Evaluation of Different Types of Pedestrian-Vehicle Separations

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One of the key elements of traffic planning is elimination of conflicts, particularly between the nonmotorists and vehicles. The importance of this planning issue was realized by the ancient and medieval planners who separated the pedestrians and vehicles at the street level. Until the late nineteenth and early twentieth centuries, most of the separations were at grade and simple. But with the proliferation of automobiles, separations became complex and diverse. This paper attempts to subdivide different types of separations on the basis of their unique physical and regulatory attributes, and then compares their performance in delivering safety, equity, comfort, and convenience to the different road users (especially to the pedestrians and bicyclists).

> Where paths cross roads, the cars have power to frighten and subdue the people walking, even when the people have the legal right of way.
> Christopher Alexander, *A Pattern Language*

In his book *Relations in Public*, Erving Goffman described the differences between a vehicular unit and a pedestrian unit. His definition captured the differences in essence. Goffman noted:

> A vehicular unit is a shell of some kind controlled (usually from within) by a human pilot or navigator. . . . a road and its traffic will support shells of somewhat different kinds—cars, bicycles, horse-drawn carts, and of course pedestrians. Viewed in this perspective, . . . the individual as pedestrian—can be considered as encased in a soft exposing shell, namely his clothes and skin. (*1*, p. 6)

Goffman further commented:

> . . . the role of unintentional physical contact differs in the two systems, collision apparently being a matter of more concern on the road than on the sidewalk. Pedestrians can twist, duck, bend, and turn sharply, and therefore, unlike motorists, can safely count on being able to extricate themselves in the last few milliseconds before impending impact. Should pedestrians actually collide, damage is not likely to be significant, whereas between motorists collision is unlikely to be insignificant. (*1*, p. 7)

Given the above differences between pedestrians and vehicles, it is important to employ different design standards for each of them so that their paths only cross at defined locations. And when their paths do cross, the pedestrians' safety is not compromised.

DESIGNING FOR PEDESTRIANS' SAFETY: ELIMINATION OF CONFLICTS

Importance of pedestrians' safety was recognized from the earliest of times. Ancient planners of the city of Pompeii separated the path of pedestrians and the vehicles. They also provided stepping stones at regular intervals for pedestrians to cross over. The stepping stones served two functions: (*a*) they acted as elevated crosswalks for pedestrians to cross over easily and (*b*) they also reduced the speed of the horse drawn carts, as the riders had to carefully negotiate the wheels between the gaps in the stepping stones.

During the Renaissance, Leonardo da Vinci had envisioned a double system of streets: street level arteries for vehicular traffic and an elevated walkway system for the pedestrians. He had worked out their structures down to the last detail, including rainwater gutters and light shafts for the lower passages. Unfortunately, the ideas were way ahead of his time (*2*).

Designing for pedestrians' safety had taken back seat in this century until the 1960s. It was the European countries that reestablished the standards and requirements for safety of pedestrians in the cities during the post-war reconstruction. By the 1970s, many of the downtown streets with high pedestrian volumes were converted into pedestrian streets or transit streets (*3*). Between the 1960s and the present, over 500 German cities and a couple of hundred Dutch towns converted some areas of their downtowns into pedestrian precincts (*4*).

In the United States, the first attempt to redesign urban downtowns for pedestrians was proposed by Victor Gruen, who had stated:

> I am perfectly willing to risk the attacks of the traffic planners when I insist that the solution to co-existence of the human and automotive population does not lie in the taming of and training of people, but in the taming of the motor car (*5*, p. 212).

He redesigned the layout for the downtown of Fort Worth, Texas. The new design would protect the central area from vehicular traffic and would be served by transit and slow-moving vehicles (for those who need special assistance). He also envisaged a vertical separation between service traffic and the pedestrians.

Gruen's ideas were never fully realized, but portions of it were used to improve pedestrian safety, such as the design of the downtown pedestrian and transit malls and the design of the suburban shopping malls.

SEPARATION OF MODES

Literature on the safety of pedestrians has stressed the importance of separation of modes. Following are a few who have written on this subject: Buchanan (*6*), Gruen (*5*), Rudofsky (*2*), Pushkarev and Zupan (*7*), Fruin (*8*), Prokopy (*9*), Breines and Dean (*10*), Brambilla and Longo (*11*), Braun and Roddin (*12*), Untermann (*4*), Smith et al. (*13*), Whyte (*14*), Zegeer and Zegeer (*15*), Tolley (*16*), Bach and Pressman (*17*), and Zegeer (*18*).

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Others, such as Appleyard (*19*), Homburger et al. (*20*), Eubank-Ahrens (*21*), Hass-Klau et al. (*22*), Vahl and Giske (*23*; interview with Vahl on October 16, 1993, in city of Culemborg, The Netherlands), and Bach and Pressman (*17*), have discussed, at length, soft separation and traffic calming.

On the basis of the review of the literature, four types of separations are possible for eliminating pedestrian-vehicular (including bicycles) conflicts: (*a*) horizontal separation, (*b*) time separation, (*c*) vertical separation, and (*d*) soft separation. Each type of separation can be subdivided further on the basis of its physical configuration and differences in regulatory attributes (Figure 1).

Each of these types of separation requires different design and planning requirements using physical, psychological, visual, and legal tools to eliminate conflicts. The different types of separations, along with the different design needs, have been explained in the following pages. In addition, this paper also discusses the performance of each type of separation in eliminating or promoting the following:

1. Elimination of conflicts;
2. Safety of vulnerable groups such as the elderly, children, and the physically/mentally impaired;
3. Elimination of barriers for nonmotorists;
4. Optimal use of public space for outdoor pedestrian activities;
5. Equitable use of the public space;
6. Comfort and convenience; and
7. Ensuring conformance.

Horizontal Separation

Horizontal separation has been used from ancient times to eliminate pedestrian-vehicular conflicts, and it still continues to be used widely all over the world to fulfill the same function.

There are three different types of horizontal separations: (a) parallel elements that accommodate all modes; (b) parallel systems that eliminate some of the vehicular traffic; and (c) displaced elements that have no vehicular traffic.

Parallel Elements Shared by All Modes. These systems accommodate pedestrian movement adjacent and at grade to vehicular movements. The elements work well when there are sufficient spaces available to distribute equitably among modes on the basis of their efficiency and productivity (Figure 2). The quality of the public space depends on the skillful use of the design elements explained in Table 1.

TABLE 1 Horizontal Separation: Parallel Elements that Accommodate All Modes

Design Characteristics of the System	Examples	Specific Elements Ensuring Protection to Pedestrians from conflicts with cars and bicycles
Parallel Elements where all modes are accommodated.	•Sidewalks (Figure 3) •Arcades/ Canopied sidewalks. •Semi malls (sidewalks are widened and there is no parking but vehicular traffic is allowed).	*Physical Means* • Separate channelization of the modes. • Barriers such as -- bollards, landscaping (Figure 5), high curbs are used to prevent improper movements of different modes. *Psychological Means* • Equal attention is given to all the modes, no one mode dominates over the others. • Low level lighting (4-5 m or 12-15 ft) along the walkways. *Visual Means* • The layout is consistent with the uses of the street. • The layout induces the expected behavior from the different road users. • Pedestrian use is uninhibited due to the absence of barriers. *Legal Means* • Time separations are provided, using traffic control devices -- signals, and stop signs. • Signs posted to remind different users to conform to the expected behavior.

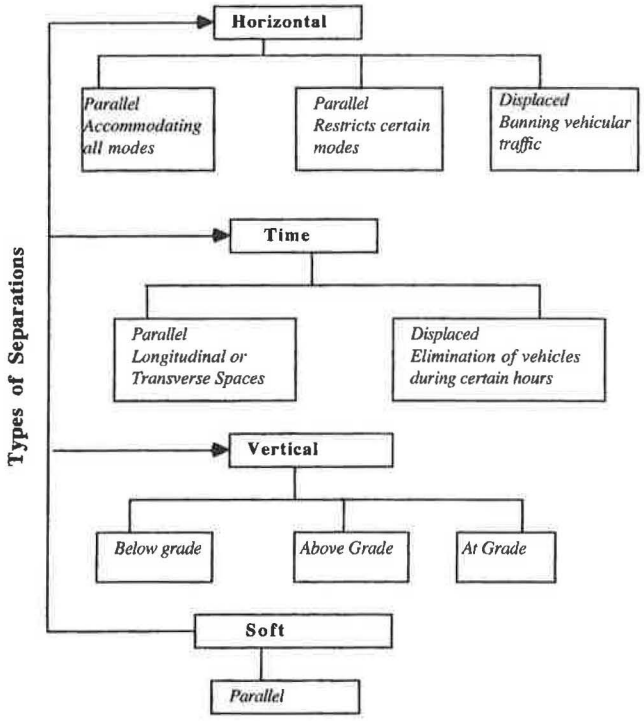

FIGURE 1 Classification of different types of separation.

FIGURE 2 Equal distribution of space among all modes; Houten, The Netherlands.

TABLE 2 Horizontal Separation: Parallel Elements with Elimination of Certain Modes

Design Characteristics of the System	Examples	Specific Elements Ensuring Protection to Pedestrians from conflicts with cars and bicycles
Parallel Elements with elimination of certain modes.	Transit Malls (Figure 3)	*Physical Means* • Wide sidewalks. • Landscaping and bollards to prevent improper movements. • Bicycles share the roads with the transit vehicles. *Psychological Means* • Streets are designed with pedestrians and cyclists in mind. Vehicular traffic (except for light rail and emergency vehicles) is banned. • Low level lighting emphasizing pedestrianization of the street. *Visual Means* • The layout is distinct and consistent with the uses of the street. *Legal Means* • Signs warning vehicles on the restrictions imposed on them. • Signs warning pedestrians of the presence of transit vehicles. • Transit vehicles are warned of the pedestrianization of the street.

Parallel Elements with Restriction on Certain Vehicles. These vehicles, which accommodate pedestrian movements adjacent and at grade, allowing certain types of vehicles in most instances, are transit vehicles (Figure 3). To maintain a conflict-free environment, cars are restricted from driving through, and service and delivery vehicles are allowed during fixed hours. Although these have limited applications, they are very useful solutions in urban areas with dense retail activities and high pedestrian volumes (Table 2).

Displaced Elements. These have eliminated vehicular traffic within the area through design and regulatory signs to facilitate pedestrian and bicycle usage. These types of systems rely on efficient underground transit systems for success (Table 3). Although they have limited application, they offer a productive, environment-friendly use of the public space. Pedestrian zones, or auto free zones, as they are popularly known, are most useful in urban areas with dense retail activities and high pedestrian volumes, or in historic areas (Figure 4).

The level of performance of different types of horizontal separations is shown in Table 4.

Time Separation

Time separation enables different road users to safely use the public space at different time intervals. There are two popularly used time separations, parallel or displaced. ("Scramble" or "all walk" has not been classified separately.)

Parallel Elements

These are transverse or longitudinal systems placed at regular intervals that are widely used to enable pedestrians and vehicles to use them at different time intervals without conflicts (see Figures 5 and 6). The design requirements are explained in Table 5.

Displaced Elements

These are systems that ban vehicular traffic and allow pedestrian movements along the entire rights of way during certain times of the

TABLE 3 Horizontal Separation: Displaced Elements

Design Characteristics of the System	Examples	Specific Elements Ensuring Protection to Pedestrians from conflicts with cars and bicycles
Displaced Element with elimination of the motorized modes.	• Pedestrian Malls • Permanent Street Closures (Figure 4). (Transit services are along parallel streets or underground.)	*Physical Means* • Bicycles are allowed where (a)the sidewalks are wide enough for pedestrian activities; and (b) the roadways can accommodate bi-directional bike movements with minimal conflict. • Bollards, and landscaping placed at ends of the street, to prevent vehicles from driving through. *Psychological Means* • Street is redesigned with pedestrians and cyclists in mind. • Low level ornamental lighting to emphasize pedestrianization of the street. *Visual Means* • The layout is distinct and consistent with the uses of the street. *Legal Means* • Vehicular traffic is banned (except emergency vehicles). • Signs warning vehicles that it is a pedestrian zone (Figure 8) . • Signs warning bicyclists that pedestrians have the right of way.

FIGURE 3 Transit street; Munich, Germany.

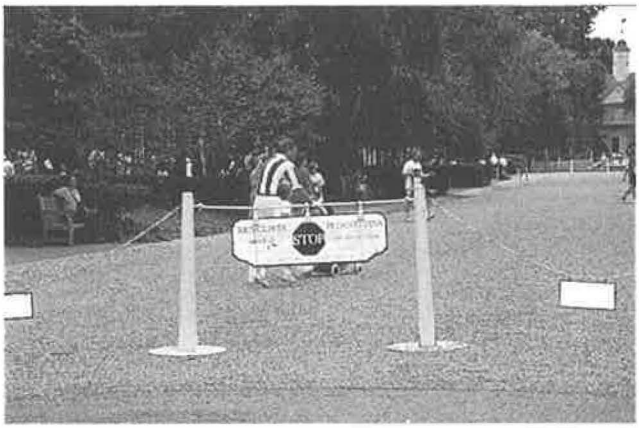

FIGURE 4 Auto-free zone; Colonial Williamsburg, Va.

TABLE 4 Performance of Horizontal Separations

	Parallel Elements (all modes are accommodated)	Parallel Elements (some of the modes are eliminated)	Displaced Element with elimination of motorized traffic
Elimination of Conflicts	• Depends on (a) the physical design; (b) treatment of psychological, visual, and legal attributes of the design; (c) the vehicle speed.	• High - Very high	• Very high
Safety of Vulnerable Groups	• Depends on the (a) physical design; (b) effective treatment of psychological, visual, and legal elements of the design; (c) the vehicle speed.	• High - Very high	• Very high
Elimination of Barriers for non-motorists	• Depends on the (a) design standards for removal of physical and perceptual barriers; and (b) the vehicle speed.	• High - Very high	• Very high
Optimal use of public space for outdoor pedestrian activities	• Depends on the (a) user-friendliness of the environment; and (b) the surrounding land use.	• High - Very high	• Very high
Equitable use of the public space	• Depends on the division of the right of way.	• In favor of non-motorists.	• In favor of non-motorists.
Comfort and Convenience	• Depends on the design for noise control, pollution dispersion etc.	• High - Very high	• Very high
Enforcement required	• Varies with the (a) design; (b) vehicle speed; and (c) attitude towards traffic rules.	• Low due to regulatory signs and designs.	• Low due to regulatory signs and designs.

FIGURE 5 Bollards and trees separate pedestrians from vehicles; Rome, Italy.

FIGURE 6 Time separation transverse with respect to Orange Avenue, Orlando, Fla.

TABLE 5 Time Separation: Parallel Elements

Design Characteristics of the System	Examples	Specific Elements Ensuring Protection to Pedestrians from conflicts with cars and bicycles
Parallel Elements Transverse or Longitudinal Separation	• Marked or Unmarked Crosswalks	*Physical Means* • Raised crosswalks to discourage drivers from speeding or blocking intersections. • Curbs are extended to improve the visibility of the pedestrians and drivers. • Tactile cues are provided to guide visually impaired. • Presence of pedestrian refuges where needed (Figure 12). *Psychological Means* • Intersection is redesigned with pedestrians and cyclists in mind. • Low level lighting to emphasize pedestrian crossing zones. *Legal Means* • Well designed traffic signals restricting vehicular movements: -- exclusive pedestrian signals; -- "all walk" signals; -- allowing pedestrian movement parallel to the traffic flow without any turning movements. (Time separation is void if turning movements are allowed.) • Stop signs at intersections along with signs warning drivers that they must yield to pedestrians. • Signs warning drivers not to block crosswalks.

day or night. They are a useful planning tool for historic areas or older urban areas, where the rights of way cannot be increased to accommodate high pedestrian volumes and vehicular traffic (Figure 7). They are a low-cost method of eliminating pedestrian-vehicular conflicts. The design requirements are explained in Table 6 and Figure 8.

The performance of time separation in ensuring safety, equity, comfort, and convenience is shown in Table 7.

Vertical Separation

These are systems in which the vehicles are displaced vertically from the nonmotorized traffic. The earliest designs for vertical separation were proposed by Leonardo da Vinci; unfortunately, they were never implemented. Three types of vertical separations are possible: below grade, above grade, and at grade. The design requirements for each type of separation are explained in Table 8.

Below-Grade Systems. The vehicular movements are above, and pedestrian movements are below the ground (Figure 9); for example, Place Bonaventure, Montreal; Transit Concourse; and Munich.

Above-Grade Systems. The pedestrian movements are above, and vehicular movements are at grade (Figure 10), for example, skyway systems of Minneapolis, and Arlington, Virginia.

Both of these systems have been used increasingly in urban areas with freezing or excessively high temperatures. Although expensive and difficult to retrofit, they can offer excellent systems of climate-controlled conflict-free walkway systems.

TABLE 6 Time Separation: Displaced Elements

Design	Examples	Specific Elements Ensuring Protection to Pedestrians from conflicts with cars and bicycles
Displaced Elements *Vehicular traffic is banned during the peak pedestrian hours (except emergency vehicles).*	Daily street closures during certain hours	*Physical Means* • Bicycles are allowed where the sidewalks are wide and the roadways can accommodate bi-directional bike movements with minimal conflicts. • Sidewalks are wide enough to accommodate pedestrian activities after the streets are reopened to vehicles. • Vertical deflections on the road surface, such as road bumps, chicanes, raised crossings, to control speed after streets are reopened to vehicular traffic (Figure 8). *Psychological Means* • Streets are redesigned with pedestrians and cyclists in mind. • Low lighting to emphasize the pedestrianization of the street. *Visual Means* • The layout is distinct and consistent with the uses of the street. *Legal Means* • Signs warning vehicles that it is a pedestrian zone during the posted hours. • Signs warning bicyclists that pedestrians have the right of way. • Reduced speed designs to warn the motorists to modify their behavior after pedestrian-only hours.

FIGURE 7 Chestnut Street Transit Mall, Philadelphia, closed to vehicular traffic during peak hours.

FIGURE 8 Street with 30-km speed limit and vertical deflections; Delft, The Netherlands.

TABLE 7 Performance of Time Separation

	Parallel Elements -- Longitudinal and Transverse	Displaced Elements
Elimination of Conflicts	• Depends on (a) the physical design; (b) treatment of psychological, visual, and legal elements; (c) the vehicle speed; and (d) the type of traffic control devices.	• Very high during street closure periods. • Variable (depending on design to eliminate conflicts) during other times of the day.
Safety of Vulnerable Groups	• Depends on --(a) design, (b) traffic control devices; and (c) vehicle speed.	• Very high during *street closure* periods. • Variable during other times of the day, depending on the design to eliminate conflicts.
Elimination of Barriers for non-motorists	• Depends on -- (a) the width of the parallel elements and presence of pedestrian refuges; (b) presence of well designed traffic control devices; (c) vehicle speed.	• Very high during street closure periods. • Variable at other times, depending on the extent to which the physical and perceived barriers have been eliminated.
Optimal use of public space for outdoor pedestrian activities	--	• High
Equitable use of the public space	Depends on -- (a) design; and (b) traffic control devices.	• In favor of non-motorists during certain times of the day or night.
Comfort and Convenience	• Depends on the design of the (a) curb ramps or raised crosswalks; (b) presence of tactile cues for the visually impaired; and (c) the type of traffic control devices.	• Depends on the design -such as- landscaping, noise control, pollution dispersion, walking surface etc.
Enforcement required	• Depends on regulatory designs (extended curbs, corner blips) and regulatory signs.	• Low due to regulatory signs and designs.

TABLE 8 Vertical Separation at Different Grade Levels

Design Characteristics of the System	Examples	Specific Elements Ensuring Protection to Pedestrians from conflicts with cars and bicycles
Below Grade	• Subways • Transit Concourses • Subwalks • Underground retail and commercial concourses or malls	*Physical Means* • Vertical separation of pedestrians from bicycles, and vehicles. • No at-grade crossings. *Psychological Means* • Well lit wide walkways. *Visual Means* • The layout and design of the walkways are coherent and consistent with the use. • The walkways are lined with retail activities making them attractive to the pedestrians.
Above Grade	• Skywalks (+5 or the +15 systems) • Skyways • Pedestrian Bridges	*Physical Means* • Vertical separation of pedestrians from bicycles, and vehicles. • No at-grade crossings. *Psychological Means* • Well lit wide walkways. *Visual Means* • The layout and design of the walkways are coherent and consistent with the use. • The walkways are connected to retail, business, and commercial activities for the convenience of the users.

FIGURE 9 Transit concourse; Munich, Germany.

FIGURE 10 Skywalk; Arlington, Va.

TABLE 9 Performance of Vertical Separation

	Below Grade	Above Grade
Elimination of Conflicts	• Very high	• Very high
Safety of Vulnerable Groups	• Very high	• Very high
Elimination of Barriers for non-motorists	• Very high	• Very high
Optimal use of public space for outdoor /indoor pedestrian activities	• Outdoor public space has limited use for activities because of inclement weather or unattractive conditions. But indoor pedestrian activities are very high.	• Outdoor public space has limited use for activities because of inclement weather, or unattractive conditions. But pedestrian activities are very high on the skyways.
Equitable use of the public space	• High - Very high	• High - Very high
Comfort and Convenience	• High - Very high	• High - Very high
Enforcement required	• Low, when appropriate design for security has been implemented.	• Low

At-Grade Systems. The vehicular traffic is directed either above or below, and pedestrian movement is maintained at grade. This type of separation has limited application, and is used more often to separate through traffic from the local vehicular traffic.

The performance of above/below-grade systems in ensuring safety, equity, comfort, and convenience is shown in Table 9.

Soft Separation (Traffic Calming)

Soft separation has been used increasingly in European countries for reclaiming public space for diverse uses. The distinctive feature of this system is that it stresses integration instead of separation of traffic in dense urban areas. Pedestrians and cyclists are treated equally in this system, and the cars are domesticated by design to adapt to the environment (*16,22*).

The parallel elements system enables different modes to share the same right of way because: (a) the existing right of way is unable to accommodate clear separation of the modes, or the designers have deliberately designed the street with narrower right of way; (b) there are high levels of pedestrian activities; (c) it would discourage excessive use of vehicles and encourage use of greener modes; and (d) it would ensure a safer environment with better quality of life.

Wide application of this type of separation is possible. It can be retrofitted in the existing residential areas and other land uses, or used in the design of new residential neighborhoods, college campuses, retail districts, etc. Soft separations with traffic-calming designs are usually applied to larger areas, thus requiring more detailed planning analysis and areawide traffic management.

The design and other requirements of such systems are detailed in Table 10 (see Figures 11 and 12).

The benefits of soft separation are more widespread, and they improve the quality of life for a large number of people when larger areas are redesigned. This alleviates transferring the problem (traffic) to surrounding streets.

The performance of soft separation in ensuring safety, equity, comfort, and convenience is given in Table 11.

USEFULNESS OF CLASSIFICATION

Most transportation planners are aware of the different types of separation, and several authors have enumerated all of them or some of them in their works (*7,2,8,9,24–26*). However, very little attempt has been made to compare and analyze the various design and planning tools required to ensure the success of each type of separation.

This paper attempts to break down the five planning and design tools, physical, psychological, visual, social, and legal, that would ensure the success of these separations in eliminating conflicts. Although no environment can be foolproof from conflicts, close encounters can be eliminated to a considerable extent if the planners attempt to address all of these five elements in the right proportions. Excessive reliance on one or two of these elements will not often yield the desired results, and this work explains the unique functions performed by each of these planning and design tools in ensuring the smooth working of different types of separations.

Additionally, in order to ensure highest possible use of the public space by the efficient and environment-friendly modes, each

TABLE 10 Soft Separation with Traffic Calming

Design Characteristics of the System	Examples	Specific Elements Ensuring Protection to Pedestrians from conflicts with cars and bicycles
Pedestrians and vehicles may share the same right of way after certain changes have been initiated.	• Dutch "*Woonerf*" or residential precincts. • Dutch *erf* and German (tempo 30) 30 km zones. • Swedish "*Handerf*" areas.	*Physical Means* • Vertical deflections in the road surface, such as road bumps, raised crossings, platform junctions raised at pavement level. • Roadway width constrictions, chicanes, corner blips, bends along the roads. • Traffic throttles, bollards, trees, street planters, barrels, lamp posts etc. *Psychological Means* • Street designed/redesigned with the pedestrians and cyclists in mind. Drivers feel like guests in these areas. • Low pedestrian lighting to stress the urban atmosphere. • Meandering vehicle paths emphasize the need to restrict speed. • Entrance to built up areas or neighborhoods is emphasized through gateway effects created by vertical features such as pergolas, barriers, or planters. *Visual Means* • The layout is clear and consistent with the appropriate uses of the street. • The layout induces the expected behavior from the drivers.
Parallel Elements		*Social Means* • Adequate information dissemination and consultation with the residents and the users of the street, on the priority changes in the area. *Legal Means* • To achieve the desired driving behavior, signs with the speed limits and the uniqueness of the precinct, are posted to remind the motorists that they must modify their behavior.

FIGURE 11 Examples of soft separations from Delft, The Netherlands.

FIGURE 12 Examples of soft separations from Delft, The Netherlands.

TABLE 11 Performance of Soft Separation

	Parallel Elements
Elimination of Conflicts	Very high due to low speed and traffic calming designs.
Safety of Vulnerable Groups	Very high due to low speed and traffic calming designs.
Elimination of Barriers for non-motorists	Very high
Optimal use of public space for outdoor pedestrian activities	Very high
Equitable use of the public space	Protects the rights of non-motorized modes.
Comfort and Convenience	Depends on the quality of the designs -- walking surface, presence of ramps, protection from weather etc. More favorable to pedestrians than vehicles and bicyclists.
Enforcement required	Low, if appropriate design and regulatory signs are used.

right of way should be graded on how well it performs with regard to safety, equity, comfort, and convenience. Each type of separation has certain inherent weaknesses or drawbacks, and these have been highlighted in this work for the convenience of traffic planners, so that they can address them effectively while improving the existing separations or designing new ones.

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