UNDERPASSES FOR PEDESTRIANS AND CYCLISTS

User Requirements and Implications for Design

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In The Netherlands growing attention is being paid to slow traffic facilities. In order to increase road safety many municipalities build or intend to build underpasses for pedestrians and cyclists. However, such traffic solutions have disadvantages, too. Often people manifest feelings of being fenced in or express fear of violence. Nevertheless, in many situations there is no better alternative. In this article designers, planners and users are presented with a checklist of user requirements and design objectives aiming at optimal solutions. In particular attention is paid to the possibilities of avoiding feelings of anxiety by means of appropriate design.

INCREASING ATTENTION FOR SLOW TRAFFIC FACILITIES

As in other countries, many Dutch people travel by private car or use public transport. Still Holland is a country of cyclists. Youngsters especially go to school or work by bike, but adults, too, use this means of transport for their work or just for pleasure. As a consequence of increasing energy prices and economic recession, but also for reasons of health, cycling is still increasing. At the time 1.2 million bicycles are sold in Holland each year. Therefore, more and more attention is paid in transport policy to the interests of this category of road users, for example, by planning a close network of safe cyclepaths, separated from fast traffic.

In the past few years increasing attention has also been paid to the interests of pedestrians. Many Dutch town centres now have pedestrian precincts providing more space for people to walk and shop safely, not hindered by smells or traffic noise. In residential areas designers try to increase quietness and safety by application of the "woonerf" concept: an integration of fast and slow traffic, achieved by speed-reducing measures (such as humps, plateaus and narrowing of streets), hence allowing playing and walking everywhere.

In this way, residential functions predominate over provisions for traffic.

SUBWAYS: A SOLUTION WITH PROBLEMS

In many cases slow traffic has to cross roads for fast traffic. If there is heavy traffic flow in various directions, multi-level intersections are preferable in view of road safety and saving of time. One might distinguish six alternative solutions for such crossings (Figure 1), each with their own problems. For example a viaduct or road tunnel is very expensive, while a bridge for slow traffic crossing a speedway or railroad requires special effort to reach bridge level, which is rather high to allow sufficient headroom for the underpassing fast traffic.

FIGURE 1 Intersections on different levels for slow and fast traffic. (a) Subway for slow traffic. (b) Bridge for slow traffic. (c) Viaduct for fast traffic. (d) Road tunnel for fast traffic. (e1) Combination of (a) and (c). (e2) Combination of (b) and (d).

Actually, an underpass may be the lesser evil, especially in combination with a gentle lifting of the highway. Indeed an underpass for slow traffic is often chosen. According to an inquiry of the Royal Dutch Touring Club ANWB¹ 35 percent of the examined municipalities in Holland intend to construct one or more underpasses in the near future. Therefore we have tried to develop for designers and planners a checklist of user requirements and implications for designing underpasses. Some of these requirements and implications are *functional*. People should be able to cross the road or railway safely and comfortably. Other requirements are *psychological*.

Closed spaces may lead to claustrophobic experiences, so measures should be taken to prevent such feelings. Furthermore, precautions are required in order to prevent feelings of insecurity e.g. fear of violence. In the next section of this article we will describe the research material on which this article is based. Subsequently we dwell on the considerations important for the optimal location of the tunnel and the design objectives related to the access area, the entrance and the tunnel tube.

PEDESTRIAN UNDERPASS DESIGN

RESEARCH MATERIAL

This article is partly based on a study made at the request of the municipal planning office in The Hague, which was focussed on the perceptual and functional aspects of the Binckhorsttunnel² (Figure 2). This frequently-used underpass for pedestrians and cyclists (about 23,000 users pass through the tunnel each week) gave rise to a continuous stream of complaints, especially related to the feelings of insecurity. Interviews with the residents of the adjacent area Bezuidenhout-West showed that 31 percent spontaneously mentioned the problem of insecurity. Women and elderly persons were especially afraid to pass through the tunnel at night. One of the most important reasons for these feelings of fear seemed to be the isolated location of the underpass with respect to its residential surroundings. Also, it appeared that 75 percent of the users had one or more complaints about functional aspects such as difficult accessibility for the disabled and for mothers with prams, grievances about littering or graffiti etc.

FIGURE 2 The Hague, Binckhorsttunnel. Accessibility through stone steps with escalators on both sides.

To complete and deepen the inquiry in The Hague, available literature about underpasses has been reviewed and 25 tunnels in Amsterdam, Rotterdam and other Dutch cities have been observed and evaluated as to their functional and perceptual qualities, with an emphasis on the perception of personal security.

THE LOCATION OF AN UNDERPASS

It is desirable to reach the tunnel in a quick, easy and safe way. If people have to ride or take a roundabout route they will probably neglect the underpass and take the level crossing of the road. Naturally this may be dangerous because through traffic does not take account of the crossing pedestrians or cyclists. Optimal access will be enhanced by integrating the tunnel trace into the existing network of cycle and pedestrian routes. In a study made by Falter and Petz at Munich,³ it was demonstrated that—in case of an insufficient integration of the tunnel alignment with the common flow of passengers—the use of the subway was less frequent in comparison with well-integrated situations. It is of utmost importance in planning to take account of the particular properties of slow traffic. For instance, diagonals can be applied in situations with a grid structure, which, according to Hakkesteege⁴, is less suited for slow traffic.

EXTERIOR DESIGN

For the sake of security of slow moving traffic, clarity of arrangement of the exterior area is important. In the English new town of Stevenage, several accidents occurred, because of poor design of some access areas and the lack of visible definition of roads.⁵

Besides good visibility of the entrance, clarity may also be obtained by the application of the principle of continuity in the design of the pavement. The currently used colour (red) for cyclepaths is an adequate method of improving the identity of the pathway. Such effects can also be attained by uniformity in the use of materials. Continuity is, according to Lynch,⁶ an important way of achieving quick and easy orientation. A proper indication of the pathway is also desired for optimal use of an underpass. Another way to increase its use is adequate route indication and the clear marking of the entrance by signs and name-plates.

Clarity of arrangement of the tunnel environment is important not only for functional reasons, but also from the point of view of social security. From studies of the effect of architectural design on the prevention of crime it is known that there exists a clear relationship between environmental characteristics and feelings of anxiety.⁷⁻¹⁰ Particularly, dark, deserted and derelict areas evoke feelings of unpleasantness. Such areas lack social control, a feeling that there are people who can see what is going on and who, if necessary, can interfere or come to aid. The following factors may contribute to an environment with a strong sense of safety and social control.

Integration of the Subway into the Environment as a Whole

The tunnel must be seen as a structural element of the total spatial concept. It should not be designed as a single object because this may lead to an isolation location with regard to its residential surroundings. This in turn may elicit a feeling of being in no-man's land. From the point of view of safety it is important that the tunnel should not be perceived as a "foreign object" in a deserted traffic area but that it should be part of the residential area and as such included in the sphere of influence of the inhabitants.

For instance through the proximity of dwellings or other facilities to attract people, a visible, audible and perceptible control is ensured. In this way a "sense of ownership" is generated, by which the degree of involvement of the residents increases and feelings of security will be strengthened.¹¹

Residential Areas Versus Traffic Areas

The impression of desertedness which is often evoked in the immediate environment of underpasses is also caused by its characteristics of being a traffic rather than a non-traffic area. Traffic areas can be described as areas, primarily designated for traffic-circulation purposes. On the other hand, in traffic-restraint areas residential functions predominate. Here, people linger, children are playing, and activities take place. The more activities take place, the more people, the greater amount of social control and the less opportunity for criminal activities. To be safe a place should have attractive features to encourage people to make use of it, because the presence of people has itself a positive effect in attracting other people.

Distinctness of the Area

Besides the presence of people it is important that the immediate environment of a subway has clearly recognizable functions. Places with an indistinct function and an ambiguous character evoke feelings of unpleasantness and desolation, because nobody seems responsible.

According to Newman⁷ semi public areas in particular are very vulnerable to vandalism or other misbehaviour since these are neither public nor private. Therefore it is necessary that differences in functions should be clearly defined in traffic and traffic-restraint areas and public and private places. For example, ambiguity can be taken away by establishing clear indications of the planned functions of the surroundings.

Maintenance

Negative feelings will also be elicited by signs of destruction and by an atmosphere of dereliction and neglect. Poor maintenance symbolizes lack of personal involvement on the part of the residents and the government. A poorly maintained area has a negative effect on the notion of norms and rules so that people are inclined to become indifferent to their environment and leave litter around.^{12,13} Consequently a declining spiral may develop: poor maintenance may generate undesired activities like graffiti or malicious damage to objects, repair requires financial costs so that it is often postponed, hence vandalism increases and so on . . . Vandalism itself is connected in a very direct way to criminal activities, against objects it is true. However mild forms of criminality can easily cause a fear of serious crimes and violence against people.

On the other hand a well-kept area is perceived as "under control." It is owned by somebody and one cannot behave entirely as one wishes. Well-kept places show that someone feels responsible. These places are perceived as less anonymous, hence people are less prone to throw away litter. In this connection Shephard¹⁴ mentions his Law of Diminishing Vandalism: removing litter and marks of vandalism very frequently results in the long run not only in a decrease of littering but also—because of the evident care and involvement—in a reinforcement of security. For easy maintenance ramps are to be preferred to staircases.

ACCESS TO THE SUBWAY

Both pedestrians and cyclists should be able to enter and leave the subway very easily. Thereby one should not only take account of the "ordinary" user but also of handicapped people and parents with prams. Easy accessibility is not only important for comfortable use. It also contributes to feelings of security. Physical obstacles such as staircases hamper the access of the subway for cyclists and police cars so that regular police patrols are impeded. For this reason ramps are to be preferred. Also, ramps have the advantage that the total time passed in the underpass is shortened. Likewise the feeling of spaciousness increases and consequently the underpass is perceived as less of a "tunnel." The ability to design using ramps depends on the available amount of space and the difference in level that has to be overcome. The Royal Dutch Touring Club¹⁵ suggests 1 to 10 h as the most appropriate gradient, with an upper permissible limit of 1 to 5 h. In case of very great differences in level, e.g. more than 6 m, a horizontal mid level landing is recommended, in view of the length of the slopes. The application of these guidelines implies rather long slopes. For

example, a difference in level of 5 m and a ratio of 1:10 h requires a length of 250 m according to the standard. It is not surprising that in many cases, especially when the difference in level is more than 2.50 m, this standard is exceeded (Figure 3). With regard to the present guidelines the following remarks can be made. Firstly, the lack of a lower limit suggests that a long and gentle slope is always preferred to a short and steep one. However, it is highly questionable that, in situations with small differences in level, the user prefers a long continued effort to a short sharp one. Also, short ramps achieve better space utilization.

Secondly, the study on which the guidelines are based does not make clear whether the data are based on the experiences of a single person or on the reactions of several different groups of users.¹⁶ Thirdly, underpasses are not distinguished from bridges. In the case of bridges there is more need for gentle slopes than with subways. In underpasses cyclists first go down, so that the upward ramp is less difficult to take. Finally, examples are found in which the limit of 1:5 h is exceeded (see Figure 3, Delft, Hoventunnel: $h = 3$ m, gradient $\approx 1:14$) without any problem for the users. Our conclusion is that a slight relaxation of standards is preferable to relinquishing ramps in favour of stairs. Less strict standards might lead to the wider application of ramps, which in turn has a positive effect on the public acceptance of subways. However, further research into the desired and maximum gradient for cyclists is recommended.

With regard to the maximum gradient for pedestrians recommendations have been developed for the disabled only. According to Goldsmith¹⁷ a maximum gradient of 1:12 is proposed, with a horizontal section if the length of the ramp exceeds 10 m. Research has shown that application of these recommendations in case of a difference in level of 1.50 m results in slopes that can be used by everybody, but at a difference in level of 3 m such ramps require too much exertion of wheelchair drivers.^{18,19} In case of long distances a maximum ratio of 1:20 is recommended.²⁰

FIGURE 3 Ramp-gradients of 21 Dutch underpasses, compared to the ANWB-guidelines.

Visibility

With regard to the access to the subway, the importance of visibility as a means to increase the feeling of personal security is also relevant. This implies a clear view of the immediate environment of the subway and the possibility of being seen by others. It is therefore very important to determine during the design process from which places the user can still be seen on his way to and through the tunnel. Visibility can be achieved by providing a clear view through the tunnel, e.g. by lifting the upper road. In order to minimize possible problems with ground water, in Barendrecht the local pavement was elevated with 2 m.²¹

Besides the advantage of a better visibility this also resulted in the application of short and rather steep ramps (1:15). Visibility is also stimulated by appropriate design. For instance, slopes at both sides of the access road are more convenient than enclosing walls with no view of the area behind. Walls strengthen the "tunnel effect" i.e. a claustrophobic feeling of being in a narrow tube, which is clearly observable in the Rijnhaventunnel in Rotterdam (Figure 4). Another way of decreasing the tunnel effect by architectural means is the application of the principle of continuity. Continuity of interior and exterior space can be obtained by the application of ramps and also by a gradual change from daylight to artificial lighting or by gradually adjusting the pavement to the situation outside. Sometimes this is achieved by the use of flagstones of the same colour.

FIGURE 4 Rotterdam, Rijnhaventunnel.

TUNNEL TUBE

An attractive and easily accessible tunnel makes high demands upon the dimensions of the tunnel tube and the shape of the alignment. Also adequate illumination is important in order to attain road safety and to create a sufficient degree of spaciousness to prevent feelings of claustrophobia. Further attention ought to be paid to good upkeep and optimal acoustic and sufficient ventilation. All these aspects contribute to a positive perception of the tunnel as a whole.

Cross-section

For cyclists a minimum headroom of 2.50 m is advisable.²² In very long tunnels some additional space is preferred to create more spaciousness. For example the headroom of the Binckhorsttunnel—with a total length of 168 m (stairs included) and of the tunnel tube 124 m—is 2.75 m. For pedestrian subways a minimum of 2.30 m

headroom is necessary. As a rule of thumb, the width of a footpath can be determined by the formula $a + b \times 0.75$ m with a = space to avoid contact with the wall (some 0.25 m according to Graichen *et al.*)²³ and b = the number of persons who can walk beside each other. In many Dutch tunnels there is a 2.50 m wide footpath along the cycle-path. The width of a cycle-path can be determined by the formula $a + b \times 0.80$ or 1.00 m with $a = 0.10$ to 0.50 m according to Volmuller²² and b = the number of traffic lines for cyclists or moped drivers. The width of tunnels is also determined by psychological factors. To prevent claustrophobic feelings the tube should not be too narrow. Therefore for pedestrians and cyclists a single tube should be preferred to separate tubes. This also means more frequent use and more informal social control, contributing to stronger feelings of security. By the same token it is preferable to construct one tube for both directions instead of separate tubes for one-way traffic. Disadvantages such as smell or noise from moped riders should be prevented by means such as an adequate ventilation system and the application of an acoustic ceiling. Figures 5-8 show some examples of different tunnel tubes.

FIGURE 5 Rotterdam, Statentunnel. Pedestrians' footpath is separated from cyclists by a close wall. Cyclists and moped riders make use of a raised and railed off cycle path so that a physical barrier is attained without visual deprivation.

FIGURE 6 Delft, Hamtunnel. Pedestrians and cyclists pass through one single tube. The separation between pedestrians and cyclists is attained by elevating the sidewalk.

FIGURE 7 Rotterdam, Diergaardetunnel. Pedestrians and cyclists go through one single tube; the separation is made by a railing. Fast traffic is separated from slow traffic by means of a closed wall.

FIGURE 8 Rotterdam, Overschie. Vehicles, cyclists and pedestrians are led through one single tunnel tube.

Longitudinal Section

For a good degree of visibility a straight alignment is required. It contributes to road safety and security. Since people do not like to stay in the tunnel too long, the length of the tunnel should be limited, e.g. by avoiding bends in the alignment and by ensuring a straight junction of the alignment with the crossing road or railway. Psychologically, shortening of the tunnel tube can also be attained by means of visual interruptions such as clerestorey windows or rooflights. Even more effective are interruptions of the tunnel tube itself by openings in the roof or walls (Figure 9). This will reduce the perceived distance of the tunnel tube, while entering of daylight and air will lead to great clarity and natural ventilation. Such interruptions should not be too narrow because these might negatively affect the sense of security.

FIGURE 9 Dordrecht, Reeweg-Oost. Visibility is attained by: view to the other end of the tunnel tube; short talus; entrance of daylight through interruption of the tunnel ceiling.

Lighting

Lighting affects visibility and clearness. To promote road safety and reduce feelings of anxiety or claustrophobia it is important that people can see what is going on. Better visibility may even reduce the actual crime rate. The amount of light which is appropriate depends on the situation. For example, different lighting levels are suggested for highways and for residential areas. With regard to underpasses for slow traffic only a few figures are found in literature. According to Brüning,²⁴ during the day a level of 100 or 250 Lux is appropriate, while at night 50 or 100 Lux is sufficient. He recommends a gradual transition between the lighting level inside and outside the tunnel by applying some additional light at the entrance.

However, it is not clear on what experience Brüning's recommendations are based. His article lacks information about user feedback.

In a Dutch user evaluation study, it was shown that the lighting levels of an underpass in Tilburg—80 or 100 Lux during the day and at night only half of this level—was sufficient according to the opinions of 43 percent of the users; 12 percent judged the level of lighting as insufficient and 45 percent did not know.²⁵ These results give only a rough indication. Further research is needed and should be focussed not only on the level of lighting but also on aspects such as the quality of lighting and finishes

(light/dark, gleaming/dull) and the location of the lighting fixtures. The ratio between direct and diffuse lighting affects the appearance of objects and persons. Vagueness or invisibility of people's faces may cause feelings of insecurity. Appropriate location of the lighting fixtures is also important to avoid vandalism, for instance by recessing lighting into the roof or walls, out of reach of the vandals but in such a way that they can be replaced easily. This prevents delay in repair which often leads to a dismal appearance of the environment. Light covers of toughened or reinforced types of glass should be used to resist the milder forms of vandalism.

Finishes

The range of finishes used in subways varies from bush-hammered or textured concrete through a variety of applied finishes to glass mosaics and tiles. Factors for selecting wall finishes can be location of the subway, degree of its use, expected degree of vandalism, method of maintenance and costs. In most areas the favourite medium for graffiti is the aerosol paint can, with lipstick a close second. The most satisfactory answer to wall drawings may be tiling, which also provides an attractive finish.²⁶ Tiles are resistant to casual scribbling, and paint and lipstick can be removed with comparative ease without damaging the tiled surface. An alternative method is the use of rather rough materials which may be painted in several colours. Such a surface prevents people sticking up posters etc. Vivid and bright colours may create more spaciousness, while gloomy and dark colours—e.g. of unfinished concrete—lead to an impression of narrowness and drabness. Variation by using different colours and materials lead to less monotony which in turn prevents people from scratching and blotting the walls. However, nowadays complete prevention from graffiti seems hardly possible.

CHECKLIST AND IMPLICATIONS OF FUTURE RESEARCH

The issues previously discussed are summarized in guidelines for designing (Scheme I). From left to right there is an increase from abstract to concrete. The recommendations are focussed on optimal comfort and safety, from the view point of road safety as well as security. Some requirements conflict. For instance, the necessity of informal control requires frequent use of the tunnel, so that one tube for the common use of all kinds of traffic seems preferable. However, to avoid noise and undesired smell from the mopeds, separate tubes might be a better solution. For each situation priorities would be drawn up. It will be clear now that designing an underpass which satisfies both function and psychological requirements is rather difficult. To avoid restricting the designer's freedom too much, the very early stage of the planning process should consider *if* and *where* an underpass is needed. For example, if a highway is first constructed and afterwards it is decided to design an underpass, it is hardly possible to elevate the highway in order to limit the difference in level between tunnel floor and cycle-path.

On several issues further research on user experience is needed. Certainly the study of the optimal or maximum gradient of ramps has not been fully examined. Other topics of research are the optimal ratio between the height and width of the tunnel tube, users' preferences as to integration or segregation of different kinds of traffic, desired levels and location of lighting and, of course, the financial consequences of the different solutions.

SCHEME 1

Design guidelines for slow traffic underpasses

Goals	Derived goals	Means
<i>I. Access area of the underpass</i>		
Visibility	Clarity of arrangement of traffic roads	Continuity in routes by uniformity in form, colour and materials for routes with the same function Differentiation in form, colour and materials for routes with a different function Adequate lighting (level, quality, location)
	Visibility of the tunnel entrance	Indication of the underpass by names or guide signs
Distinctness	Identity and recognizability	
	Clear functions	Clear distinction between public and private areas
	Clear references to ownership	Indication of planned functions
Reachability	Prevention of physical and psychological barriers	Preventing people from making a long round-about way Shortening of perceived distances by means of an attractive arrangement of the area
Amenity	Integration of the tunnel in its (residential) surroundings	Housing and other facilities in the immediate vicinity Creating a residential character for public places, instead of traffic functions only
	Creating conditions by which people feel concerned and responsible	User participation in an early stage of the planning and design processes
	Clear signs of municipal involvement and responsibility	Regular maintenance Immediate repair in case of damage Presence of waste bins
<i>II. Entrance and tunnel tube</i>		
Visibility	View from the environment to the entrance	Avoidance of high closed walls on both sides of the entrance routes
	View from the entrance to the other end	Elevating the crossing road to obtain smaller difference in level between tunnel floor and outside routes Avoiding bends in the alignment of the tunnel Proper lighting, especially in long tunnels daylight is needed by interruptions in ceiling or walls
Accessibility	Easy access both for "ordinary" users and for the disabled or parents with prams	Applications of ramps if possible, even if a slight exceeding of the standards is necessary In case of fixed stairs: special attention is needed to the size of stair rise and treads In case of escalators: facilities are required to guarantee continuous use Preventing slipperiness caused by rain or snow
	Minimal differences between street level and tunnel floor	Elevating the crossing road
Penetrability	Easy and comfortable passage for pedestrians and cyclists	Sufficient free headroom Adequate width of foot- and cyclepath Clear separation of pedestrians and cyclists, symbolic (a white line) or physical (raised footpath, separation by railings, gates or transparent walls etc.)
Amenity	Avoidance of a "tunnel effect"	Tough and flat pavement, e.g. asphalt Application of talus instead of high closed walls at the entrance route

SCHEME 1 (continued)

Goals	Derived goals	Means
		Minimal duration of time spent in the tunnel by optimum accessibility (ramps!) and a minimum length of the tunnel tube (no bends, straight crossing of highway and tunnel alignment)
		Shortening perceived distance by appropriate lighting and visual interruptions
		Gradual transition from exterior to interior places (ramps, continuity in pavement and lighting)
		Adequate ventilation system
		Use of noise absorbant ceilings etc.
	Promoting frequent use of the tunnel	Integration of different user categories through one single tube
	Openness and spaciousness	Proper width of the tunnel tube
		Optimum ratio between height and width
		Adequate lighting
		Application of vivid and bright colours
	Optimal conditions in order to decrease graffiti and vandalism	Regular maintenance (which requires ease of access for the cleaning services, so again: ramps!)
		Immediate repair in case of mischievous or unintentional damage
		Application of vandal proof and easy-to-replace materials
		Tough finishes like tiles or stones instead of soft plaster or parget

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