The importance of correct adjustment of headlights should be emphasized during campaigns, and drivers should be told where this service is available. The use of headlights should also be encouraged during daylight hours when impaired visibility occurs. This happens during heavy rainfall and fog and at dawn and dusk, when the sun's rays are almost horizontal and blind drivers, making oncoming vehicles almost invisible unless they have their headlights on.

Some bus and other vehicle operators in the United States require their drivers to keep their head- and tail-lights on at all times, after pilot tests showed that action led to a reduction in accidents with company vehicles of about 10%. Some European countries, for the same reason, now require that all vehicles be equipped with a switch that couples these lights to the ignition, switching them on automatically when the motor is started, and off when the motor is turned off.

These examples of themes for campaigns demonstrate the importance of disseminating the contribution of traffic engineering to the welfare of the population.

Treatment of Illumination and Visibility Problems

Some applications of better illumination and visibility to improve traffic safety are described below.

Installing a "vision-project"

This consists of using yellow lines or other devices to prohibit the parking of vehicles near intersections, to increase visibility of vehicles that pass through the intersection. The prohibition is limited to places and parking spaces where there is significant interference with visibility (Figures 10.46 a and b).

FIGURE 10.46a
EXAMPLES OF "VISION-PROJECT"

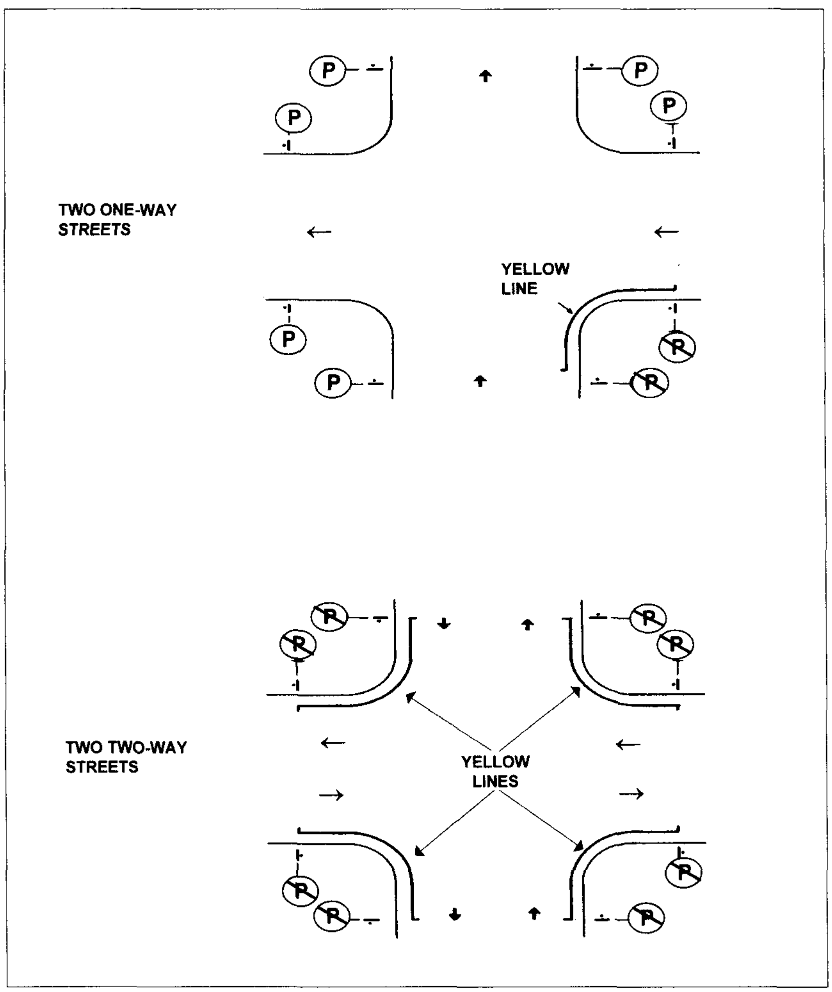
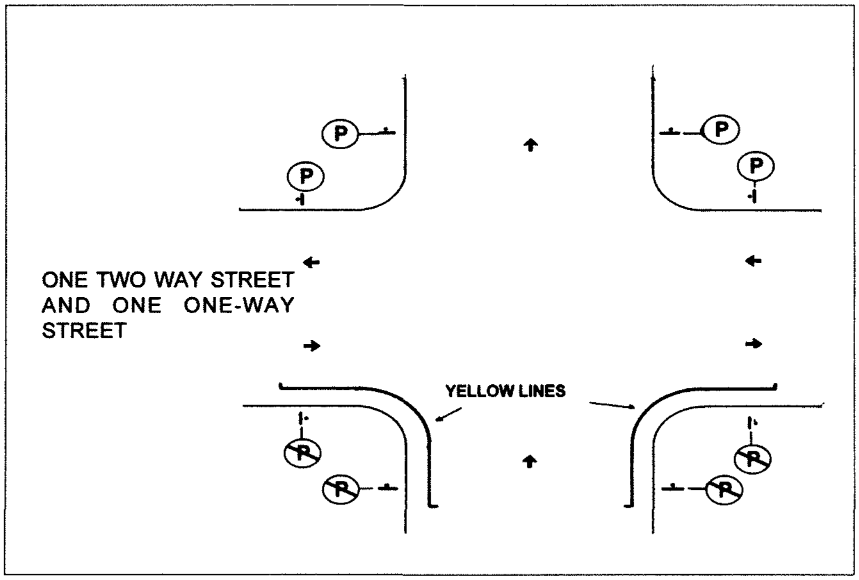


FIGURE 10.46b
EXAMPLES OF "VISION-PROJECT"



Special illumination of transverse obstacles

Speed humps, transverse speed reducing channels, street-level railway crossings, and other obstacles may receive special illumination to improve nocturnal visibility, similar to that described in the next item for pedestrian crossings (Figure 10.47).

Special illumination of pedestrian crossings

Traffic safety requires that drivers perceive pedestrian crossings and the presence of pedestrians in time to stop their vehicles. General street lighting is often insufficient for this purpose, and special illumination can be used to make pedestrian crossings stand out clearly from the background. High intensity lamps installed over the pedestrian crossing can notably improve visibility.

The CET in São Paulo studied projects in other countries and developed a standardized project with high efficiency and low cost, subsequently installed in 200 locations in 1997-1998. Preliminary evaluation suggests significant reductions in both pedestrian and non-pedestrian accidents and reduced pedestrian fear of muggings.

One-way streets allow positioning the light source to illuminate pedestrians from the side, rather than from above, making pedestrians much more visible to drivers of approaching vehicles. On two-way streets, the technical feasibility of this solution depends on the particular characteristics of each location. In some cases, the position of the light sources may blind drivers of oncoming vehicles.

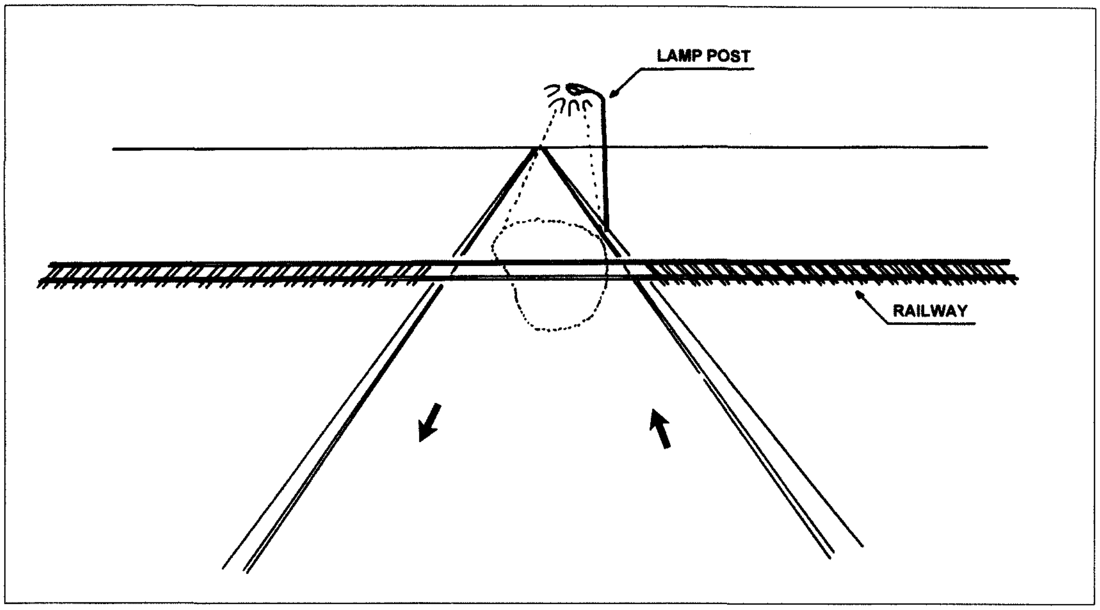
Traffic authorities should work with the media, schools, and workplaces to promote the use of light-coloured clothes at night, as they make pedestrians much more visible to drivers, reducing the risk of pedestrian accidents.

Reinforced signs and road markings for islands and median strips

There are several ways of improving the visibility of these elements.

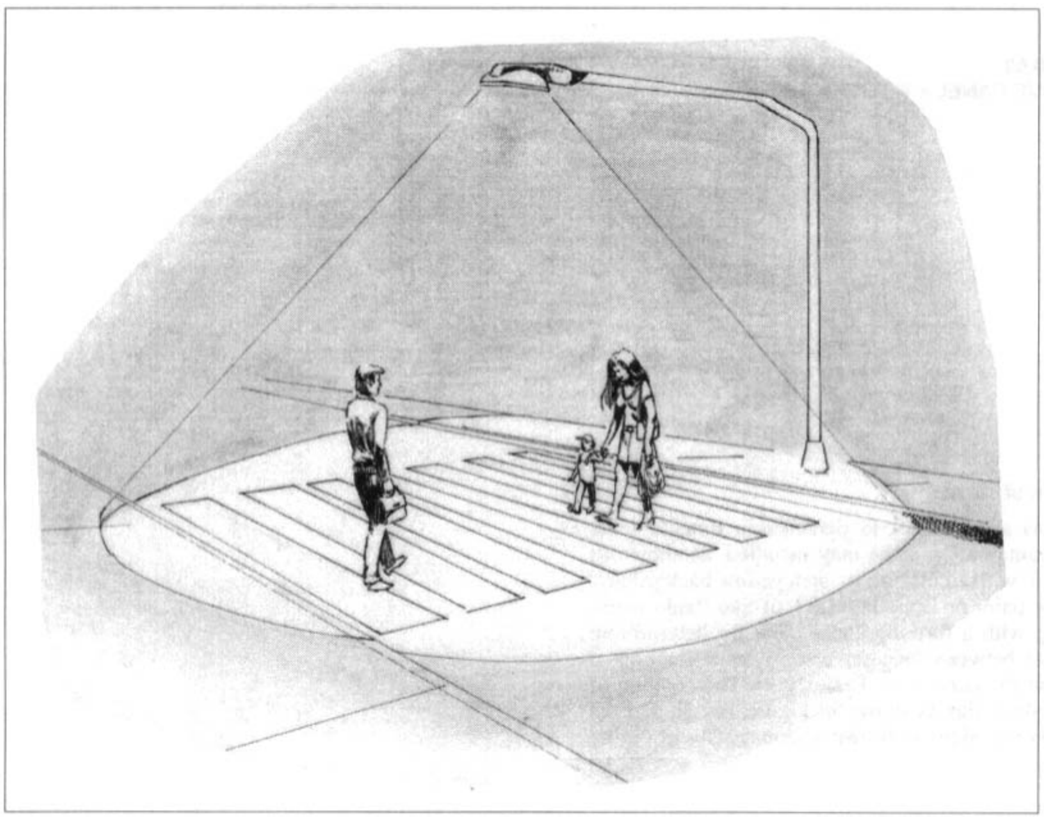
- Cover the kerbs with reflective paint or, if unavailable, white paint.
- Install reflective elements, such as reflective studs, on the kerbs (Figure 10.49).
- Install special vertical visual devices on pedestrian refuges, such as the *bollards* used in London. These are approximately 1.2 m high. (To minimize damage to vehicles, they should be made of plastic, fiberglass, or similar materials). The bollards have a sign, made of translucent material, indicating on which side vehicles should pass, with illumination, enclosed within the casing, to make them stand out clearly at night (Figure 10.50). As an alternative, a flashing yellow light may be installed. However, this type of light tends to decrease the visibility of the refuge to drivers. If electric lighting cannot be used at the refuge, a sign with reflective material should be installed (Figures 10.51 and 10.52).

FIGURE 10.47
SPECIAL ILLUMINATION OF OBSTACLES



Source: CET, Technical Bulletin Nº 27, p. 95.

FIGURE 10.48
SPECIAL ILLUMINATION OF PEDESTRIAN CROSSINGS



Drawing: Renê José Micheletti.

FIGURE 10.49
USE OF REFLECTIVE
STUDS ON KERB

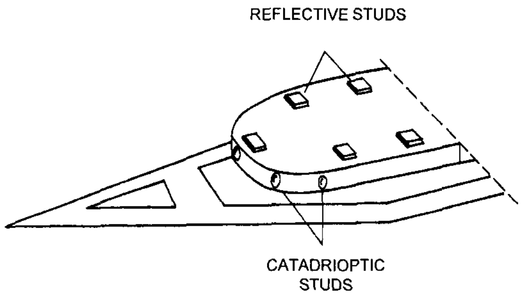


FIGURE 10.50
BOLLARD

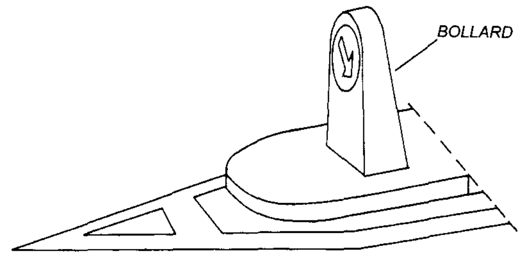


FIGURE 10.51
FLASHING LIGHTS + KEEP RIGHT SIGN

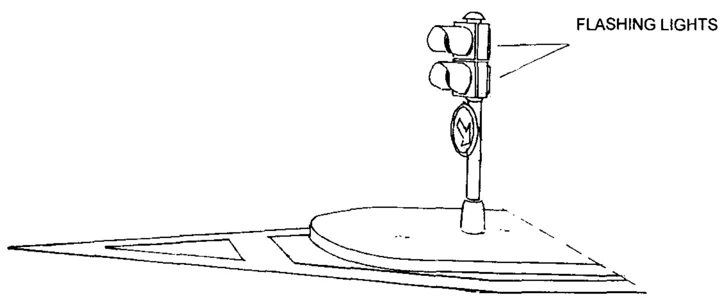
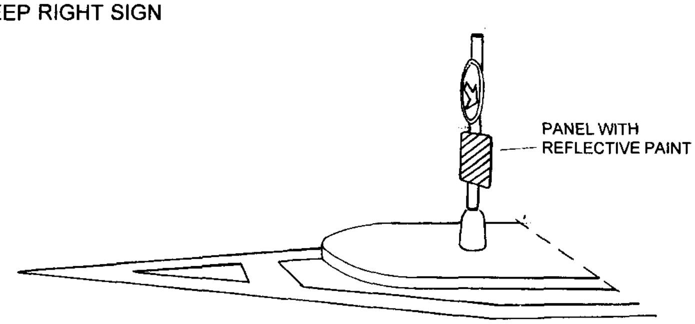


FIGURE 10.52
REFLECTIVE PANEL + KEEP RIGHT SIGN



Demarcation of curves

Some curves are difficult to perceive in time to react properly. Demarcation signs may installed, as shown in Figure 10.53, with a black arrow on a yellow background, in reflective paint or film. The CET of São Paulo is experimenting with a formula and a table for determining the distances between successive signs, as a function of the radius of the curve (see Table 10.9). The position of the demarcation sign is shown in Figure 10.53b and the spacing between signs is shown schematically in Figure 10.53c.

FIGURE 10.53a
DELINEATION SIGNS INDICATING THE EXISTENCE OF A CURVE

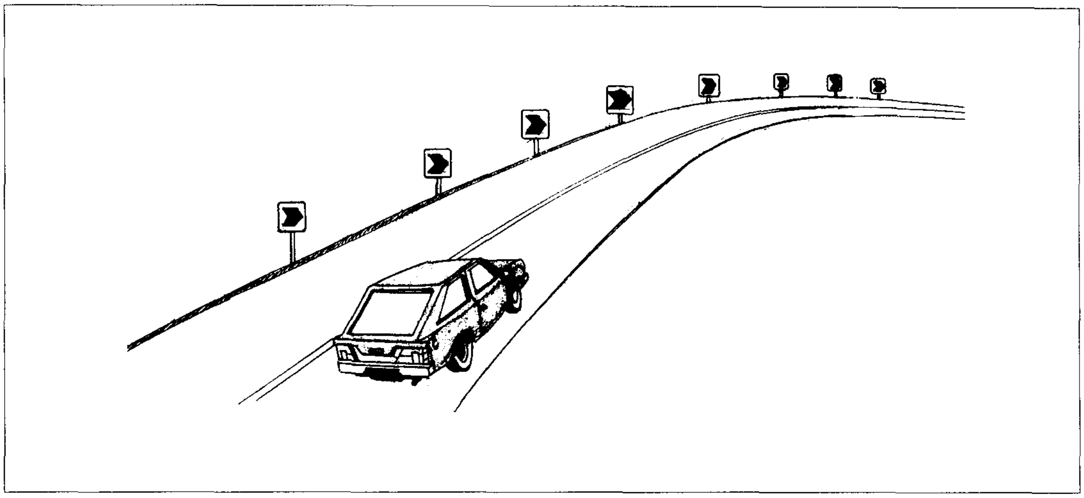
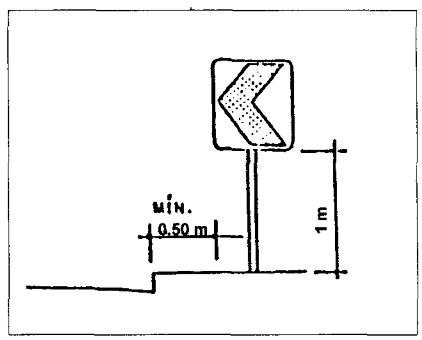


TABLE 10.9
CURVE DELINEATION. EXPERIMENTAL METHOD PROPOSED BY CET FOR CALCULATING THE DISTANCE BETWEEN SIGNS

R Radius of curve (m)	D Distance in curve (m)	Distance before curve (m)		
		1st. space	2nd. space	3rd. space
10	6	12	18	36
20	7	14	21	42
30	8	16	24	48
40	9	18	27	54
50	10	20	30	60
60	11	22	33	60
70	12	24	36	60
80	13	26	39	60
90	14	28	42	60
100	15	30	45	60
200	20	40	60	60
300	25	50	60	60
400	30	60	60	60
500	35	60	60	60
>1000	45	60	60	60

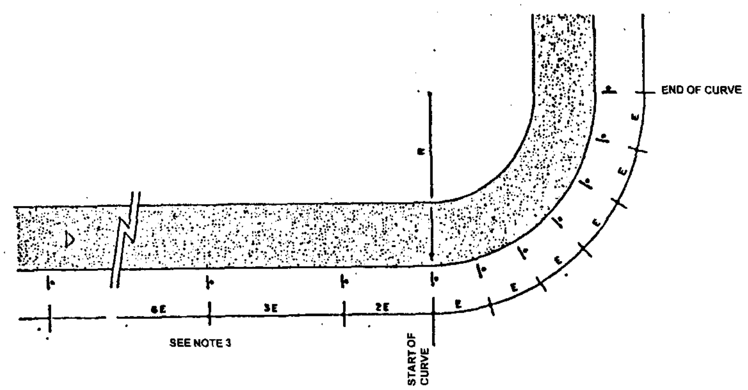
Source: CET (1978).

FIGURE 10.53b
POSITION OF THE DELINEATION SIGN



Source: CET (1978).

FIGURE 10.53c
CALCULATION OF DISTANCES BETWEEN DELINEATION SIGNS



NOTES:

1. The distance between delineation signs for a radius other than those specified in the table should be calculated using the equation:

$$E=1{,}5\sqrt{R}$$

2. In the stretch of road immediately before the curve delineation signs should be implemented with spacings of 2E, 3E and 6E, respectively.
3. The minimum recommended distance between delineation signs is 6 m and the maximum 60 m.
4. The spaces should be distributed to place the last delineation sign at the end of the curve and at least two delineation signs within the driver's visual field.

Source: CET (1978).

Demarcation of paved roads without kerbs

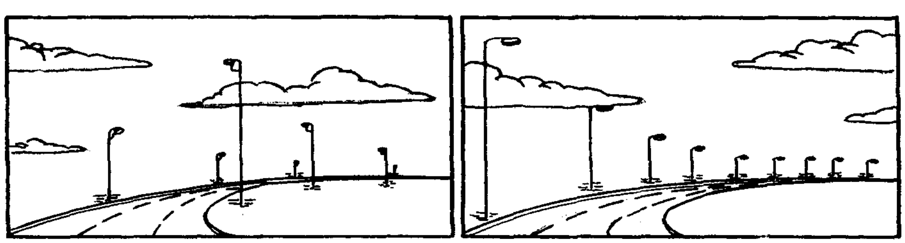
On this type of highway, the edges of the road should be marked with a border line, supplemented with small or large reflective studs and/or *cat's eye* vertical markers. These elements are essential for safety during rainy nights, as long as drivers are using their headlights.

Illumination of horizontal curves

All light posts should be located on the same side of the road so that the drivers perceive the extension and form of the curve (Figure 10.54, case *b*). They will be confused if the posts are placed on alternate sides of the roadway (case *a*).

FIGURE 10.54
STREET LIGHTING ON HORIZONTAL CURVES

CASE (A): NOT RECOMMENDED CASE (B): RECOMMENDED



Source: CET, Technical Bulletin, No. 27, p. 49.

Illuminating tree-lined streets

Tree-lined streets are aesthetically pleasing, but present problems of visibility. During the day, the strong contrast between areas of sun and shade impairs the drivers' vision of the street. Trimming branches periodically can reduce this effect. At night, street lights installed above the trees or covered by branches produces some interesting visual effects, but do little to illuminate the roadway. The height and position of lights should be fixed so as to guarantee an acceptable level of illumination. Since illumination decreases with the square of distance, each high-intensity bulb can be substituted by two lower intensity bulbs positioned nearer the road and with half the distance between them than between each pair of high-intensity bulbs.

Improving the layout of street furniture

Street furniture, such as newsstands, telephone boxes, lampposts, waste baskets, benches, and kiosks, is often found at corners, where it interferes with the visibility and circulation of pedestrians. The city should relocate these elements to places where they are less dangerous to pedestrians and drivers.

Illuminating obstacles in the road

Illumination should not camouflage the interruption of traffic that occurs on streets with large islands, road closures, or other blockages of traffic. The point of interruption should be highlighted. The illumination should also highlight the perimeter of large roundabouts. If light posts cross these islands in a straight line, the driver will have the impression that the road continues through the middle of the roundabout, provoking accidents.

Negative effects of illuminated billboards

Illuminated outdoor advertisements and strong spotlights interfere with drivers' vision and perception, especially of traffic lights. The Brazilian Traffic Code prohibits the installation of lights and inscriptions that may generate confusion or interfere with the visibility of signs, signals, and road markings (Article 81). These light sources should be eliminated; if this is impractical on busy commercial streets, the traffic lights should be remodelled, using an anti-dazzle screen to reduce the negative effects of the competing lighting and messages.

The installation of advertisements near traffic lights is unacceptable, since they distract and confuse drivers (some of the most dangerous illuminated advertisements are seen installed alongside traffic lights, even mounted on the same projecting arm).

10.8 Temporary Safety Signs and Signals

Entities that operate urban traffic networks frequently have to deal with emergency situations, such as traffic accidents, works in progress on sidewalks, fires, and floods. These situations require partial or total closure of some streets and the channelization of vehicle and pedestrian flows away from these sites, using effective, temporary mobile signs and signals.

Special traffic operations exist, with programmed times for installation and deactivation, such as *school operations*, carried out during the arrival and departure times of students.

Works in progress

The most common interferences in the carriageway are those caused by programmed public works, both large and small. These works are very different from emergency interventions and often generate much inconvenience for the public over long periods. Works in progress in the carriageway impair vehicle flow and create situations that facilitate accidents. As such, the signing and signalling of these works is essential to:

a) warn drivers and pedestrians of the presence of the works in the roadway;
b) smooth vehicle channelization, reducing the negative impacts on traffic flow; and
c) make the limits of the works area highly visible, especially at night, protecting drivers, pedestrians, and the workers.

To guarantee this, signing and signalling material should be used in two situations described below.

Approaches to the works area. Aspects (a) and (b) require: (i) signs advising of the existence of the works; (ii) warning signs that inform the nature of the problem (road narrows, detour, limited height, etc.); (iii) cones and/or directional markers; and (iv) vehicle channelisation barriers.

Depending on the type and duration of the works (principally those that occupy the road over long periods), conventional signs and signals should also be used, including road markings, signs, traffic lights, or devices such as concrete prisms, to effectively supplement the signs and signals of the works. Large banners with messages painted on them are also very effective (Figure 10.55).

At the works area. Aspect (c) requires barriers, screens, netting, and portable guardrails, along with specific signs and signals for pedestrians.

In both situations special elements for nighttime visibility should be added to those already mentioned.

Traffic Detours

With emergency situations or public works in progress, partial or total closure of a street may require diverting part or all of the traffic. These detours may alter the traffic directions in one or more streets and require specific and effective signing and signalling.

When projecting signs and signals at the locations of works, special attention should be given to luminous elements. These may be of two types:

- *Flashing (intermittent) light devices*, which should emit yellow light with a frequency of 50 to 60 pulses per minute, to warn of the existence of dangerous situations. They may be fixed to barriers or screens, or mounted on their own supports, 1.0 m above the ground. They may also be fixed to the back of vehicles involved in the works activities, or to the ground at the beginning of deceleration lanes.

FIGURE 10.55
EXAMPLE OF THE USE OF BANNERS FOR TEMPORARY SIGNING

Fixed light devices. In Brazil, electric lamps are often placed inside red translucent plastic buckets, which are placed on top of the screens, at intervals of up to 10 m, clearly delimiting the required vehicle paths.

Table 10.10 provides the recommended lengths of the deceleration (transition) lanes, marked with cones, demarcation elements, or barriers, as a function of vehicle approach speed.

Where:

L = transition distance

V = vehicle approach speed

a = width of obstruction

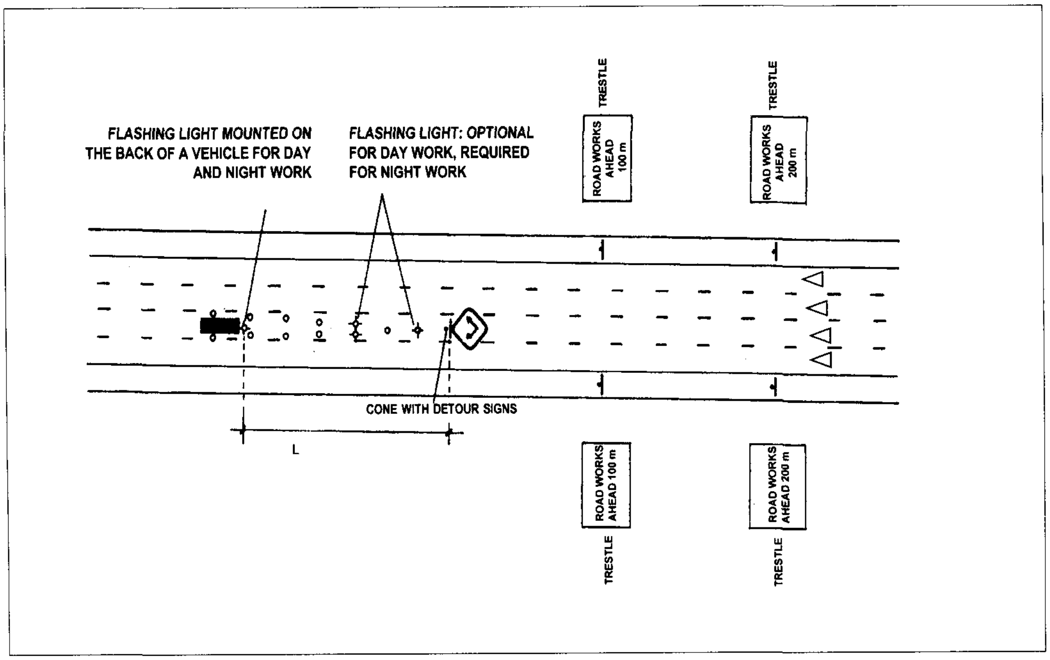
Figures 10.56 to 10.58 present some schematic examples of works signing and signalling.

TABLE 10.10
LENGTH OF TRANSITION AREA AS A FUNCTION OF SPEED

V (km/h)	L (m)
less than 40	13 a
40 - 60	19 a
60 - 80	25 a
80 - 100	31 a

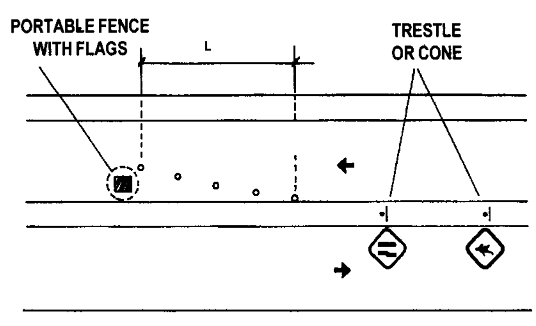
Fonte: CET (1978), V.8, p.46.

FIGURE 10.56
ROAD MAINTENANCE IN THE MIDDLE OF THE ROAD (SPEED $\geq$ 60 km/h)



Source: CET (1978), V. 8, p.65.

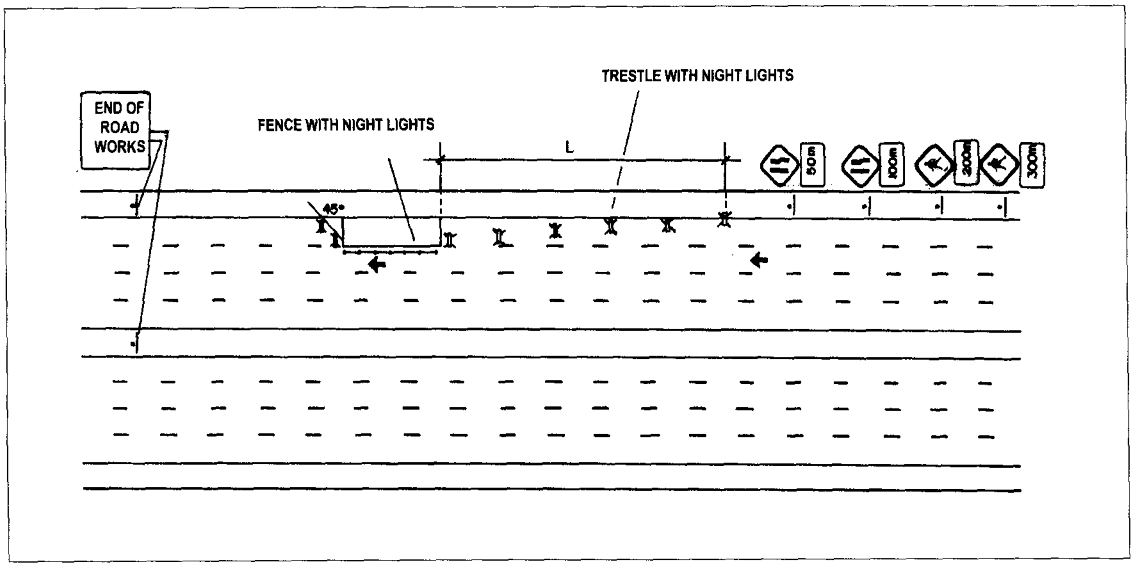
FIGURE 10.57
QUICK WORK IN MAN-HOLE ON MAIN ROAD (OR WITH v$\geq$60 Km/h)



OBS:
1. SEE TABLE 10.10
2. IF THERE IS A HUT, IT SHOULD BE WITHIN THE AREA ENCLOSED BY FENCES
3. USE CONES OR TRESTLE

Source: CET (1978), V. 8, p.67.

FIGURE 10.57
ROAD NARROWING (ONE LANE) IN FAST TRAFFIC ROAD (v≥ 60 Km/h)



Source: CET (1978), V. 8, p. 59.

School Crossing project

São Paulo's *School Crossing Project* was first implemented in 1983, and has been very effective. It consists of the utilization of crossing supervisors and special mobile signs and other equipment in front of primary schools, during the arrival and departure times of the students. Five items of mobile equipment are used:

- life-size hardboard human figures to warn of the existence of the school ahead;
- cones for channelisation of traffic;
- school crossing warning signs;
- speed limit signs to lower vehicle speeds; and
- STOP signs, held over the road by the crossing supervisors while pupils are crossing.

A crossing supervisor is a person designated by the school administration (usually an employee or father/mother of a pupil) to direct the traffic and the pupils, stopping the traffic with the STOP sign when pupils are waiting to cross.

The supervisor must wear an identification jacket, preferably with reflective markings, and be authorised and trained by the traffic authority. The vehicle flow should not be stopped for more than one minute at a time during this type of operation.

The set of mobile equipment should be put in position thirty minutes before the school entrance time and removed only after all pupils have arrived. For departure, the equipment should be set up ten minutes before exit time and removed only when departure is complete.

The sketch in Figure 10.59 illustrates this type of operation.

---

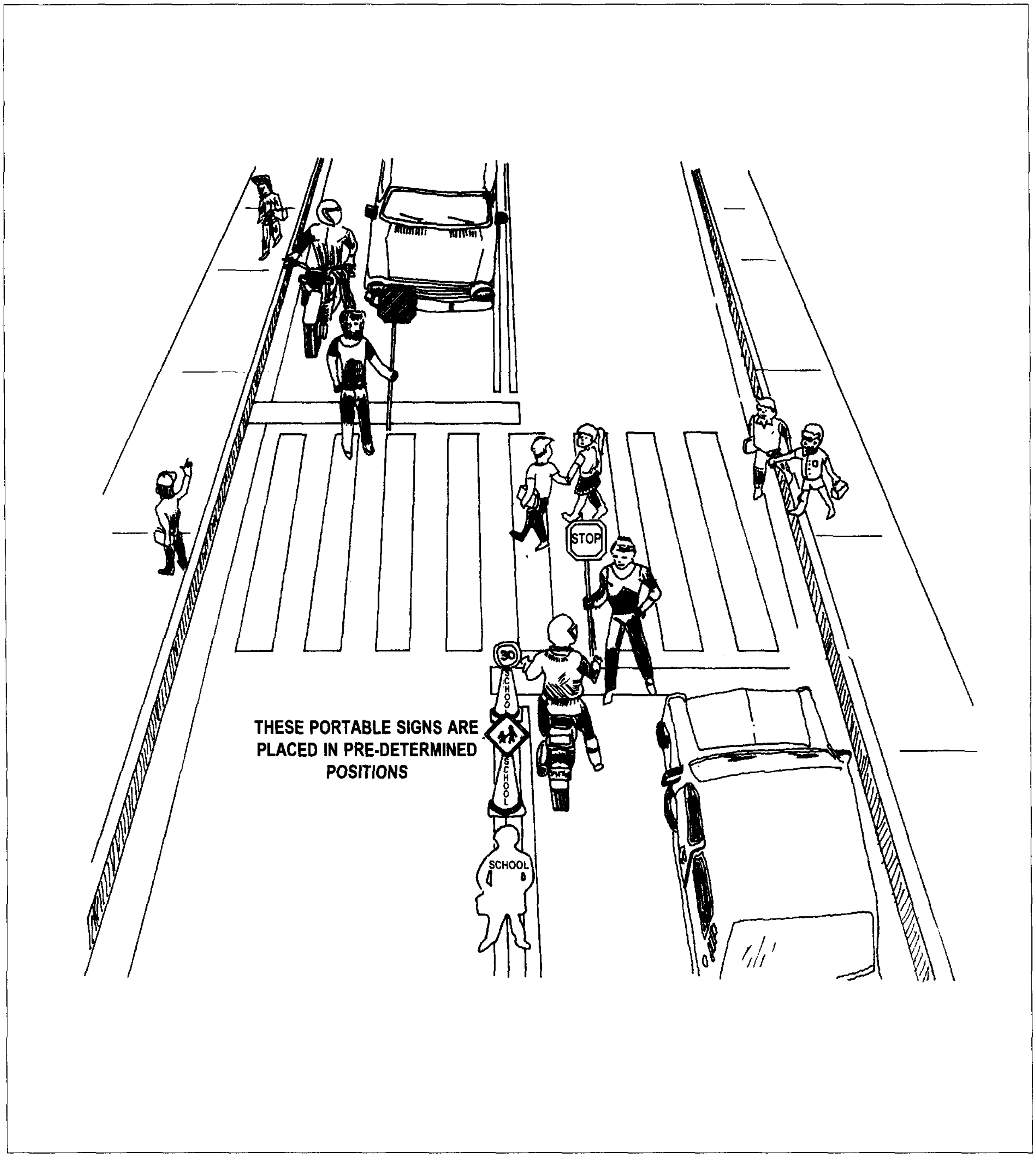
1 Disabilities are a widespread problem in all societies, of which the most severe cases (the blind and people in wheelchairs) are a very small percentage of the total. For example, a survey in Vancouver, Canada, found that 30% of metro users had visual disabilities (although very few were blind) and that even users without physical disabilities also experienced difficulties with locomotion due to the necessity of carrying children, belongings, books, and shopping (Wright, 1992, 172-173).

2 Other devices, such as "cushions", which fit between the wheels of vehicles, are being developed and tested in some countries (Tight, 1997).

3 The use of colours varies from country to country. In some countries the "green" pedestrian phase is represented by a white light, which begins flashing when pedestrians may no longer begin crossing, followed by a red phase that indicates the green phase for cars is imminent.

4 This criterion comes from the first project manual produced by the CET and may be modified in future versions. The original English projects were developed to facilitate traffic flow and were not specifically directed to accident reduction.

FIGURE 10.58
PORTABLE SIGNS AND CROSSING SUPERVISORS:
"OPERATION-SCHOOL CROSSING" (SÃO PAULO)



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CHAPTER 11

CARE IN PROJECT IMPLEMENTATION AND MAINTENANCE

This chapter describes how to avoid accidents during and after the implementation of traffic engineering projects. Omission of signs and signals and other essential procedures at works in progress often has serious or fatal consequences.

11.1 Normal Procedures During Implementation

These procedures are necessary only for projects that alter the direction of traffic flows on one or more streets, requiring changes in the habits of drivers and pedestrians. The various measures to be adopted are designed to guarantee the safety of road users until they assimilate the alterations.

Procedures for the project implementation phase should be applied:

(i) *before implementation* (a period of between 2 days and a week before implementation);

(ii) *during implementation* (between the start of implementation and its conclusion); and

(iii) *immediately after implementation* (during which a special operational scheme should be activated, usually lasting between one day and one week).

Procedures Before Implementation

Projects should be implemented preferably on Saturdays, when there is less traffic. This permits evaluation (and adjustment, if necessary) before Monday, when traffic becomes intense again.

During the week before implementation, the public should be informed of the effects the project will have on their usual routes, by such means as messages painted on cloth banners, hung across the streets. The messages may warn, for example, of a change of traffic direction on the street where the banner is hung or on transverse streets, and should include the dates of these changes.

Similar messages should be hung over the sidewalks to prepare pedestrians for the changes to be made.

When project implementation detours traffic, the banner should indicate the direction drivers should take (see Figure 10.55 in the previous chapter).

Example:

ATTENTION DRIVERS

THE DIRECTION OF TRAFFIC ON THIS ROAD WILL CHANGE NEXT SATURDAY.

Other actions are also recommended.

- Distribution of informative leaflets, for drivers and pedestrians, explaining and illustrating the modifications and the new alternative routes. These leaflets should be distributed two days before implementation, during implementation day, and during the first working day after implementation. The leaflets should be distributed only during peak hours if it is not possible to print and distribute a large quantity of them. The most appropriate distribution points are intersections with traffic lights, near the project location.
- Distribution of a release for the media (the press, radio, television), to reach a large part of the population.

When appropriate, the project implementation coordinator should also:

- request a team of "pedestrian crossing supervisors" (people who help guide pedestrians through the new crossing procedures required by the project that will be implemented);
- contact the public transport authorities, when there are alterations to bus routes, bus stops, and taxi points;
- show police the project and organise a joint strategy for implementation and normal operation;
- organise delivery of support equipment, such as a towing vehicle, service vehicles, radio transmitter, trestles, cones, ropes, reflective jackets, and rain coats. This material is used by the implementation and maintenance teams, along with civil engineers and the police; and
- call a meeting of all who will participate in the operation, to achieve good project organisation and synchronisation.

Procedures During Implementation

During the implementation period the team responsible for installing signs and signals should obtain the assistance of the police (principally when installing traffic lights and road markings), and should have material available for temporary channelisation of vehicle traffic and pedestrians. When the road will be partially or totally closed for works in the carriageway, effective daylight and nocturnal signs and signals and other appropriate equipment are needed to protect road users and site workers (see pp.153-56). Special devices exist to absorb the impact of out-of-control vehicles that invade the works area. The designer of the project should accompany the implementation team to guarantee that the project is installed correctly and completely, and to detect problems, including any related to project design, requesting immediate correction. To prevent problems arising at this stage, site visits should be carried out before implementation to double check all aspects of project design and the implementation plan.

A strategy for traffic operation and channelisation should be organised to ensure a smooth transition from the moment implementation begins until the modified road system is again opened to normal traffic use. The project coordinator should decide the necessary duration of these measures. Cloth banners should also be installed, replacing or renewing the previous ones, to provide pedestrians with information about the new situation.

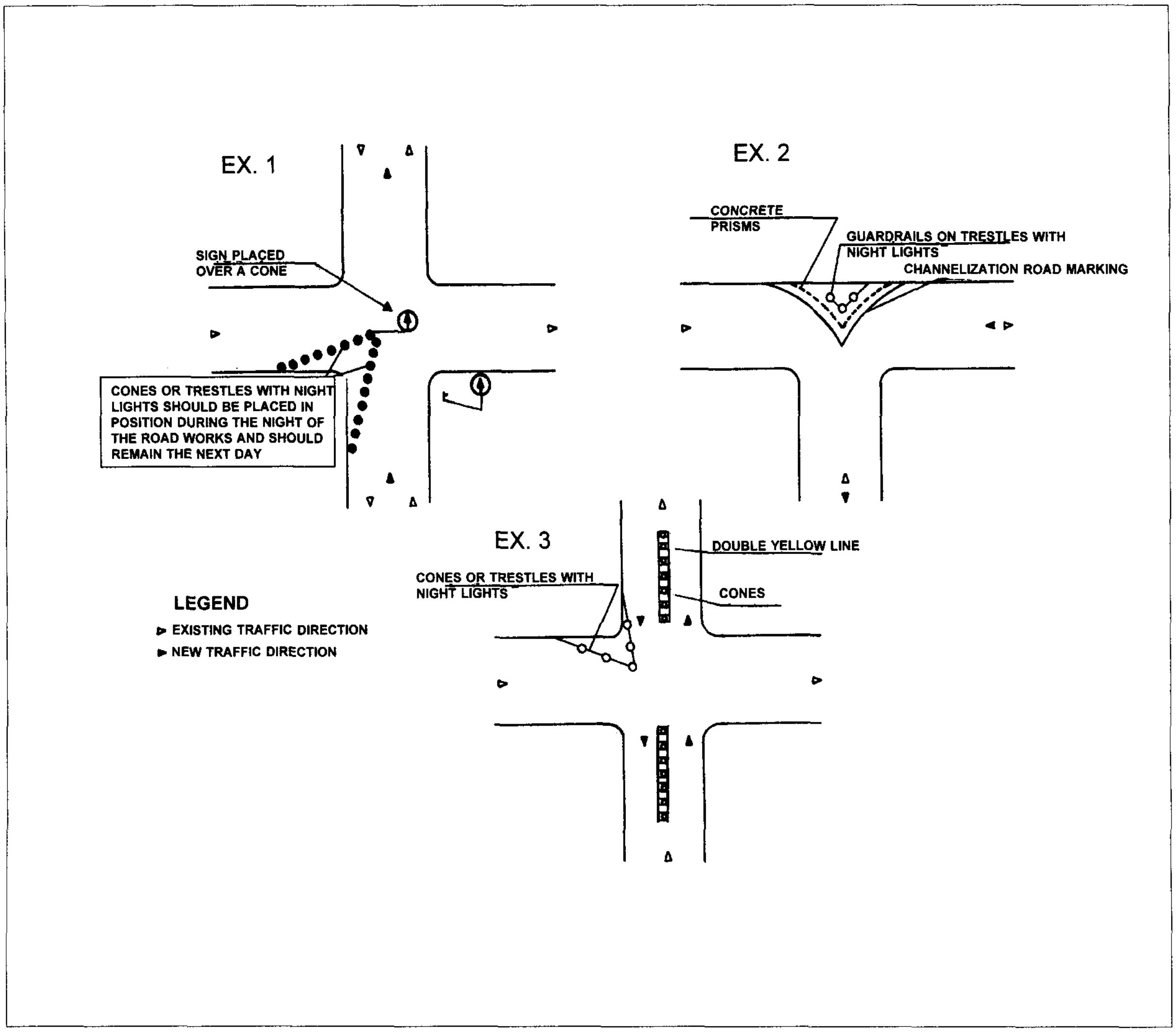
Example:

ATTENTION PEDESTRIAN

THE DIRECTION OF THE TRAFFIC ON THIS ROAD HAS CHANGED. CROSS WITH CARE.

Figure 11.1 provides some examples of channelisation projects, designed to prevent now prohibited vehicle movements that were permitted until the implementation of the new project, by bringing the alterations to the attention of road users.

FIGURE 11.1
SCHEMES FOR CHANNELIZATION IN INTERSECTIONS



Procedures immediately after implementation

The process of informing road users should be initiated before implementation and continue during implementation. Explanatory leaflets and posters should be distributed with up-to-date information, and the work of traffic supervisors should be maintained.

The operational strategy for the project should provide road users with all the orientation they need for traffic safety. This phase may require fine-tuning some elements of the project, such as the traffic lights programs.

11.2 Special Precautions During Implementation

These precautions must be taken during the implementation of any traffic engineering project.

- People working in the road should wear light-coloured reflective jackets, and should use all necessary channelisation equipment (cones, trestles, flashing warning lights, etc.)
- When installing an island made of concrete prisms, or any other fixed elements that partially or totally eliminate a traffic lane, the road markings that delimit the lanes must be altered (along with the studs, if included in the project), *before* installing the fixed elements. These markings provide the necessary advance warning to drivers accustomed to using the lane that will be eliminated. The omission of this precaution causes serious or fatal accidents.
- When the project includes the construction of a speed hump (especially if made with concrete asphalt), trestles should be used to narrow the street and attract the attention of drivers, until the signs, signals, and road markings are installed.
- When works are in progress on the roadway (construction of islands, for example) guardrails or portable screens with nocturnal illumination should be installed around the perimeter of the works area, until all permanent signs, signals and roadmarkings have been implemented.
- If vertical signs are installed before the project is ready to be opened to traffic, they should be covered with non-transparent plastic. This is especially important for regulatory signs.

The project designer should accompany closely the implementation of more complex traffic engineering projects, resolving the implementation team's doubts, and detecting and directing any on-site adjustments that are needed.

11.3 Monitoring Project Performance

After project implementation, the first results should be monitored to identify possible improvements. The best indicator of project effectiveness is what happens to the accident index, before and after implementation. This should be represented as a before-and-after graph of data for at least one year before project implementation, compared with the results in the months after implementation. Sometimes this reveals that the expected accident reduction has not occurred and the project needs to be altered or replaced by something more effective.

Site inspections and surveys should be made to verify the users' response in the project area. Behaviour sometimes changes, as road users become accustomed to certain traffic engineering features. For example, transverse rows of large studs drastically reduce vehicle speeds immediately after implementation. However, as drivers begin to perceive that they cause no damage to their vehicles, they begin to increase their speeds again. Drivers start to disobey traffic lights installed in locations with small volumes of vehicle traffic, some time after implementation, if there is insufficient enforcement.

During site inspections, a talk with local residents, shopkeepers and road users can supplement information about project performance or provide observations on problems that have appeared or persist after implementation.

User behaviour should be compared before and after project implementation. For example, to evaluate the performance of a speed-reducing device, the speed profile must be measured before, one week after, and six months after installation. When the project causes inconvenience to drivers, as occurs with new traffic lights and speed reducing obstacles, vehicle volumes, before and after implementation, should also be measured and compared. In these situations some drivers may prefer to avoid the street and use parallel ones that are not prepared for the resulting increase in traffic.

Each implemented project provides new lessons in user behaviour and project effectiveness. Project designers should take the opportunity to learn from experience, continuously improving project design.

11.4 Maintenance

One of the most important aspects of traffic engineering projects, often wrongly given low priority, is the maintenance of signs, signals, and road markings. Many types of projects operate very effectively when recently implemented but, without adequate maintenance, practically disappear within a few months or years.

Respect for, and comprehension of, signs, signals and road markings depend directly on their being seen by the road users. An intersection cannot operate adequately if the road markings are faded and the traffic lights have dirty lenses and bad programming. All types of signs, signals and road markings need to be in good condition to obtain the desired effects. This requires a designated budget for preventive and corrective maintenance, and work plans for the maintenance teams.

For urban road networks, the necessary types and quantities of maintenance equipment depend on the size of the city. However, even small cities should normally have equipment for the maintenance of vertical signs and traffic lights.

A minimum team for this type of work consists of a driver, who would also work as a general services assistant, and an electrical technician for maintenance of traffic lights and vertical signs. Larger cities will require proportionately more maintenance staff.

Equipment necessary for this small team consists of:

- a small truck, preferably with a radio transmitter, a personnel safety platform (with lateral protection) and an extendable staircase that provides access to traffic lights;
- the usual electrician's equipment and tools;
- tools for general use (hammer, saw, spanners/ wrenches, etc.);
- spades, a manual excavator, some cement, and sand for on-site preparation of concrete to fix signposts in the ground;
- spare posts and the most commonly used signs ("parking prohibited", "one-way", "left turn prohibited", etc.), permitting immediate substitution of damaged or missing signs;
- spare bulbs, lenses, and controllers for traffic lights; and
- cleaning equipment (water, sponges, brushes, detergent, solvents, etc.).

Larger cities should have two separate sets of teams: one for vertical signs and one for traffic lights.

Implementation and maintenance of road markings require more specialised material and labour, and should be carried out by qualified companies, contracted by the municipal administration.

All maintenance activities are either preventive or corrective.

Preventive Maintenance

The objectives of preventive maintenance are to preserve satisfactory performance of signs, signals and road markings, and to maximise their useful life through routine activities carried out by the respective maintenance teams.

All traffic lights should receive preventive maintenance at least once a year. The main activities are:

- checking the impermeability of the lenses and, if necessary, renew them;
- cleaning the lenses and reflectors;
- checking the voltage reaching the bulbs and, if not according to specification, correcting the defect;
- cleaning and lubricating mechanical controllers;
- cleaning and, if necessary, painting the traffic light posts;
- removing elements that obstruct drivers' vision of traffic lights, such as tree branches, advertisements, badly positioned signs, and street vendor kiosks;
- correcting any irregularity that occurs, such as lenses wrongly aligned, lack of anti-glare screens or shields, and accumulation of dirt on the lenses; and
- checking the traffic lights program and, if necessary, making adjustments. Whenever traffic light programs are fixed, the correct program, written on a sheet of paper in a waterproof envelope, should always be left inside the controller box.

In addition to the work of the maintenance teams, traffic engineers should periodically check the validity of the traffic lights programs since, as time passes, the capacity of the street and/or the traffic volume may vary, requiring a new program.

The frequency for preventive maintenance of vertical signs depends on local conditions. Normally, signs in industrial areas, or in streets with heavy traffic flows, require more frequent cleaning than those in residential areas. Cleaning four times a year is suggested for the first case, and three times a year for the second. In both cases the required activities are:

- cleaning signs and posts with detergent or solvents;
- painting posts when necessary;
- replacing deteriorated signs;
- correcting locations of wrongly positioned equipment; and
- removing elements that obstruct vision, such as vegetation and advertisements.

Site inspections should be made to collect data on the quality and durability of the materials used, as inputs for the minimisation of the resources required for a given set of signs, signals, road markings, and equipment.

Corrective Maintenance

Corrective maintenance must be carried out quickly and efficiently, to minimise the exposure of road users to unexpected, abnormally high accident risks. For example, absence of a "one-way" sign can result in vehicles travelling in the wrong direction, causing head-on collisions. A burnt-out bulb in the red lens of a traffic light at an intersection results in vehicles passing when vehicles in the other approach have a green light. The absence or poor condition of road markings also provokes accidents, principally at night and when rain is falling.

Corrective maintenance requires a well-equipped emergency maintenance team, with a communications system that permits rapid detection and solution of problems. Each city should have a traffic information centre, to receive reports and complaints concerning defects of signs, signals, accidents, road surface defects, irregularly parked or abandoned vehicles, traffic jams, and suggestions about the road network. This centre should have an special telephone number to facilitate road user communication of information and complaints (in São Paulo, 194 is used). In small cities, this centre may be extremely simple.

The information centre should be agile enough to immediately contact the maintenance team, the fire department, police, and auxiliary emergency services. A radio communication system is very useful for this purpose.

Vandalism

In certain areas, traffic signs and signals are often stolen or deliberately destroyed, with the police unable to identify and detain the vandals. In these cases, public information campaigns may help to reduce such behaviour, or different materials may discourage theft and vandalism. Creativity should be used in the choice of materials and location of signs and signals, within the limits of the traffic regulations and norms.

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CHAPTER 12

EVALUATION OF THE ECONOMIC[1] FEASIBILITY OF PROJECTS

12.1 Introduction

This chapter presents the cost-benefit methodology for the economic evaluation of projects to reduce traffic accidents.

This economic evaluation may be carried out at various moments during the process of basic conception, detailed design, implementation and monitoring of a project. In this chapter we will consider the ex-ante evaluation of a project already designed, but not yet implemented. Thus all data referring to the period after implementation must be estimated, including the extent of the reduction in accident frequency and the project maintenance costs. For evaluations carried out after project implementation (ex-post), these estimated values should be replaced by the real data.

The text is illustrated with a hypothetical project whose characteristics are representative of typical projects designed to reduce traffic accidents in urban areas.

12.2 Step 1 – Estimate the Useful Life of the Project

How many years may the effects of a successful traffic accident reduction project be expected to last?

This question is not concerned with the durability of the material used for signs, signals and road markings, which we assume will be adequately maintained. Rather, it refers to the safer traffic conditions generated by the project, when compared to the situation without the project.

There is no standard reply to this question, other than "It depends..."

The mini-roundabouts described in Chapter 10 represent one extreme. Many were introduced in various parts of São Paulo city more than 15 years ago, resulted in accident reductions of up to 80% in the first year after implementation, still exist in 1999 and still operate within traffic conditions similar to those registered at the time of project design and implementation. At the other extreme, emergency accident reduction projects are sometimes implemented in locations scheduled for large scale modification, resulting in their disappearance within a few months or, at most, two years after their implementation.

Between these two extremes there are many other cases, leading to the conclusion that the useful life of a traffic engineering project may vary from a few months to more than 15 years.

The traffic engineer should estimate the useful life of the project (*T* years), using available data and experience. If this is not possible and the project is expected to last a considerable time, a period of 10 years may be adopted.

A useful life of 10 years was adopted for the example project, used to ilustrate the methodology throughout the chapter.

12.3 Step 2 – Calculate the Project Implementation Cost

The implementation cost of a typical traffic engineering project, designed to reduce accidents, is the sum of the costs of material, labour and equipment. Annex III provides four examples.

First, calculate the quantities of each component of each type of modification to be made (to remove existing materials and to install, paint, repaint, relocate, etc.). Second, update unit prices of purchase and installation for each component and multiply these by their respective quantities to obtain the cost of each component. Third, find the sum of the costs of all components, obtaining the total implementation cost – TIC of the project.

Only *modifications* of the existing situation are included in project implementation costs. For example, if the project includes traffic lights where they already exist and no changes are planned in their number or type, then the cost of purchasing traffic lights will be zero. If the project includes changes in the positions of one or more sets of traffic lights, then the cost of these modifications should be taken into account. Another project might require an increase from an existing 8 sets of traffic lights to 12 in the new project, but with no changes to the existing traffic lights. In this case the project implementation cost should include the cost of purchasing and installing 4 sets of new traffic lights (12 - 8 = 4).

A total implementation cost of US$ 30,000 is used for the example project.

Projects of this order of magnitude typically include installation of new traffic lights, some geometric modifications and/or channelisation, and installation of road markings (paint and/or studs) and vertical signs. Many projects that effectively treat problematic locations cost less the US$ 30,000 used in the example.

12.4 Step 3 – Estimate Annual Maintenance Costs for the Useful Life of the Project

After implementation, traffic engineering projects require periodic maintenance to compensate for or reduce the wear and disadjustment of the constituent materials and equipment. Each type and quality of material and equipment has its maintenance schedule and cost. Some types of paint for road markings require repainting every 6 months, for example, whereas other, more expensive types, last 2 years. Traffic lights may last 10 years or more.

The project designer should define the estimated maintenance program for the useful life of the project, taking into account the quantities and quality of the selected materials. The unit costs can then be used to calculate the maintenance costs for each year of the useful life of the project. If it is impossible or impractical to predict detailed maintenance needs over time, due to lack of data and/or staff time, the following criteria can be used to provide an acceptable estimate.

A project may include elements that require frequent or at least yearly maintenance, and other elements that need maintenance every 2, 3 or 5 years. Adjustment of traffic light controllers and replacement of burnt-out light bulbs are examples of the first type. Repainting road markings, initially applied with durable, resistant paint, is an example of the second type. The project should be examined and two numbers should be estimated:

1. *Annual maintenance* as a percentage of the total implementation cost (TIC). If no better estimate is available, 2% per year may be used.
2. *Periodic maintenance (every x years)*, as a percentage of the total implementation cost. For example, 5% of the total implementation cost, every 3 years.

In this way, using the previously suggested numbers, the annual maintenance costs of the example project are:

TABLE 12.1

ANNUAL MAINTENANCE COSTS OF THE PROJECT AS A PERCENTAGE OF IMPLEMENTATION COST

YEAR	MAINTENANCE COSTS
1	0.02 X TIC
2	0.02 X TIC
3	0.07 X TIC (2%+5%=7%)
4	0.02 X TIC
5	0.02 X TIC
6	0.07 X TIC
etc.	etc.

TIC = Total implementation cost of project

If the project was designed for a location that already has signs, signals and road markings, only the differences between the maintenance costs of the existing and new projects should be considered. These differences may be positive, zero, or even negative, depending on whether the maintenance cost of the new project is more than, equal to, or less than that of the existing project.

For the project in our example, maintenance costs are expressed as percentages of the total implementation cost of US$ 30,000. For regular maintenance, 2% per year of that cost is used, and for periodic maintenance 5% every 3 years (Table 12.2).

12.5 Step 4 – Set up the Annual Costs Stream

The annual costs stream is the sum of the costs of implementation and maintenance in each year of the useful life of the project. This is the total of the values calculated in steps 2 and 3 (Table 12.2).

Normally, engineering projects to reduce traffic accidents are implemented in a short time (a day, a week; almost always in less than a year). In these cases, the project implementation cost may be considered to be fully disbursed during year 0 (zero), with all expenditure from year 1 on being exclusively for maintenance.

Their are two types of exception to this general rule:

(i) large projects with implementation periods of more than a year; and

(ii) projects with implementation programmed in phases, with periods of a year or more between successive phases. In these cases implementation and maintenance costs may occur in the same year, with the total annual cost being the sum of these two costs.

12.6 Step 5 – Calculate the Average Annual Cost to Society of the Accidents that Occurred at the Location before Implementation of the Project (the "without project" situation)

The cost to society of a traffic accident is the sum of all the costs it generates, including:

- damage to vehicles involved;
- damage to signs, signals, and street furniture;
- damage to private property;
- police services;
- emergency services provided to the victims;
- ambulance services;
- emergency medical treatment in hospitals;
- rehabilitation of the injured and mentally traumatised;
- legal expenses;
- time and fuel lost in resulting traffic congestion;
- lost production;
- manufacture of equipment necessary for resulting handicapped people; and
- services of clearing and cleaning the road.

Calculation of these costs for individual accidents is possible, but would require an excessive amount of time and resources compared to the utility of the results. For most purposes, a standard average value is sufficient, such as those utilised by the CET for the economic evaluation of

TABLE 12.2
PROJECT IMPLEMENTATION
AND MAINTENANCE COSTS (US$)

YEAR	IMPLEMENTATION	REGULAR MAINTENANCE (2% x TIC)	PERIODIC MAINTENANCE (5% x TIC)	TOTAL COST
0	30,000	-	-	30,000
1	-	600	-	600
2	-	600	-	600
3	-	600	1,500	2,100
4	-	600	-	600
5	-	600	-	600
6	-	600	1,500	2,100
7	-	600	-	600
8	-	600	-	600
9	-	600	1,500	2,100
10	-	600	-	600

its projects. These average costs result from adaptation of foreign studies to Brazilian conditions, costs, and prices, and are shown in Table 12.3.

TABLE 12.3
COSTS OF ACCIDENTS IN SÃO PAULO[2]

TYPE OF ACCIDENT	AVERAGE COST (US$)
Property damage only	1,410
Minor injuries	3,530
Serious injuries	17,630
Fatal	141,000

Source: CET.
Obs: Values in 1997 US$

However, the available accident information may not discriminate the severity of injuries of the victims. If so, weights may be used for property damage only accidents, personal injury accidents (excluding those involving pedestrians), and pedestrian accidents. The weights defined by the CET take into account that the severity of the injuries sustained by pedestrians generally exceed those of vehicle occupants. These weights and resulting average costs are exhibited in Table 12.4.

TABLE 12.4
WEIGHTED COSTS OF ACCIDENTS

TYPE OF ACCIDENT	WEIGHT	AVERAGE COST (US$)
Property damage only	1	1,410
Injury (excluding pedestrians)	4	5,640
Pedestrian accidents	6	8,460

The traffic engineer should calculate the total cost of the accidents registered at the project location during the year immediately preceding project implementation. When evaluating a project not yet implemented, he or she should calculate the cost of the accidents registered during the most recent year. If data are available for a period longer than one year, the average annual cost of accidents during this period should be used.

If the data include at least one fatal victim and the traffic engineer is calculating separately accidents with minor, serious and fatal injuries (Table 12.3), he or she should make an additional calculation, replacing the value of US$ 141,000 for each fatal victim, by US$ 17,360, the value normally used for accidents with serious, but not fatal, injuries.

The engineer using weighted average accident values (Table 12.4) should also make an additional calculation, if the data include at least one fatal victim. For each non-pedestrian accident fatality, the value of US$ 5,640 should be replaced by US$ 141,000. Similarly, for each pedestrian fatality, the value of US$ 8,460 should be replaced by US$ 141,000.

The additional calculation may avoid controversy over the monetary value of a lost life, without excluding loss of life from the evaluation. In the CET example, the monetary value of a lost life includes the present value of the lost future earnings of an average fatal traffic accident victim in Brazil, which is the key factor in increasing the value to US$ 141,000. Almost all the types of project described in this book show very strong economic feasibility even without the utilisation of this value. It is, however, a real cost to society and can be useful in *marketing* the project, to obtain the resources necessary for implementation. Thus, the engineer should always make the two calculations of economic benefits, when evaluating projects designed for locations with fatal victims.

In the example project, we assume data were available for 3 years prior to implementation, and there were no changes that affected the occurrence of accidents during this period. The following average accident frequencies are used:

20 DO accidents per year
8 PI accidents per year
3 PE accidents per year

All fatal victims were drivers: 2 in one year; 1 in another; and 0 in another. The average was 1 fatal victim per year. No information is given concerning the severity of the non-fatal injuries sustained by the other victims. Consequently the method of weights was most appropriate, resulting in the calculations shown in Table 12.5.

TABLE 12.5
COSTS OF ACCIDENTS WITHOUT PROPOSED PROJECT (1997 US$)

TYPE OF ACCIDENT	ACCIDENTS PER YEAR	COST PER ACCIDENT (US$)	TOTAL (US$)
Property damage only	20	1,410	28,200
Injury (excluding pedestrians)	8	5,640	45,120
Pedestrian accidents	3	8,460	25,380
Total	31	–	98,700

The total annual cost of the accidents before the project was US$ 98,700, not including the value of US$ 141,000 for a fatal victim. To include the cost of the yearly driver fatality, the cost of one PI accident, US$ 5,640, is replaced by that of a fatal accident: US$ 141,000. Thus, the value of US$ 135,360 (US$ 141,000 - US$ 5,640) is added to the total of US$ 98,700, yielding US$ 234,060. The inclusion of the cost of the fatality more than doubles the cost of the accidents.

Conclusion: Annual cost of accidents without project:

- *US$ 98,700 (not considering the cost of a fatal victim);*
- *US$ 234,060 (with the cost of a fatal victim)*

12.7 Step 6 – Calculate the Value of the Accident Reduction Expected for the First Year After Project Implementation

During the design phase, the project is normally examined to verify if it is highly likely to reduce accidents (using, for example, statistical significance tests). Thus, when the present phase of economic evaluation is reached, the extent of accident reduction expected for the first year after project implementation should already have been estimated.

Depending on what method of calculation is being used, this reduction may be expressed:

- as a percentage of the number, or average number, of accidents per year for the situation without the project, when there is no discrimination of the accident type or severity; or
- as percentages, perhaps distinct, of the numbers of property damage only accidents, personal injury accidents (not involving pedestrians), and pedestrian accidents.

With either method, the traffic engineer should calculate the total benefits of the expected reduction in accidents in the first year after project implementation, using as a base the costs resulting from Step 5.

Analysis of these criteria for the hypothetical example project yields the following predicted reduction: approximately 30% of the DO accidents; 50% of PI accidents (excluding pedestrians); and 10% of PE accidents. Table 12.6 shows the calculation of the value of the accident reduction expected for the first year after project implementation.

Without including the costs of a fatal accident, the estimated cost reduction for the first year is US$ 33,558. To include the value of US$ 141,000 for a fatal victim, together with the expected reduction of 50% for the PI accidents, half the value of a PI accident (US$ 5,640 x 0.5 = US$ 2,820) is replaced by half the value of an accident with a fatal victim (US$ 141,000 x 0.5 = US$ 70,500). The result, US$ 67,680 (US$ 70,500 less US$ 2,820) is added to the former total of US$ 33,558. This yields a total of US$ 101,238, or three times the benefit obtained without considering the cost of a fatal victim.

Thus, the estimated benefits for accident reduction for the first year after project implementation are:

- *US$ 33,558 (without the cost of fatal victims);*
- *US$ 101,238 (with the cost of fatal victims).*

These cost reductions represent, respectively:

- *34% of the annual cost of accidents without the cost of fatal victims [(US$ 33,558/US$ 98,700) x 100%]; and*
- *43.253% of the annual cost of accidents with the cost of fatal victims [(US$ 101,238/US$ 234,060) x 100%].*

12.8 Step 7 – Calculate the Value of the Accident Reduction Expected for each Year of the Useful Life of the Project

The effect of the new project may vary during its useful life. If it were constant, *without* the project accidents would always average x accidents per year and *with* the project, y accidents, with the benefit or reduction in each year being $x - y = z$ accidents.

TABLE 12.6
VALUE OF EXPECTED ACCIDENT REDUCTION DUE TO PROJECT (1997 US$)

TYPE OF ACCIDENT	ACCIDENTS/YEAR (WITHOUT PROJECT)	EXPECTED REDUCTION		BENEFITS PER ACCIDENT AVOIDED (US$)	TOTAL BENEFITS (US$)
		%	ACCIDENTS PER YEAR		
Property damage only	20	30	6	1,410	8,460
Injury	8	50	4	5,640	22,560
Pedestrian	3	10	0.3	8,460	2,538
Total	31	-	10.3	-	33,558

However, the population of urban areas usually grows somewhat and, at least in the medium term, both vehicle and pedestrian flows also increase. This implies growing frequencies of potential conflicts between vehicles and between vehicles and pedestrians. Consequently, without traffic engineering projects or other measures designed to reduce accidents, the frequency of accidents will increase.

If the project is expected to eliminate, say, 50% of the accidents in the first year, this effect might be maintained, even with growing traffic. This implies that, with each passing year, the project would avoid 50% of a growing number of accidents. Therefore, the absolute number of avoided accidents would also increase. For both the situations with and without the project, equal rates for traffic growth and accident increase may be assumed, unless better information is available.

The population of São Paulo increases at a rate of between 2% and 3% per year. The utilisation of a rate of 2% per year for the increase of the value of the accident reduction would be a conservative estimate. If the expected reduction in the first year is z accidents; in the second, it would be $z(1.02)$; in the third, $z(1.02)^2$, etc.

This rule should not be applied randomly: once again, it depends...

For example, if a new commercial centre is being built at the project location, or nearby, the traffic growth rate may be much higher than 2-3% per year during the first years after inauguration of the centre. If reasonable estimates of annual growth rates can be made, they should be used in the project evaluation.

At the other extreme, zero traffic and accident growth could be assumed for a project designed for the centre of a built-up urban area where traffic flow has already saturated the road network's capacity. Annual benefits from accident reduction would be constant for the whole useful life of the project.

In any event, the project leader should evaluate the relevant factors and make reasonable assumptions to calculate the expected reduction in accidents for each year of the useful life of the project.

In the example project, a general accident growth rate of 2.5% per year was predicted for the area of influence of the project. Table 12.7 shows the total annual costs of the accidents with and without the project, with and without the cost of a fatal victim. It also provides the annual benefits of the expected accident reductions. These benefits may be calculated either as the differences in each year between the total costs of the accidents with and without the project or simply by the repeated annual application of the general growth rate (2.5%) to the base value of the reduction in the first year (see Table 12.7).

TABLE 12.7
EXPECTED ANNUAL ACCIDENT COSTS AND BENEFITS GENERATED BY PROJECT (1997 US$)

Year	Accident costs without project		Accident costs with project		Benefits: Reduction of accident costs	
	XF	WF	XF (-34%)	WF (-43,253%)	XF	WF
0	-	-	-	-	-	-
1	98,700	234,060	65,142	132,822	33,558	101,238
2	101,168	239,912	66,771	136,143	34,397	103,769
3	103,697	245,909	68,440	139,546	35,257	106,363
4	106,289	252,057	70,151	143,035	36,138	109,022
5	108,946	258,358	71,905	146,611	37,042	111,748
6	111,670	264,817	73,702	150,276	37,968	114,541
7	114,462	271,438	75,545	154,033	38,917	117,405
8	117,323	278,224	77,433	157,884	39,890	120,340
9	120,256	285,179	79,369	161,831	40,887	123,349
10	123,263	292,309	81,353	165,877	41,909	126,432

Obs.:
XF - without cost of fatal victim
WF - with cost of fatal victim
Adopted general growth factor: 2,5% per year

12.9 Step 8 – Calculate the Present Values of the Annual Costs and Benefits

The analyst has now calculated the useful life of the project and the annual costs and benefits streams. Normally, the cost stream consists of the relatively large implementation cost in year zero (or during the first years for large-scale projects) and the lower maintenance costs during the remaining years. The benefits stream normally has very different characteristics, starting with zero in year zero (implementation), and a moderately high value in the first year after implementation, which remains constant or gradually increases during the rest of the useful life of the project.

The cost and benefit streams now need to be compared, considering the value of money in relation to time. We are not concerned here with inflation, which may be compensated by monetary correction so that the purchasing power remains constant. Rather, we are dealing with the issue of US$ 1,000 today being worth more than an equal amount of purchasing power a year from now.[3] If the money were received today it could be invested. With an interest rate of 12% per year, for example, there would be US$ 1,120 at the end of the year. It is more advantageous to receive the money as soon as possible.

Reversing the perspective for the same example, if the interest rate is 12%, the present value of US$ 1,120 to be received at the end of one year is:

$$US\$1.120 \ / \ 1,12 = US\$ \ 1.000$$

If US$ 1,000 will be received at the end of one year, the present value is:

$$US\$ \ 1.000 \ / \ 1,12 = US\$ \ 892,86$$

or US$ 107.14 less.

This technique of calculating the present value of future payments and savings may be used to compare the two streams of money (costs and benefits) over time. For maintenance costs in each year, this answers the question of how much money would have to be deposited in the bank today (at the start of project implementation), earning interest, so that C_t dollars would be available in year t, sufficient to pay all the maintenance costs for that year?

For benefits, this answers the question of what quantity of money would need to be deposited today to generate a benefit of B_t dollars in year "t"?

For the first question: to obtain C_t dollars in year t, with an interest rate of i per year, a quantity would be necessary today that, after receiving interest, and interest on interest during t years, reaches the value C_t. If this value is called C_o, then:

$$C_t = C_o \ (1+i)^t \qquad (12.1)$$

and

$$C_o = \frac{C_t}{(1+i)^t} \qquad (12.2)$$

Thus, to obtain US$ 10,000 in current values, after 3 years, with 12% interest per year, the quantity which would need to be deposited today is:

$$C_o = \frac{US\$ \ 10.000}{(1+0,12)^3} = \frac{US\$ \ 10.000}{1,4049} = US\$7.117,80$$

In project evaluation, a cost of US$ 10,000, disbursed in the third year after project implementation and discounted at a rate of 12% per year, yields a present value of US$ 7,117.80.

In reply to the second question, if the value of a reduction in accidents (benefit) of US$ 4,000 expected for the fourth year after project implementation, could be anticipated and received today, it would have the value calculated as follows, using a discount rate of 12% per year:

$$B_o = \frac{US\$4.000}{(1+0,12)^4} = \frac{US\$ \ 4.000}{1,5735} \approx US\$ \ 2.542,07$$

The question remains of choosing the most appropriate discount (interest) rate for this type of project evaluation. Here, the discount rate is taken as 12% of real interest per year, the value generally used by multilateral banks such as the Inter-American Development Bank (IDB).

By fixing the discount rate, the project designer/evaluator can now calculate the present value of each annual element of the project costs and benefits streams.

Table 12.8 presents the annual benefits and costs streams for the example project, calculated previously in Steps 7 and 4, respectively, and their present values, in year zero, applying a discount rate of 12% per year.

12.10 Step 9 – Calculate the Total Present Values of the Costs and Benefits

The total present value of the project costs, **C**, is obtained by adding the present values of all the annual costs. It is equivalent to the money that, if deposited in the bank at the start of project implementation at a real interest rate (excluding inflation) of 12% per year, would pay all the expected costs of implementation and maintenance during the useful life of the project.

*In the example project (see the last column of Table 12.8), the total present value of the costs is US$ 35,759. The total present value of the project benefits, **B**, is obtained by adding the present values of the annual benefits, and is equivalent to US$ 207,652 without considering the cost of a fatal victim (third column from the right in Table 12.8), and US$ 626,447, if the cost of a fatal victim is considered (second column from the right in Table 12.8).*

TABLE 12.8
ESTIMATED PROJECT COSTS AND BENEFITS (1997 US$)

YEAR	CURRENT VALUES			PRESENT VALUES		
	BENEFITS		COSTS	BENEFITS		COSTS
	XF	WF		XF	WF	
0	--	--	30,000	--	--	30,000
1	33,558	101,238	600	29,963	90,391	536
2	34,397	103,769	600	27,421	82,724	478
3	35,257	106,363	2,100	25,095	75,707	1,495
4	36,138	109,022	600	22,967	69,286	381
5	37,042	111,748	600	21,018	63,409	340
6	37,968	114,541	2,100	19,236	58,030	1,064
7	38,917	117,405	600	17,604	53,108	271
8	39,890	120,340	600	16,111	48,603	242
9	40,887	123,349	2,100	14,744	44,481	757
10	41,909	126,432	600	13,494	40,708	193
TOTAL				207,652	626,447	35,759

Obs.:
The totals may differ from the sum of the column values due to rounding.
XF - without cost of fatal victim.
WF - with cost of fatal victim.
Discount rate= 12% per year

12.11 Step 10 – Calculate the Net Present Value (NPV) of the Project

The net present value (**NPV**) of the project is obtained by subtracting the total present value of the project costs, **C**, from the total present value of the project benefits, ***B***:

$$B - C = NPV \qquad (12.3)$$

with:

$$B = \sum_{t=o}^{T} \frac{B_t}{(1+i)^t}$$

and

$$C = \sum_{t=o}^{T} \frac{C_t}{(1+i)^t}$$

where: B_t = benefits in year t
C_t = costs in year t
i = real annual discount rate (real interest rate)
T = useful life of project, in years

*In the example project, without considering the cost of a fatal victim, the NPV is obtained by subtracting **C** from **B=XF**, using the values of the last line of Table 12.8:*

B–C = US$ 207.652–US$ 35.759 = US$ 171.893,

and considering the cost of a fatal victim:

US$ 626.447 – US$ 35.759 = US$ 590.688.

In this case, NPV > 0. The net present value measures how much the project benefits exceed the costs of implementation and maintenance, after discounting all costs and benefits at a real interest rate of 12% per year. If the NPV had been negative, this would indicate that the project costs exceed the project benefits (both discounted).

This number (NPV) is useful when comparing projects with similar costs. However, care is required when using it to compare projects with very different costs, because it does not provide information regarding the economic efficiency of the project, as shown in Table 12.9 for two hypothetical projects.

TABLE 12.9
TWO PROJECTS WITH EQUAL NET PRESENT VALUES BUT DIFFERENT COSTS AND BENEFITS (US$)

PROJECT	PRESENT VALUE OF BENEFITS	PRESENT VALUE OF COSTS	NET PRESENT VALUE
1	2,000	1,000	1,000
2	20,000	19,000	1,000

Both projects have the same net present value, however each dollar invested in Project 1 generates 2 dollars of benefit, but in Project 2 only US$ 1.05 (US$ 20,000/US$ 19,000 = 1.05).

To overcome this limitation of the NPV criterion, the benefit cost ratio (B/C) and the internal rate of return (IRR) are used.

12.12 Step 11 – Calculate the Benefit/Cost Ratio

The benefit/cost ratio (B/C) of a project is calculated by dividing the total present value of the benefits by the total present value of the costs.

$$B/C = \frac{\sum_{t=o}^{T} \frac{B_t}{(1+i)^t}}{\sum_{t=o}^{T} \frac{C_t}{(1+i)^t}} \qquad (12.4)$$

When B/C is larger than 1, each dollar invested in the project produces an income of more than one dollar, as expressed by the value of avoided accidents. For example, a ratio of 2.5 means that each dollar invested produces 2.5 dollars of avoided accidents, an excellent result.

When the ratio is less than 1, this means that, although the project has generated a reduction in accidents, the cost was relatively high: each dollar invested produced less than a dollar in avoided accidents. This does not necessarily imply that the project should be rejected. Public authorities that give high priority to the reduction of death and injury in traffic accidents may wish to implement a project that is expensive and not economically efficient, but whose results are compatible with their priorities.

The total present values of the benefits and costs of the example project are shown in the last line of Table 12.8.

Without considering the cost of a fatal victim, the benefit/cost ratio of the example project is:

B/C = US$ 207,652/US$ 35,759 = 5.81;

and, considering the cost of a fatal victim:

B/C = US$ 626,447/US$ 35,759 = 17.52

In the first case, each dollar invested generates a return of US$ 5.81 and, in the second, US$ 17.52.

12.13 Step 12 – Calculate the Internal Rate of Return (IRR) of the Project

The internal rate of return (IRR) of the project is the discount rate that, when applied to the streams of benefits and costs, produces equal total present values for benefits and costs. This means that the net present value equals 0 (zero) and the benefit/cost ratio is 1.

The IRR indicates the return on the project investment in percentage and is calculated using the following formula:

$$\sum_{t=o}^{T} \left(\frac{B_t - C_t}{(1+r)^t} \right) = O \qquad (12.5)$$

where r is the IRR of the project and the other terms maintain their previous definitions.

Note that, in formula (12.5), the discount rate *r* is an unknown that needs to be calculated, whereas in equations (12.1) and (12.4) the discount rate *i* has a value fixed arbitrarily (= 0.12 in the examples). However, the IRR has to be compared with a value considered as the minimum acceptable, to know if the project is satisfactory or not; in this example IRRs > 12% are acceptable and IRRs < 12% are not.

Equation (12.5) cannot be solved exactly; *r* is calculated by successive approximations.

Although NPV and B/C may be calculated using a simple pocket calculator, IRR is almost always calculated with a computer and software such as EXCEL, Lotus 1-2-3 or Quattro-Pro[4].

The calculation is illustrated in Table 12.10 for the case of benefits that exclude the reduction in costs of fatal victims. The last column, containing net benefits (B_t-C_t), is used, and the mathematical IRR function is applied to the values of this column.

The IRR of the example project is approximately 112%, without considering the cost of fatal victims.[5]

Care should be taken with this procedure when the sign of the net benefits column changes more than once, as equation (12.5) may have multiple roots, with no economic meaning.

TABLE 12.10
FLOW OF NET BENEFITS AND CALCULATION OF
INTERNAL RATE OF RETURN (NOMINAL 1997 US$)

YEAR	BENEFITS XF	COSTS	NET BENEFITS
0	0	30,000	- 30,000
1	33,358	600	32,958
2	34,397	600	33,797
3	35,257	2,100	33,157
4	36,138	600	35,538
5	37,042	600	36,442
6	37,968	2,100	35,868
7	38,917	600	38,317
8	39,890	600	39,290
9	40,887	2,100	38,787
10	41,909	600	41,309
		IRR =	1.12

12.14 Step 13 – Calculate the Payback Period

The engineer should calculate the minimum number of years necessary for the benefits of the project to cover its costs. This simply requires the summing, year by year, of the accumulated value of benefits less costs, in present values, as shown in Table 12.11 for the case without the cost of fatal victims.

The net accumulated value of benefits less costs (the last column in Table 12.11) is negative but approximately zero in the first year and becomes positive in the second year, signifying that in a little more than one year the benefits start to outweigh the costs.

When the value of the reduction of fatal victims is included (Table 12.8), in the first year the benefits (US$ 90,391) are already almost three times the implementation costs (US$30,000) and the maintenance costs of the first year (US$536).

As in this example, many small real projects generate net benefits after one or two years. Thus, in terms of economic evaluation, they should be implemented even if the project is expected to be removed in a few years when a larger engineering project is scheduled to be built at the same location.

TABLE 12.11
PROJECT PAYBACK PERIOD

YEAR	PRESENT VALUES (US$)			
	BENEFITS XF	COSTS	B_t-C_t	Σ (B_t-C_t)
0	--	30,000	-30,000	-30,000
1	29,963	536	29,427	-573
2	27,421	478	26,943	26,370

Source of data in columns 2, 3 and 4: Table 12.8.

12.15 Step 14 – Sensitivity Analysis

In some projects, the results of the economic evaluation may be significantly altered by small changes in one or more of the parameters.

To know if the results are sensitive to such changes, the margin of variation of the key parameters should be estimated and NPV and IRR should be recalculated (and also, if pertinent, the values of B/C and the payback period).

As an exercise, the reader may verify that NPV > 0 and IRR > 12% for the original example project, even if there is a large increase (such as 25%) in the costs and a similar reduction in the benefits.

Sensitivity analysis is especially necessary in those cases for which the IRR is close to the minimum acceptable value.

12.16 Conclusion

The economic evaluation of projects, presented here in a simplified form, is a useful tool to distinguish between projects with high and low returns. It is particularly useful when insufficient resources are available to implement all designed projects, making it necessary to select the most cost-effective ones. This may be achieved by arranging the projects in descending order of their IRRs, and selecting the first ones in the list, maximising the global NPV, within a budget constraint.

These indicators are also useful in convincing authorities to maintain or increase the budget allocated to accident reduction projects, since they typically generate large social and economic benefits.

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[1] The traditional method of economic evaluation of projects, benefit/cost, is used here, but without the adjustments that economists make to compensate taxes, subsidies, and other distortions in market prices. These topics are outside the scope of this book, but do not substantially affect the conclusions of a great majority of the project evaluations mentioned in the text.

[2] These data apply to São Paulo in 1997; they may not represent costs at other times or locations and should be periodically updated.

[3] It is assumed that inflation would be added to the nominal value, maintaining the purchasing power of the currency constant. All calculations in this chapter assume that such *constant values* are being considered.

[4] Which are also used to calculate NPV and B/C in most real-world applications.

[5] As an exercise, the reader may repeat the calculations, including the costs of fatal victims (IRR = 338%).

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ANNEX I
TABLES TO AID SITE INSPECTIONS

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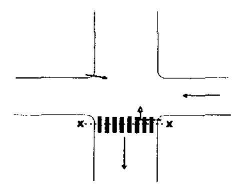
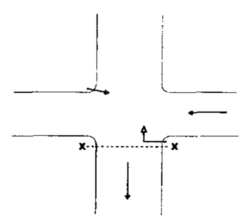
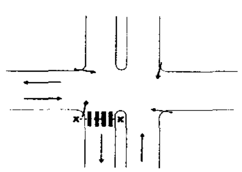
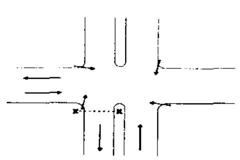
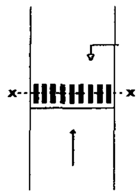
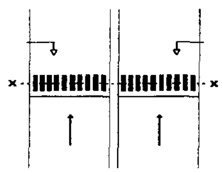
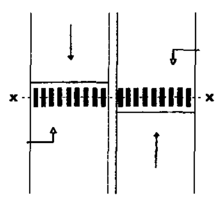
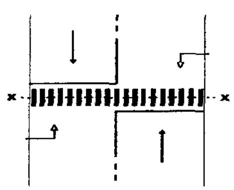
Table AI.1: Pedestrian Accidents at Intersections with Traffic Lights: Intersection Exit

Pedestrian accident location	Observed behaviour	Possible improvements										
Intersection with traffic lights: intersection exit (choose diagram that corresponds to study location)		1. Move pedestrian crossing away from intersection and install a pedestrian phase	2. Install pedestrian traffic lights with a pedestrian phase	3. Install service or educational signs for pedestrians	4. Install guardrails (if it is believed that this will improve safety)	5. Install warning signs for drivers	6. Install educational signs for drivers	7. Improve traffic light visibility	8. Remove obstacles to visibility pedestrian-vehicle	9. Install speed reduction devices	10. Install automatic enforcement equipment	11. Implement corner sidewalk widening
One-way with pedestrian crossing 	1. PEDESTRTIANS cross during gaps of insufficient duration at the change of phases	I	I			I			I			
	2. PEDESTRIANS start crossing during the all-red phase, but finish during the vehicle green phase	I	I			I			I			
One-way without pedestrian crossing 	3. PEDESTRIANS start crossing during the vehicle green phase	I	I	I		I			I			
	4. PEDESTRIANS cross without observing all potentially conflicting vehicle flows	I	I	I		I			I			
Two-way with median strip and pedestrian crossing 	5. PEDESTRIANS cross away from the pedestrian crossing*	I	I	I	I	I			I			
	6. VEHICLES do not stop at the beginning of their red phase					I	I	I	I	I	I	
Two-way with median strip, without pedestrian crossing 	7. VEHICLES stop at red traffic light, but procede before the green phase						I				I	
	8. VEHICLES do not stop at red light					I	I	I	I	I	I	
	9. VEHICLES parked in positions which interfere with visibility											I

I= improvement to be considered — post-mounted traffic light — traffic light mounted on extended arm

* the location chosen by pedestrians may be safer than the marked pedestrian crossing – evaluate

Table AI.2: Pedestrian Accidents between Intersections: with Pedestrian Crossing with Traffic Lights

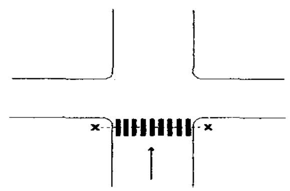
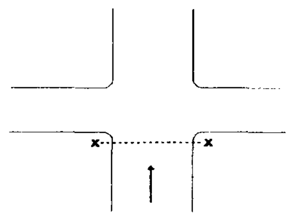
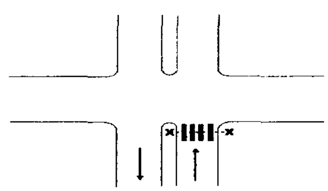
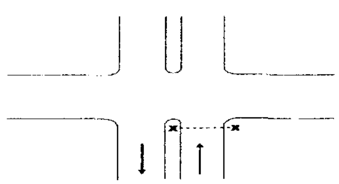
Pedestrian accident location	Observed behaviour	Possible improvements													
Road section with traffic lights: with pedestrian crossing painted (choose diagram that corresponds to study location)		1. Install pedestrian traffic light	2. Install pedestrian activated traffic lights	3. Build safety island or median strip	4. Install service or educational signs for pedestrians	5. Install warning signs for drivers	6. Install educational signs for drivers	7. Improve traffic light visibility for drivers	8. Increase pedestrian green phase	9. Install speed reduction devices	10. Install guardrail to channelise pedestrian flows	11. Increase width of pedestrian crossing if not sufficient	12. Install anti-skid surfacing	13. Remove obstacles to visibility	14. Install automatic enforcement equipment
One-way 	1. PEDESTRIANS complete crossing after start of vehicle *green phase*	I	I	I		I			I			I		I	
	2. PEDESTRIANS start crossing during vehicle green phase	I	I	I		I						I		I	
One-way with median strip 	3. PEDESTRIANS cross without looking at approaching vehicles	I	I	I	I	I								I	
	4. PEDESTRIANS cross away from the pedestrian crossing*	I	I	I	I	I			I		I	I		I	
Two-way with median strip 	5. VEHICLES do not stop at start of their red phase					I	I	I		I				I	I
	6. VEHICLES stop at red light, but proceed before start of green phase						I							I	I
	7. VEHICLES do not stop during red phase					I		I		I			I	I	I
Two-way without median strip 	8. VEHICLES parked in positions that interfere with visibility													I	
	9. VEHICLES stop at red, but encroach upon the pedestrian crossing						I	I		I			I	I	I
	10. VEHICLES stop at red, but with sudden braking and/or *skidding*					I		I		I			I	I	

I= Improvement to be considered

Traffic light mounted on post with or without extended arm

* the location chosen by pedestrians may be safer than the marked pedestrian crossing – evaluate

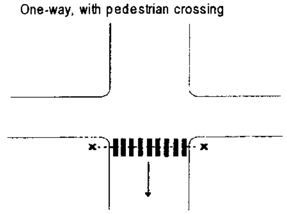
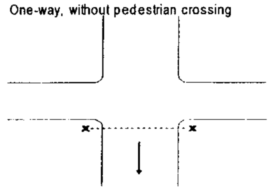
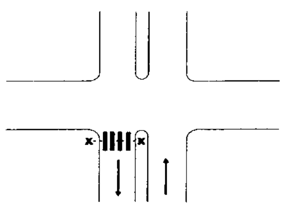
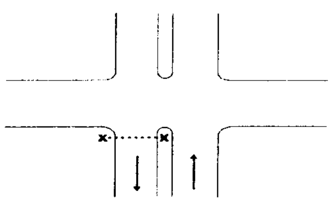
Table AI.3: Pedestrian Accidents at Intersection without Traffic Lights: Approaches

Pedestrian accident location	Observed behaviour	Possible improvements								
Intersection without traffic lights: approach (choose diagram that corresponds to study location)		1. Install service or educational signs for pedestrians	2. Increase gap frequency and/or duration, controlling traffic in neighbouring streets	3. Build safety island if crossing distance is long	4. Install warning signs for drivers	5. Install traffic lights	6. Install guardrail to channelise pedestrian flows	7. Remove obstacles to visibility for pedestrians and drivers or widen sidewalk	8. Install speed reduction devices	9. Install anti-skid surfacing on the approaches to the intersection
One-way with pedestrian crossing 	1. PEDESTRIANS do not wait for adequate gaps	I	I	I	I	I				
	2. PEDESTRIANS have difficulty in evaluating gaps on a wide road		I	I	I	I				
One-way without pedestrian crossing 	3. PEDESTRIANS almost never find an adequate gap – continuous traffic		I	I	I	I				
	4. PEDESTRIANS cross without looking at approaching vehicles	I		I	I	I				
Two-way with median strip and pedestrian crossing 	5. PEDESTRIANS cross away from pedestrian crossing – at some distance *from the* intersection*	I		I		I	I			
	6. VEHICLES parked in positions that interfere with visibility							I		
Two-way, with median strip without pedestrian crossing 	7. VEHICLES with excess speed				I				I	
	8. VEHICLES stop suddenly, with difficulty, to avoid hitting pedestrians				I			I	I	I

I= improvement to be considered

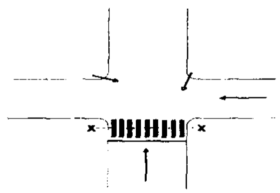
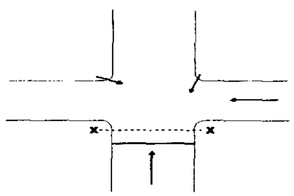
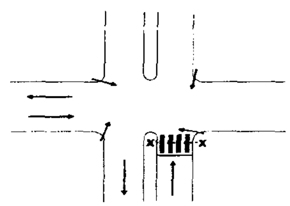
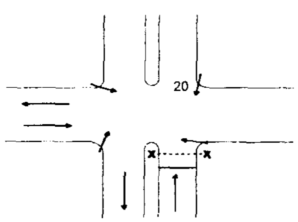
*the location chosen by pedestrians may be safer than the marked pedestrian crossing - evaluate

Table AI.4: Pedestrian Accidents at Intersections without Traffic Lights: Exits

Pedestrian accident location	Observed behaviour	Possible improvements									
Intersection without traffic lights: exit (choose diagram that corresponds to study location)		1. Install traffic lights	2. Increase gap frequency and or duration, controlling traffic on neighbouring streets	3. Install service or educational signs for pedestrians	4.Install educational signs for drivers	5. Install or increase number of speed limit signs	6. Install signs and/or road markings for drivers	7. Install speed reduction devices	8. Remove obstacles to visibility for pedestrians and drivers	9. Widen sidewalk at corner	10. Build safety island
One-way, with pedestrian crossing 	1. GAPS with insufficient frequency and/or duration	I	I								I
	2. PEDESTRIANS cross without waiting for adequate gaps	I	I	I			I	I	I		I
One-way, without pedestrian crossing 	3. PEDESTRIANS do not look in all directions of approaching vehicles	I		I			I	I	I		
	4. VEHICLES: drivers turning left or right do not give preference to pedestrians				I		I	I	I		
Two-way with median strip and pedestrian crossing 	5. VEHICLES parked in positions that interfere with visibility								I	I	
Two way, with median strip without pedestrian crossing 	6. VEHICLES with excess speed	I				I	I	I	I		

I= improvement to be considered

Table AI.5: Pedestrian Accidents at Intersections with Traffic Lights: Approaches

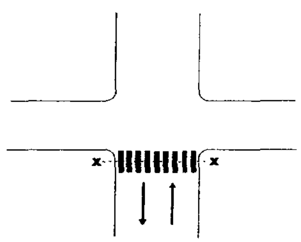
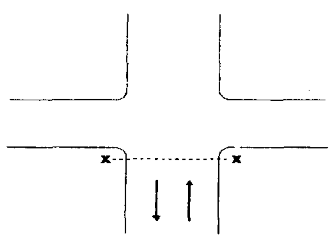
Pedestrian accident location	Observed *behaviour*	Possible improvements											
***Intersection with traffic lights: approach* (choose diagram that corresponds to study location)**		1. *Install* pedestrian traffic lights	2. *Build* safety island especially if crossing distance is long	3. *Install* service and/or educational signs for pedestrians	4. *Install* warning signs for drivers	5. *Install* educational signs for drivers	6. *Improve* visibility of traffic lights	7. *Remove* obstacles to visibility of pedestrians and vehicles	8. *Install* speed reduction devices	9. *Install* guardrails to chanelise pedestrian flows	10. *Increase* width of pedestrian crossing if not sufficient	11. *Install* automatic enforcement equipment	12. *Widen* sidewalk at corner
One way, with pedestrian crossing 	1. PEDESTRIANS complete crossing *after start of vehicle* green phase	I	I		I			I			I		I
	2. PEDESTRIANS begin crossing during vehicle green phase	I	I		I			I			I		
One way, without pedestrian crossing 	3. PEDESTRIANS cross without looking *at approaching* vehicle flows	I	I	I	I			I					
	4. PEDESTRIANS cross away from pedestrian crossing*	I	I	I	I	I	I	I		I	I		I
Two-way with median strip and pedestrian crossing 	5. VEHICLES do not stop at the start of the vehicle red phase				I	I		I	I			I	
	6. VEHICLES stop at red light, but proceed before start of vehicle green phase						I	I				I	
Two way, with median strip without pedestrian crossing 	7. VEHICLES do not stop at red light				I			I	I			I	
	8. VEHICLES parked in positions that interfere with visibility							I					I
	9. VEHICLES stop at red light, but encroach on pedestrian crossing area				I	I	I	I	I			I	

I= improvement to be considered

↘ traffic light mounted on simple post

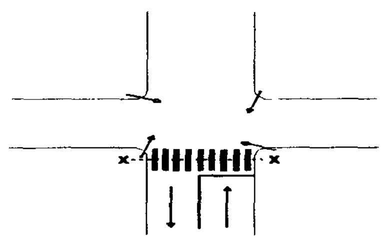
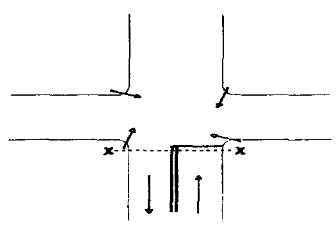
*the location chosen by pedestrians may be safer than the marked pedestrian crossing – evaluate

Table AI.6: Pedestrian Accidents at Intersections without Traffic Lights: Approaches and Exits: Two-way without Median Strip

Pedestrian accident location	Observed behaviour	Possible improvements									
Intersection without traffic lights: approaches and exits; Two-way without median strip (choose diagram that corresponds to study location)		1. Install traffic lights	2.Increase gap frequency and/or duration, controlling trafic on neighbouring streets	3. Install service or educational signs for pedestrians	4. Install or increase number of speed limit signs	5. Install or increase warning-type road-markings: e.g. the word SLOW	6. Install speed reduction devices	7. Remove obstacles to visibility for pedestrians and drivers	8. Install warning signs for drivers	9. Widen sidewalk at corner	Build island, dividing opposing trafic flows
With pedestrian crossing 	1. GAPS of insufficient frequency and/or duration	I	I			I		I	I	I	I
	2. PEDESTRIANS cross without waiting for adequate gaps, and become surrounded by vehicles in the middle of the road	I	I	I		I		I	I		I
	3. PEDESTRIANS unable to evaluate gaps – many vehicle approach directions	I		I		I		I	I	I	I
Without pedestrian crossing 	4. PEDESTRIANS not aware of all vehicle approach directions			I		I		I			I
	5. VEHICLES with excess speed				I		I	I			
	6. VEHICLES parked in positions that interfere with visibility							I		I	

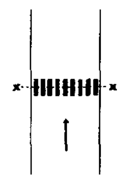
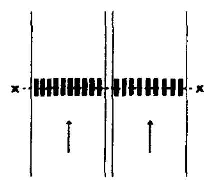
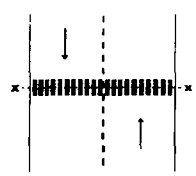
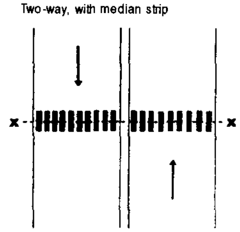
I= improvement to be considered

Table AI.7: Pedestrian Accidents at Intersections with Traffic Lights: Approaches and Exits; Two-way without Median Strip

Pedestrian accident location	*Observed* behaviour	Possible improvements			
Intersection with traffic lights: ***approaches and exits*** **Two-way without median strip (choose diagram that corresponds to study location)**		1. Install pedestrian crossing, *pedestrian traffic signal, and a* pedestrian phase	2. Prohibit vehicle *turning movements*	3. Protect pedestrians *from vehicle turning* movements with a partial vehicle turning phase	4. Build safety insland *separating opposing* vehicle flows
With pedestrian crossing 	1. PEDESTRIANS cross at the change of phases, but become surrounded by vehicles in the middle of the road	I	I	I	I
Without pedestrian crossing 	2. PEDESTRIANS cross during the vehicle red phase, but become surrounded by vehicles in the middle of the road		I	I	I
	Plus: all behaviours and improvements from Tables AI.1 and AI.5				

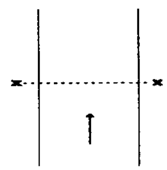
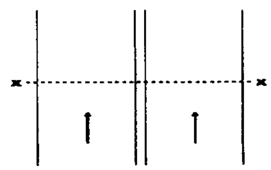
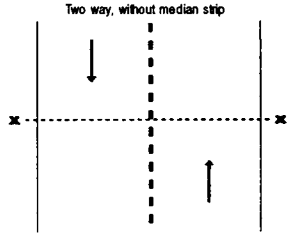
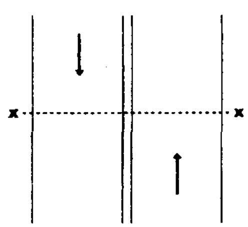
I= improvement to be considered ▲ traffic light mounted on simple post

Table AI.8: Pedestrian Accidents between Intersections, with Pedestrian Crossing but without Traffic Lights

Pedestrian accident location	Observed behaviour	Possible improvements							
Section with pedestrian crossing, but without traffic lights (choose diagram that corresponds to study location)		1. Install traffic lights, pedestrian-activated if possible	2. Increase gap frequency and/or duration, controlling traffic on neighbouring streets	3. Eliminate the pedestrian crossing and make crossing impossible at the location: install signs indicating nearest location for crossing	4. Eliminate the pedestrian crossing and make crossing impossible at the location; create a safer crossing at an alternative location	5. Change the position of the pedestrian flow generator and eliminate the pedestrian crossing	6. Install service or educational signs for pedestrians	7.Install warning signs for drivers	8. Build safety island
One-way, without median strip 	1. GAPS of insufficient frequency and/or duration in at least one direction	I	I	I	I	I			I
One-way, with median strip 	2. PEDESTRIANS cross without looking in the direction of approaching vehicles						I	I	I
Two-way, without median strip  Two-way, with median strip 	3. DRIVERS do not respect the right of way of pedestrians at the pedestrian crossing	I		I	I	I		I	

I= improvement to be considered

Table AI.9: Pedestrian Accidents between Intersections, with no Signs or Signals

Pedestrian accident location	Observed behaviour	Possible improvements							
Section with no signs or signals (choose diagram that corresponds to study location)		1. Install pedestrian crossing with road-markings and traffic lights	2. Make crossing impossible at the location; install signs indicating nearest location for crossing	3. Make crossing impossible at the location; create a safer crossing at an alternative location	4. Create adequate gaps,controlling traffic in neighbouring streets	5. Change the position of the pedestrian flow generator	6. Install service or educational signs for pedestrians	7. Install warning signs for drivers	8. Build safety island in the middle of the road
One-way, without median strip 	1. GAPS of insufficient frequency and/or duration in at least one direction	I	I	I	I	I			I
One way, with median strip 	2. PEDESTRIANS cross without looking in the direction of approaching vehicles	I					I	I	
Two way, without median strip  Two way. with median strip 	3. PEDESTRIANS cross without waiting for an adequate gap	I			I		I	I	I

I= improvement to be considered

Table AI.10a: Right-Angle Accidents in Intersections without Traffic Lights: Identification of Possible Contributing Factors

Observed behaviour		Possible reasons															
Vehicle 1	Vehicle 2	Definition of the right of way					Driver's visibility of signs impaired				Drivers's visibility of vehicles on the other street impaired				Vehicle flow characteristics		Drivers's visibility of intersection impaired
Without right of way	With right of way																
		Disobedience of right of way	Unexpected loss of right of way	Driver unaware of having right of way	Anomalous situation: there is no right of way	No signs of road-markings defining right of way	Hidden by vegetaion	Badly positioned	Hidden by parked vehicles	Poor street lighting (night)	Posts, newstands, trees, etc.	Parked vehicles	Bus stop	Inadequate street and/or building geometry	Large volume of vehicles	Excess speed	
1. Crosses intersection without reducing speed	Vehicle(s) approaching	pf	pf			pf	pf	pf	pf	pf					pf	pf	pf
2. Crosses intersection without stopping but reduces speed	Vehicle(s) approaching										pf	pf	pf	pf	pf	pf	
3. Enters the intersection,red-ucing speed suddenly at the last minute; then stops in the area of the intersection, or crosses through without stopping	No vehicle(s) approaching		pf				pf	pf	pf	pf						pf	pf
4. The same as previous item (3)	Vehicle(s) approaching	pf	pf			pf	pf	pf	pf	pf	pf	pf	pf	pf	pf	pf	pf
5. Stops at intersection. When proceeding (almost) enters in conflict with vehicle 2 or, if not, with other vehicles after passing vehicle 2	Vehicle(s) approaching										pf	pf	pf			pf	
6. The same as previous item (5)	Stops (as if to give way to vehicle 1)			pf	pf						pf	pf	pf	pf			
7. Anomalous situation: both drivers stop to give way to the other. Then one or both advance, with risk of several types of accidents				pf	pf	pf					pf	pf	pf	pf			

Pf= possible contributing factors

Table AI.10b: Right-Angle Accidents at Intersections without Traffic Lights: Contributing Factors and Possible Improvements

POSSIBLE CONTRIBUTING FACTORS		POSSIBLE IMPROVEMENTS				
DEFINITION OF RIGHT OF WAY	1. Disobedience of right of way	Install or reinforce signs and road markings to define right of way*	Invert right of way*	Install mini-roundabout	Install traffic lights	
	2. Unexpected loss of right of way	Install or reinforce signs and road markings to define right of way*	Invert right of way*	Install mini-roundabout	Install traffic lights	
	3. Driver unware of having right of way	Install or reinforce signs and road markings to define right of way*	Invert right of way*	Install mini-roundabout	Install traffic lights	Create signs and/or road markings to define right of way
	4. Anomalous situation: there is no right of way					Create signs and/or road markings to define right of way
	5. No signs or road markings defining right of way	Install necessary signs and road markings				
DRIVER'S VISIBILITY OF SIGN(S) IMPAIRED	6. Signs hidden by vegetation	Cut or eliminate vegetation				
	7. Signs badly positioned	Move sign(s) to better location(s)				
	8. Signs hidden by vehicles parked at or near the corner	Move sign(s) to better location(s)	Install signs prohibiting parking	Widen sidewalk at corner		
	9. Poor street lighting (night)	Move sign(s) to better location(s)	Increase or reinforce road markings	Install or improve street lighting		
DRIVER'S VISIBILITY OF VEHICLES IN THE OTHER STREET IMPAIRED	10. Obstacles: posts, newsstands, trees, etc.	Move obstacles to better location(s)	Remove obstacles			
	11. Parked vehicles	Install or reinforce signs prohibiting parking	Widen sidewalk at corner			
	12. Bus stop	Move bus stop to an alternative location without penalizing passengers				
	13. Inadequate street and/or building geometry	Install channelisation to advance stop line				
VEHICLE FLOW CHARACTERISTICS	14. Large volume of vehicles	Install traffic lights	Redirect part of the vehicle flow			
	15. Excess speed	Install speed limit signs	Install road markings such as SLOW	Install mini-roundabout	Install speed reduction devices	
VISIBILITY	16. Impaired driver visibility of intersection	Install warning signs	Remove obstacle to visibility	Install or improve street lighting		

***If this will not create or reinforce an "anomalous situation."**

Table AI.11: Rear-End Accidents at Intersections: Causes and Corrective Measures

REASON FOR SPEED REDUCTION OF FIRST VEHICLE	POSSIBLE IMPROVEMENTS	
	WITHOUT TRAFFIC LIGHTS	WITH TRAFFIC LIGHTS
A. DRIVER OBEYED SIGNS AND OR SIGNALS		
1. Stop sign	• Change position of sign to be visible also to driver of vehicle 2 • If the street is one way, repeat the sign on the left side • Install an additional warning, STOP SIGN AHEAD, along the approach to the intersection • Paint SLOW on the road, along the approach to the intersection	Non-existent or impossible situation
2. Yellow light (the driver stops) and red light (the driver stops)	(Impossible situation)	• Modify/add more traffic lights for them to become more visible to driver of vehicle 2 • Install warning sign, TRAFFIC LIGHTS AHEAD • Paint TRAFFIC LIGHTS AHEAD on the road along the approach to the intersection
3. Article 29 IIIc of CTB (Brazil): right of way for vehicles approaching from the right at normal intersections with no signs, signals or road markings	• Install warning sign indicating intersection ahead	Non-existent situation
B. PRECAUTION		
1. Visibility of intersection impaired at night	• Install/improve street lighting	• Install/improve street lighting
2. Visibility of orthogonal street impaired by fixed objects	• Remove fixed objects	• Remove fixed objects
3. Visibility of orthogonal street impaired by vehicles parked at or near the corner	• Prohibit parking with appropriate signs, or • Widen sidewalk to avoid parking	• Prohibit parking with appropriate signs or • Widen sidewalk to avoid parking
C. DRIVER NEEDED TO STOP OR PARK		
1. Taxi, for boarding or alighting of passengers	• Create an off-road bay	• Create an off-road bay
2. Bus, for boarding or alighting of passengers	• Create an off-road bay or move the bus stop (or install signs warning of bus stop ahead)	• Create an off road bay or move the bus stop (or install signs warning of bus stop ahead)
3. End of driver's journey	• Prohibit parking at this location	• Prohibit parking at this location
4. Driver took wrong way, or thought so	• Install/improve directional signs	• Install/improve directional signs
D. DOUBT		
1. Vehicle has right of way, but driver is not aware of this	• No solution unless traffic code includes signs or road markings to indicate to a driver that he or she has the right of way in this situation	• Should not occur unless green light is not working. Change bulbs/repair
2. The driver slowed down to look for or read a directional sign	• Change the position of the sign to be more visible to drivers and/or install additional signs further back along the street	• Change the position of the sign to be more visible to drivers and/or install additional warning signs further back along the street

* Warning sign

(continues)

Table AI.11: Rear-End Accidents at Intersections: Causes and Corrective Measures (conclusion)

REASON FOR SPEED REDUCTION OF FIRST VEHICLE	POSSIBLE IMPROVEMENTS	
	WITHOUT TRAFFIC LIGHTS	WITH TRAFFIC LIGHTS
E. PEDESTRIANS CROSSING THE ROAD		
1. Low volume of vehicles, but pedestrians do not wait for an adequate gap	• Install/improve signs and road markings indicating presence of pedestrians crossing	• Check need for traffic lights: remove if appropriate
2. Moderate volume of vehicles, but there are no adequate gaps for crossing	• Control vehicle flow at neighbouring intersections with traffic lights to create adequate gaps, or install traffic lights (careful: this may increase accidents)	• Install pedestrian-activated phase
3. Pedestrians crossing away from the designated crossing location	• Evaluate real crossing conditions for pedestrians at the designated location • If they are unsatisfactory, improve the signs and/or road markings, or move the crossing to a more adequate location • If crossing conditions are adequate, install channelisation of pedestrian flow	• Evaluate real crossing conditions for pedestrians at the designated location • If they are unsatisfactory, improve the signs and/or road markings, or move the crossing to a more adequate location • If crossing conditions are adequate, install channelisation of pedestrian flow
4. Pedestrians crossing during vehicles' green phase	Non-existent situation	• Install pedestrian traffic lights: if they already exist, interview pedestrians to discover why they cross during the wrong phase
5. Pedestrians with dificulties to cross because of high volume of vehicle turning movements	• Install traffic lights, with pedestrian-activated phase if possible	• Introduce a traffic light phase for pedestrians to cross
6. Pedestrians not adequately visible to drivers at night (See also Tables AI.1 – AI.9)	• Install/improve street lighting	• Install/improve street lighting
F. DRIVER NEEDS TO TURN RIGHT/LEFT		
1. Right turn	• Create channelisation and road markings	• Create channelisation and road markings
2. Left turn	• Create a lane for left turns or prohibit left turns (at least during critical periods)	• Create a lane for left turns or prohibit left turns (at least during critical periods)
G. OTHER CIRCUMSTANCES		
1. Road surface defect	• Install temporary signs/signals and repair the defect	• Install temporary signs/signals and repair the defect
2. Rain water drainage channel in road	• Install warning signs	• Install warning signs
3. Intersection visibility impaired	• Install sign warning drivers of intersection ahead	• Improve visibility of traffic lights and install warning sign TRAFFIC LIGHT AHEAD
4. Vehicles appear unexpectedly from the other street	• Remove obstacles to visibility and/or install speed reduction devices	• Improve visibility of traffic lights on the other street and/or remove obstacles to visibility
5. Excess speed	• Paint SLOW on the road along approach to the intersection or install speed reduction devices	• Paint SLOW on the road along the approach to the intersection or install speed reduction devices
6. Vehicles from the other street block the intersection	• Install sign DO NOT BLOCK INTERSECTION	• Modify the traffic lights program • Install signs (e.g., DO NOT BLOCK INTERSECTION)
7. Road blocked due to traffic accident	• Only reducing accident occurence	• Only reducing accident occurence
8. Heavily used vehicle access	• Install warning signs	• Install warning signs
9. Taxi stops for boarding/alighting of passengers	• Create an off-road taxi bay, with appropriate signs and road markings	• Create an off-road taxi bay, with appropriate signs and road markings
10. Bus stops at bus stop	• Move the bus stop or create an off-road bus bay, with appropriate signs and road-markings	• Move the bus stop or create an off-road bus bay, with appropriate signs and road-markings

* Warning sign

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ANNEX II

TREATMENT AND STANDARDS FOR SPEED HUMPS

Brazil currently has a very large number of speed humps. These speed reduction devices are regulated by CONTRAN Resolution nº 39 (21 May 1998), which establishes two types of speed humps. Type I humps are up to 0.08 m in height and have a cross-section width of 1.50 m. Type II humps are up to 0.10 m in height and have a cross-section width of 3.70 m. Their dimensions and constructive characteristics are given in Figures AII.1 and AII.2.

Speed humps are permitted only in certain types of locales and must always be preceded by warning signs and road markings. Type I speed humps may only be installed on local streets not used by regular bus routes and where maximum speed needs to be restricted to 20 km/h (12.5 mph). Those of Type II may only be installed on:

- sections of rural expressways or highways that cross built-up urban areas; or
- secondary streets; or
- local streets, where the maximum speed needs to be restricted to 30 km/h (18.8 mph).

Their installation in both cases also requires the following traffic conditions:

- a high accident index or potential risk of accidents;
- on highways, no slopes exceeding 4% along the entire section;
- on urban streets, no slopes exceeding 6% along the entire section;
- no curves or visual interferences that impede good visibility of the humps;

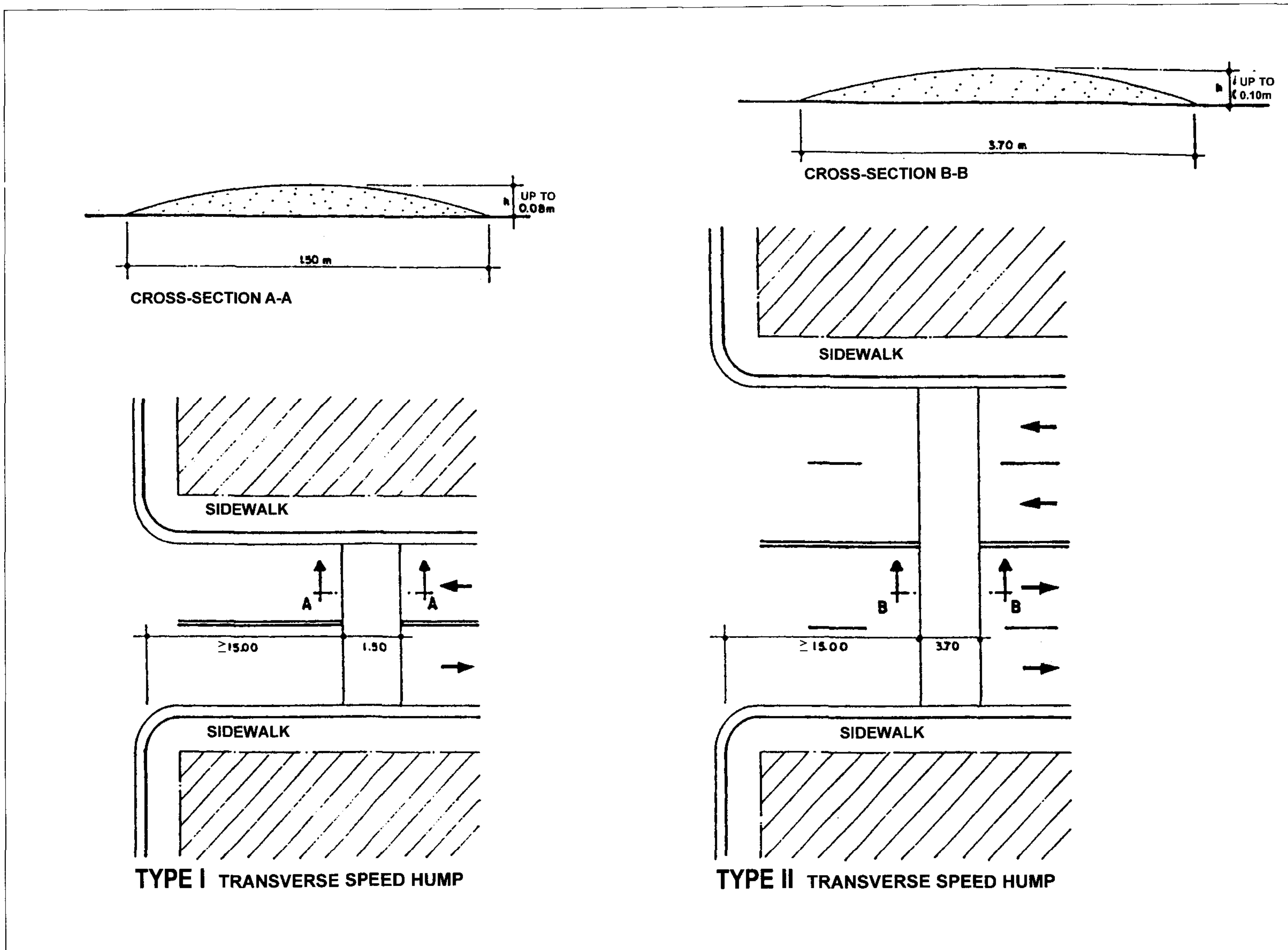
- peak-hour traffic volumes under 600 vehicles per hour; the traffic authority may allow higher volumes in places with large numbers of pedestrians, if justified by traffic engineering studies of the locale;
- well maintained rigid, semi-rigid or flexible pavements; and
- on urban streets, the humps should be at least 15 m from the kerb line of the nearest intersecting street.

Warning signs, signals and road markings should include, at minimum

- a speed limit sign restricting the speed of crossing the hump to 20 or 30 km/h (12.5 or 18.75 mph), as required, with complementary speed limit signs before the first hump to ensure smooth transitions down from the higher local speeds, and after the last hump, for the reestablishment of normal speed;
- warning signs showing the symbol of a hump and an arrow indicating its position (one or more of the A-18 signs in Figure AII.3); and
- yellow diagonal stripes of at least 0.25 m in width (alternatively, yellow and black stripes may be used or the whole hump may be painted yellow).

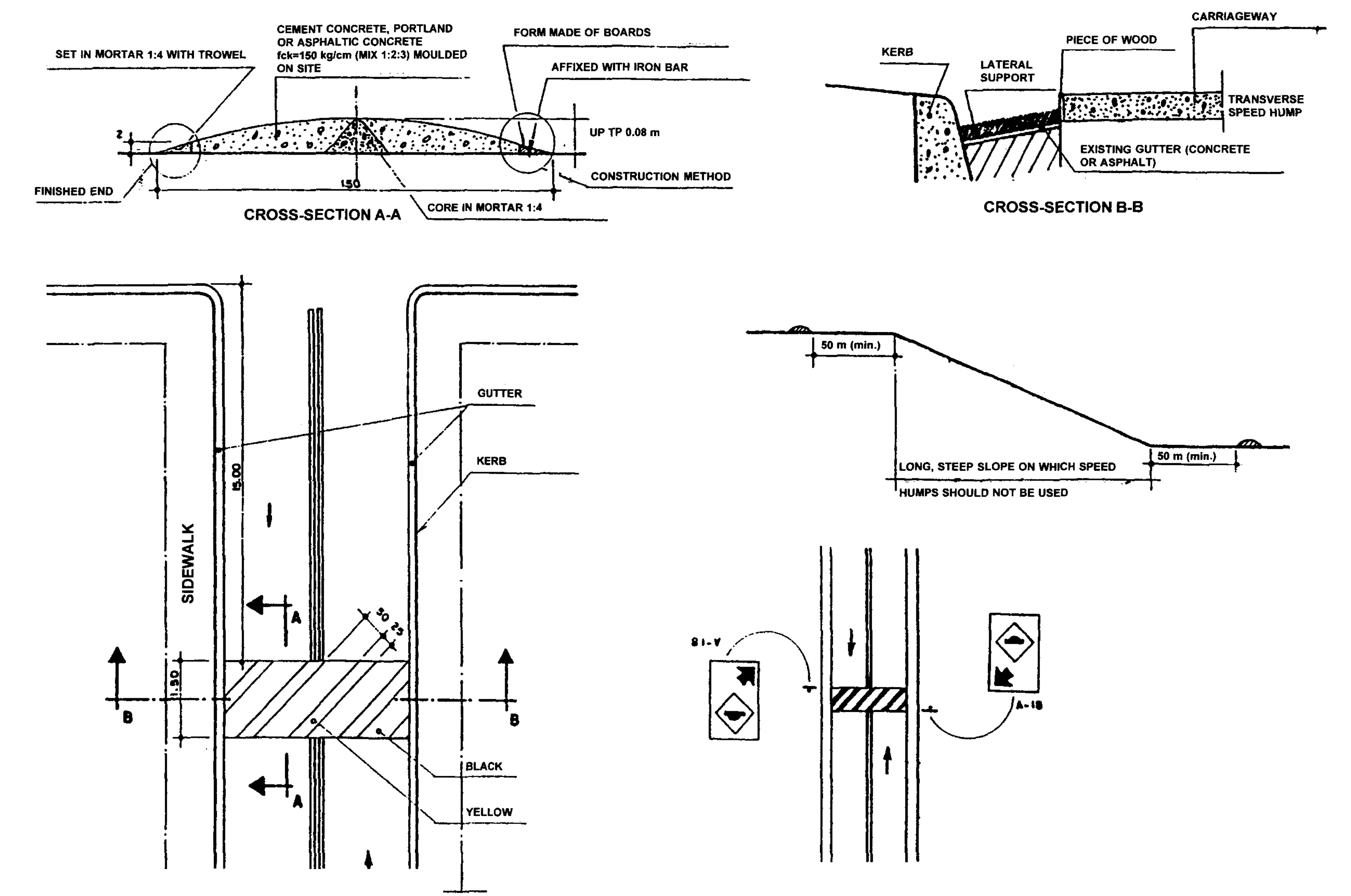
For highways, Resolution 39 also recommends that Type 2 humps be preceded by "Transverse Lines to Stimulate Speed Reduction," spaced at distances calculated according to the operational speed of the roadway (see Figure 10.2, p. 107). When a series of consecutive humps are being installed, they must be preceded by signs with complementary information.

FIGURE AII.1
DIMENSIONS OF TYPE I AND TYPE II SPEED HUMPS



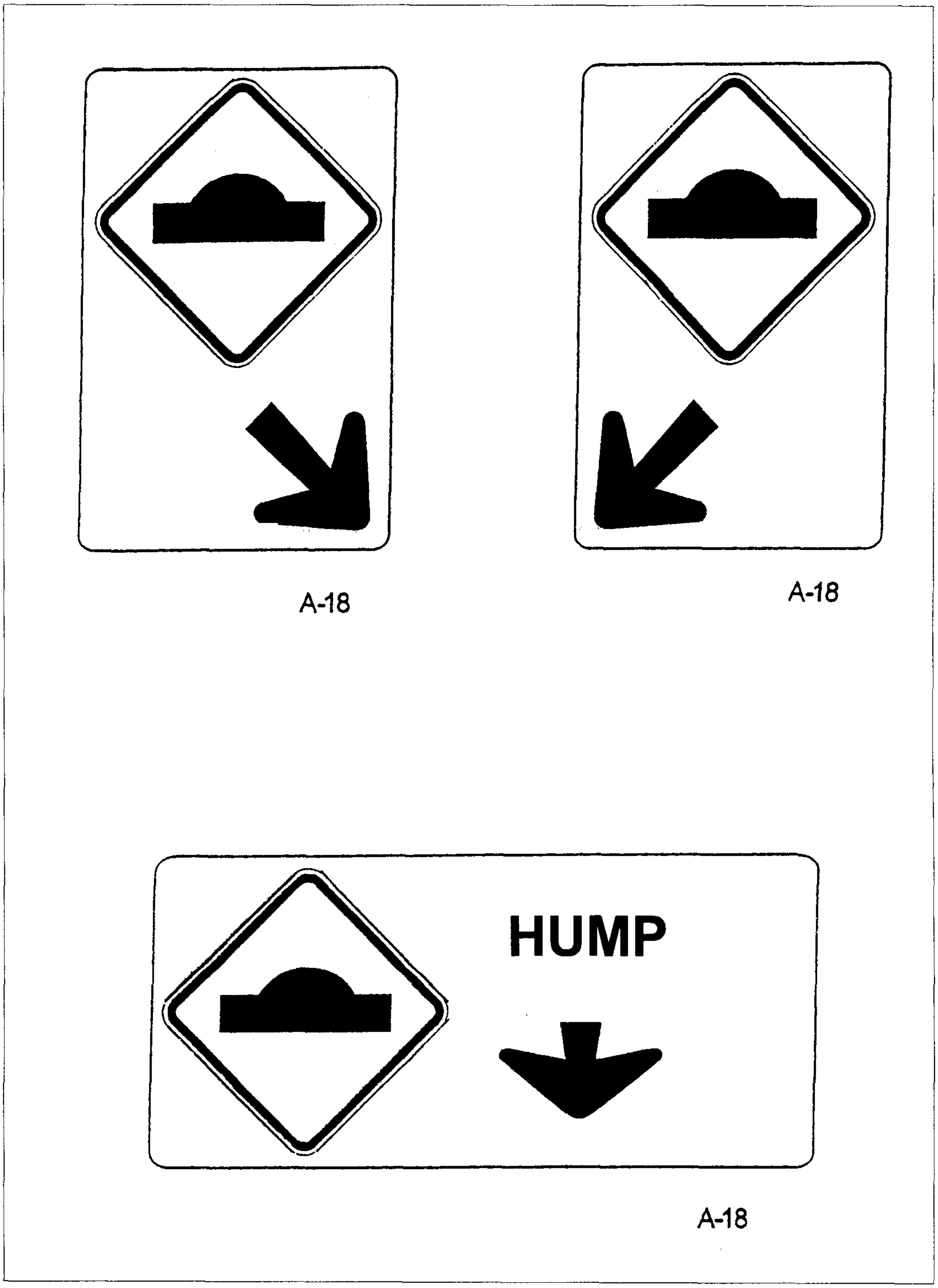
Source: CONTRAN, Resolution nº 39, (5.21.98).

FIGURE AII.2
CONSTRUCTION DETAILS, POSITION, SIGNS AND ROAD MARKINGS



Source: CONTRAN, Resolution nº 39 (5/21/98)

FIGURE AII.3
EXAMPLES OF SPEED HUMP SIGNS (A-18) FROM THE BRAZILIAN TRAFFIC CODE



Fonte: CONTRAN, Resolution nº 39, (5/21/98).

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ANNEX III

EXAMPLES OF PROJECTS AND THEIR IMPLEMENTATION COSTS

This annex presents four alternative solutions to reduce accidents at a critical spot. The best solution depends on the analysis of the accident data and site inspections. A simple location, typical of urban areas, was chosen to illustrate the approximate costs of projects of different levels of complexity. The costs, in US dollars, are based on real costs in São Paulo City, Brazil, in early 1998. They include items and quantities of signs, signals, road markings, materials, and labour. For each project they represent the real cost of implementation.

The examples refer to a simple intersection of a one-way street with a two-way street. Before implementing the new project, there were only regulatory signs that informed drivers on the two-way street that the other street was one-way, according to the city's standards at the time. Any other existing signs or road markings at the location were considered to be too deteriorated to use in the new project.

The implementation cost of the new project is the sum of the costs of all items of signs, signals, and road markings, with the exception of the existing one-way signs that would be left in place by the new project.

In Project 1, the simplest of the four, the existing one-way signs remain, pedestrian crossings are painted, and STOP signs are installed in the two-way street (Figure AIII.1). The total implementation cost of this project is US$ 2,257 (Table AIII.1).

In Project 2, three items are added to the signs and road markings of Project 1 (Figure AIII.2):

- a double yellow line to divide the road for 2-directional traffic;

- stop lines in the two-way street; and
- the word STOP painted on the carriageway to reinforce the message of the signs.

The total cost of installing this project is US$ 2,893 (Table AIII.2).

In Project 3 (Figure AIII.3), two more items are added to the signs and road markings of Project 2:

- two signs, mounted on projecting arms, with educational messages, PROCEED WITH CAUTION; and
- two blinking yellow lights, one by the side of each educational sign.

The total cost of installing this project is US$ 4,444 (Table AIII.3).

Project 4, the most complete of the four, introduces traffic lights to control the conflicting traffic flows and supplementary road markings (Figure AIII.4). Its total implementation cost is US$ 6,784 Table AIII.4).

In Chapter 12, *Evaluation of the Economic Feasibility of Projects*, we estimated the social costs of property-damage-only accidents and non-fatal personal injury accidents as US$ 1,410 and US$ 5,640 respectively[1]. The cost of the most expensive of the four projects presented here (US$ 6,784) would be approximately covered by preventing one non-fatal personal injury accident or five property-damage-only accidents.

[1] The reader may recall that on highways and other roads with high speed traffic and higher proportions of commercial vehicles, accident costs are much higher (see Chapter 1).

FIGURE AIII.1
PROJECT 1

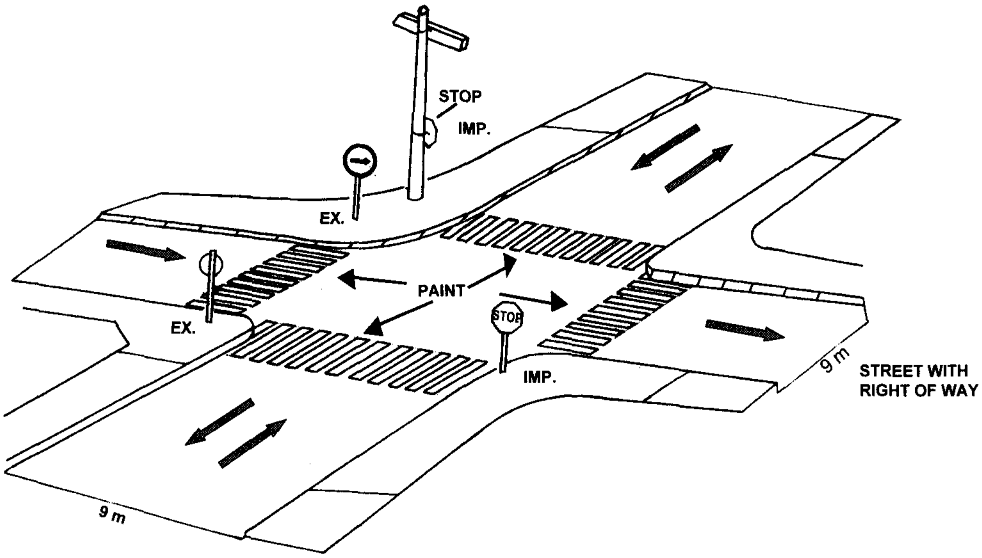

TABLE AIII.1
PROJECT 1 MATERIALS AND COSTS

MATERIAL	QUANTITY	COSTS (US$)	
		PER UNIT	TOTAL
STOP sign	2	17.83/SIGN	35.66
2.5" Post	1	45.02/POST	45.02
Pressurised thermoplastic (3mm)	57.6m²	37.78/m²	2,176.13
TOTAL			2,256.81

CET Costs, March 1998.

FIGURE AIII.2
PROJECT 2

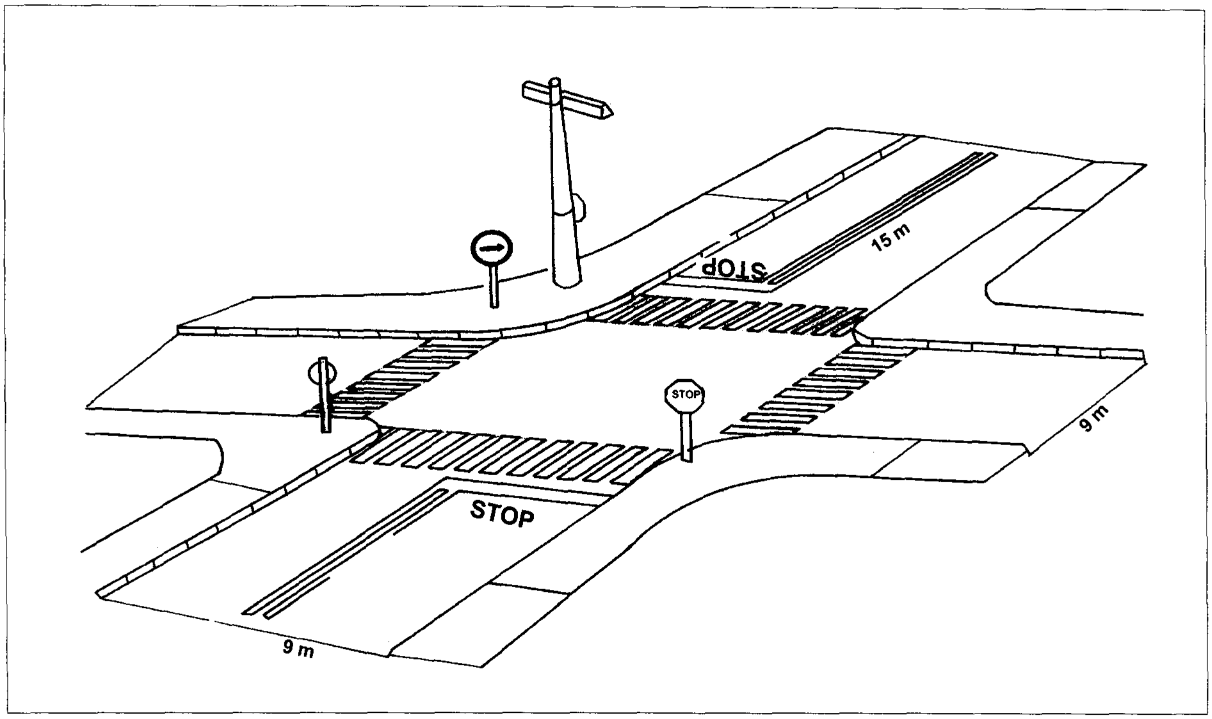

TABLE AIII.2
PROJECT 2 MATERIALS AND COSTS

MATERIAL	QUANTITY	COSTS (US$)	
		PER UNIT	TOTAL
STOP sign	2	17.83/sign	35.66
2,5" post	1	45.02/post	45.02
Pressurised thermosplastic (3mm)	69.36m²	37.78/m²	2,620.42
Aspersion-applied (spray) thermoplastic (1,5mm)	6.0m²	31.93/m²	191.58
TOTAL			2,892.68

CET costs, March 1998.

FIGURE AIII.3
PROJECT 3

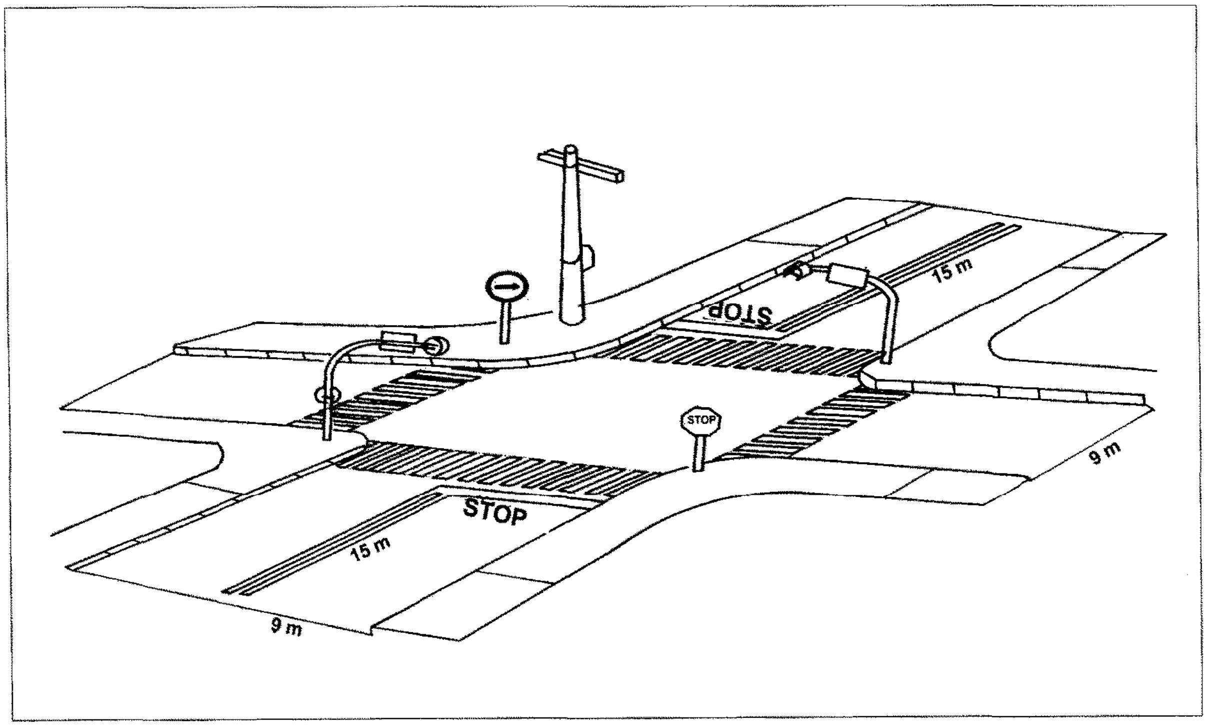

TABLE AIII.3
PROJECT 3 MATERIALS AND COSTS

MATERIAL	QUANTITY	COSTS (US$)	
		PER UNIT	TOTAL
STOP sign	2	17.83/placa	35.66
2.5" Post	1	45.02/coluna	45.02
Pressurised Thermoplastic (3mm)	69.36m²	37.78/m²	2,620.42
Aspersion-applied (spray) thermoplastic (1.5mm)	6.0m²	31.93/m²	191.58
Educative sign	2	45.44/placa	90.88
Single traffic light (300mm)	2	100.00/foco	200.00
Post with projecting arm	2	540.28/coluna	1,080.56
Controller for blinking light	1	180.00/cont.	180.00
TOTAL			4,444.12

CET Costs, March 1998

FIGURE AIII.4
PROJECT 4

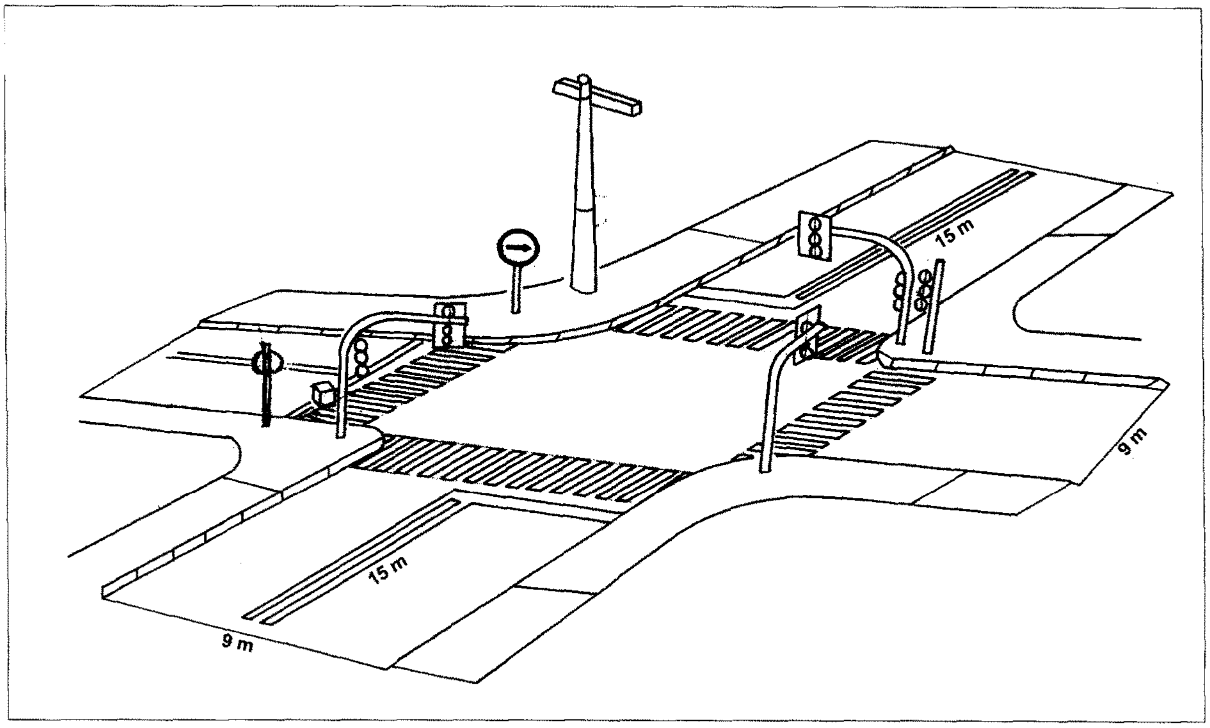

TABELA AIII.4
PROJECT 4 MATERIALS AND COSTS

MATERIAL	QUANTITY	COSTS (US$)	
		PER UNIT	TOTAL
Traffic signals unit 300x200x200	3	375.11/unit	1,125.33
Traffic signals unit 200x200x200	3	296.95/unit	890.85
Post with projecting arm	3	540.28/post	1,620.84
Post	1	129.21/post	129.21
2-phase traffic signals controller	1	400.00/unit	400.00
Pressurised thermoplastic (3 mm)	64.2 m²	37.78/m²	2,425.48
Aspersion-applied (spray) thermoplastic (1.5 mm)	6.0 m²	31.93/m²	191.58
TOTAL			6,783.29

CET costs, March 1998.

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