The Amsterdam Experiment in Mixing Pedestrians, Trams and Bicycles

Mixed-Mode Streets Are Being Proposed As a Solution to Local Traffic and Land-Use Problems. In the study described in this feature, a de facto mixed-mode street in Amsterdam with relatively high traffic volume was studied to determine how the modes and directions are accommodated.

Pedestrian zones have become a familiar feature in the central areas of European cities. Private cars are always excluded from these zones, while delivery vehicles are permitted during off-peak hours. Bicycles and taxis are typically relegated to a circumferential service road. Some have argued that such rigid traffic separation contributes to economic and environmental disparity between the pedestrian zone and its surroundings. The concentration of high-value retailing, services and pedestrians within the zone contrasts with low values and heavy car traffic at the periphery. Traffic-calming experiments during the 1970s and 1980s demonstrated that environmental design could reduce both the volume and the environmental impact of cars in local areas. These results have led to speculation about how a controlled mix of traffic modes might be made to lessen these central-area contrasts. The role of the bicycle in particular has not been addressed in pedestrian zone planning. The bicycle is typically treated as a vehicle even in those cities where its use is encouraged. However, since environmental design cannot be used to exclude cyclists from pedestrian areas, planners have to rely on cyclist adherence to regulation, a dubious proposition in many cities.

The Netherlands has consistently embraced the principles of traffic separation while promoting use of the bicycle. Pedestrianized core areas and an extensive system of separate bikeways are found in all major towns and cities. Bicycles are routinely used for all kinds of intra-urban trips and are found not only on bicycle pathways but on all other streets as well. The extensive pedestrian zones, some exceeding a 30-minute walk across the diameter, make the bicycle more attractive than pedestrian or public transportation alternatives. The bicycle offers significant time saving, relative safety and convenience.1 The pedestrian zones provide cyclists with alternate routes that are often illegal but are nevertheless used on a regular basis. Authorities tolerate cyclist use of these pedestrian paths, as long as it does not contribute to pedestrian discomfort or accidents. Some Dutch observers argue that such a liberal approach works best since the level of cyclist use is largely self-regulating. According to the self-regulation theory, cyclists take responsibility for collision avoidance and pedal through pedestrianized zones if pedestrian traffic volumes allow them to do so comfortably and safely.

This de facto mixing of modes merits study for several reasons. If such systems can be made to work safely and efficiently, they can solve many planning problems. The major issues in addition to level of service are comfort, convenience, safety and attractiveness.2 While engineers have generally supported traffic separation as safer than mixing, not all agree with this view, citing the persistent accident rates at intersections of pedestrian and bicycle pathways with vehicular routes.3 The self-regulating theory also requires empirical verification. In particular, we need to understand how pedestrian volume flow level impacts on bicycle volume flow.

Separated bicycle pathways take space on the street, usually the width of a traffic lane in each direction. In Amsterdam as in many other cities in Europe and North America, implementing such an arrangement with separated footpaths means a drastic reduction in the space allocated to vehicles, if not their elimination from the street.

One of the major questions raised by such designs is their carrying capacity.
and, in particular, the sustainability of the traffic mix when the total volume of traffic is increased.\(^4\)\(^5\) Also, in the event that the number of pedestrians remains stable while the number of bicycles increases, will there be more conflict situations? Alternatively, if the number of pedestrians increases, how will this affect the cyclist's experience and his/her decision to use this street?

Effective width of the street is less than the real one because pedestrians do not use all of it.\(^6\) The design factors in preference for a particular path trajectory need to be examined. It has been suggested that walkway capacity will be reduced when there is two-way movement and when this movement is uneven.\(^7\) This is because the secondary flow will be dispersed in and among those moving in the opposite direction. Even flows in opposite directions will tend to sort into separate streams but only at density levels somewhat greater than those in the Leidsestraat. In typical commercial streets, there is bound to be an uneven distribution of pedestrians in the observed streams, and the streams themselves may not be stable. While such conditions may be tolerable for pedestrians traveling at approximately the same speed and with considerable maneuverability, this may not be the case when cyclists are added to the mix.

These questions are addressed in a field study of the Leidsestraat, a major pedestrianized street in the historic core of Amsterdam.

**RESEARCH METHODS**

In this feature, we examine the patterns of movement as they appear over time and in relation to the plan of the street. We show how the various identifiable streams of movement (eight of them) use various parts of the street surface, overlap, expand and contract. Secondly, we discuss the role of environmental design in the behavior of pedestrians and cyclists. Finally, we consider how variations in density impact on the space available for cyclists.

Our method involved videotaping sections of the street from elevated positions on bridges with a digital camera. Midday samples were taken at three sections of the street, each with the same cross-sectional design but with different intersection configurations and different pedestrian volumes.

The tape was sampled in single frames taken at sufficient intervals so that all the pedestrians in the earlier frame had been replaced in the later one. The section of the street represented in the frame was reproduced as a computer-based drawing. Individual pedestrians, bicycles and trams in the frame were plotted on the plan. In this way 45 frames were selected from the video record for detailed consideration. These layered maps are then reproduced as density diagrams to reveal the directionality of the flows and the intensity of use of various parts of the available channel.

Finally, we approach the question of the impact of an increase in pedestrian and cyclist presence by considering the behavior of individuals at the various recorded density levels. When the overall density is higher, is there a concomitant tendency for individuals to spread themselves over the available space or do they tend to reduce the amount of space between them within the channels already heavily used? For example, Liu\(^8\) found that the width of the channel used by cyclists is linearly related to the flow rate. However, pedestrians tend to spread out to gain greater physical and psychological comfort. As a result, it may be that relatively low overall pedestrian densities will present the cyclist with as difficult an obstacle course as a street with higher density. To find out what effect higher pedestrian density had on the maneuvering capability of the cyclists, we measured the distance between each individual and the three nearest individuals in each frame. The figures for pedestrians and cyclists were compared with overall densities.
THE LEIDSESTRAAT CASE STUDY

The Leidsestraat is a particular case but typical for the questions raised by such de facto shared pedestrian corridors. The street is officially pedestrianized and directly linked with the most heavily traveled parts of the central walking system, including the Kalverstraat and Nieuwendijk (Figure 1). These latter streets are narrower with higher overall flow levels and no bicycles except in off-peak hours. The Leidsestraat is the most important north-south transportation corridor through the city, at least until the north-south metro line is completed.

The street is also the major traffic carrier in an area of four- to six-story buildings with high site coverage, even though the street itself is only 12 meters (m) wide. The Leidsestraat is lined with clothing, houseware and gift shops as well as small restaurants. The transversal streets also are lined with restaurants, which generate considerable traffic in the evenings. The Leidsestraat itself empties into the Leidseplein, one of the most important entertainment centers in the city and the junction of several tramlines, bicycle and car routes. During the peak period from noon until 3 p.m., pedestrian volumes vary from 3,000 to 4,000 persons/hour (h). Although the great majority of pedestrians are natives, tourists form an important minority, more for their conspicuous behavior than for their actual numbers. Three tramlines pass through these streets at headways of about two minutes, for a carrying capacity of 2,800/h. The cyclist volume varied between 200 and 300/h.

The street is demarcated by a single, overlapped tramtrack in the center, set in asphalt and bordered by a gutter grating. Both sides of the grating to the building faces are paved in brick. These wide strips of brick are divided into two parts, the inner building edge being finished in a variegated and unevenly laid brick while the central strip is flat and even (Figure 2). Part of the rough brick surface also is used for store displays, bicycle parking and refuse bins. Pedestrians are concentrated in the flat brick area but also stray onto the tramtracks when the density is high. Up to half of the bicycles follow in the wake of the tram, share the asphalt strip between the rails or veer between groups of moving pedestrians. Faster moving pedestrians usually choose to venture into the tramtrack area, moving out of the way of oncoming pedestrians, cyclists or trams (Figure 3).

The first impression of the Leidsestraat from the raised bridge portions over the canals is that of a chaos of
movement. Movement in both dominant directions is heavily intermixed, with additional movement from side to side of the street. Through the center at two-minute intervals trains pass alternately in both directions. Bicycles weave through all of this movement. Dozens of collision accidents appear ready to happen at any one moment although very few are witnessed (none in several days of observation).

**RESEARCH RESULTS**

The Leidsestraat never experiences a density of traffic resulting in the overall slowing of pedestrian movement, although individual progress is impeded frequently and temporarily. The average peak of 4.6 persons/minute/m is below those levels found to result in reduced speed, platooning and reduced cross-movement, all of which can however be observed nearby on the Kalverstraat. The pedestrian density on the Leidsestraat is 0.18 pedestrians/m². This is much less than the critical value of 1 for a reduction of speed. Nevertheless, it has been suggested that truly unimpeded walking requires about 12 m²/pedestrian, equivalent to 6.5 pedestrians/minute/m of walkway width. The Leidsestraat average pedestrian density is 6.1 m²/pedestrian with a standard deviation of 2.1. If only effective walkway width is considered, i.e., the flat-bricked area, then the space/pedestrian would approach 4 m². While the average walking speed is a relatively high 5.3 kilometers per hour (kph), slower-moving platoons and meandering tourists frustrate free movement several times while traversing a single block.

The regularity of our data is important to our conclusions, especially in light of the variety of movement patterns. Several studies have related the volume of pedestrian movement and limited observations (see Ref. 11 for instance). Haynes12 provided a way to estimate the sampling error in pedestrian counts, using the pedestrian environment in Norwich. At the flow rate and for the sampling times in our street, we could expect about 10 percent error.
Our own samples showed relatively low standard deviations; for example, for an average count of 32.7 pedestrians, the standard deviation was 5.0. In other words, our samples are representative of the situations and times observed. These samples are not, however, representative of the much greater range of densities over the day and over the week.

At these suboptimal conditions, traffic streams already show a statistical tendency to right-handed travel but with the opposing movement completely mixed. There is no observable reduction in speed in this arrangement although there is a need to be alert to possible collision with other pedestrians. For the cyclist in particular, the challenge is substantially greater since people in the street are moving toward and away from their own moving bicycle and in a constantly changing distribution across the width of the street. While cyclists tend to seek the underused central portion of the street, they share a relatively narrow strip. The space between the rails is just wide enough for two bicycles to squeeze by with a clearance of a couple of centimeters, otherwise requiring a fairly sharp movement to cross the rails at an obtuse angle. Cyclists tend to keep to the right of each other within the available channel for them (Figure 4).

Moreover, the individual paths are clustered together in a relatively small part of the available channel. Figure 5 illustrates traffic density on the same section of the Leidsestraat as illustrated in Figure 1.

Shoppers make up only 5 percent of the traffic in any one section of the street. Since the street is long, a higher proportion of the pedestrians are also shoppers at some part of the street, but they do not behave as shoppers for the most part. Shoppers tend to weave across the streams of traffic, deferring to the through movement and only occasionally coming into conflict with others. Other shoppers cling to the relatively untraveled portion of the street next to the building facade. Much more cross movement is encountered at the block ends where transversal streets carrying car traffic cross the Leidsestraat. At this point, cyclists and drivers attempt to cross the Leidsestraat traffic streams without explicit rules or traffic lights to guide them. Cross movement defers to through movement, although this often amounts to edging into the stream until pedestrians yield the right of way.

Finally, we considered the question of whether pedestrians and cyclists tend to distribute themselves variably across the street surface at various densities. Our measurements from each individual to the three nearest neighbors were thought to capture all spacing maneuvers individuals were likely to engage in. These measurements included those individuals walking together who could not be expected to disperse at lower overall pedestrian density. We can nevertheless observe a tendency toward dispersion over the whole sample, as shown in Figure 6. This means that an increase in density does not produce a linear increase in pedestrian presence over the road surface.

Cyclists were observed to maintain a greater distance from each other and from pedestrians than pedestrians did from each other. The distances between cyclists and others include only nine instances out of 248, which are less than 1 m, representing comfort distance. No relationship is found between cyclists and others as a function of overall density ($R = -0.001$). Over the density range in our sample, the conflicts that occurred were not attributable to density but to chance encounters.

CONCLUSIONS

Visitors to Amsterdam are often amazed to observe the free movement of pedestrians, cyclists, and trams and especially the skill of the Amsterdam cyclist. Others are impressed by the apparent insouciance of parents with babies mounted front and back of the bicycle, riding in the rain between tramtracks and pedestrians (Figure 7).
In this particular case, we were interested in sorting out the movements to develop an approach to measuring thresholds for such mixed-use streets. While the Leidsestraat seems to operate within tolerable limits of mixing, increased density will surely lead to an increasing number of conflicts and the eventual elimination of the bicycle from the street.

We have discovered that the variations in density observed here have little or no effect on cycling behavior. Moreover, overall density may be a poor measure of the capacity of the street, since the spatial distribution of pedestrians is clearly a more important factor in the accommodation of the bicycle. The most promising feature of the Leidsestraat case is the role of environmental design in the location of movement streams. Subtle changes in paving are closely related to the distribution of pedestrians and bicycles in the street.

To study thresholds for pedestrian and bicycle mixes for different street configurations, we will need a much larger set of visual records, covering a wider range of densities. It also would be useful to conduct a study of individual trajectories within a dynamic field to develop a more complete catalog of behavior that could be incorporated into an eventual model.

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References


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