VI. THE OFF-CARRIAGEWAY

VI.1. Comparison of guidelines

As stated in chapter 2 (Terminology) the areas between the inner edge line markings and the tunnel lining are called the off-carriageways.

The off-carriageways comprise the hard clearances and the walkways (if any) or (and) the safety barrier or guard rail (if any). This is illustrated in figures 6.1, 6.2 and 6.3.

The main difference in the hard clearances adjacent to driving and overtaking lanes is that “usually” the hard clearance adjacent to the driving lane is wider since broken down vehicles are parked on or adjacent to this lane. On roads of the motorway type in the open air usually an emergency lane is provided. Hard clearances in tunnels are often restricted for economic reasons. This restriction can make it impossible for broken down vehicles to park on the hard clearance adjacent to the driving lane without occupying part of the driving lane and thus disrupting traffic flow.

For that reason two tables are presented giving information on the width of off-carriageways adjacent to the driving lane: one for tunnels where it is impossible for motorists to park their vehicles on the carriageway without interfering with normal traffic (Table 6-1) and one for tunnels where this is possible (Table 6-2). The width necessary to park vehicles (passenger cars) without interfering with normal traffic is assumed to be 2.00 m from the inner side of the edge lane marking.

A third (Table 6-3) gives the information on widths of elements of the off-carriageways adjacent to the overtaking lanes.

Eventually table 6-4 gives the dimensions of walkways as employed in various countries.

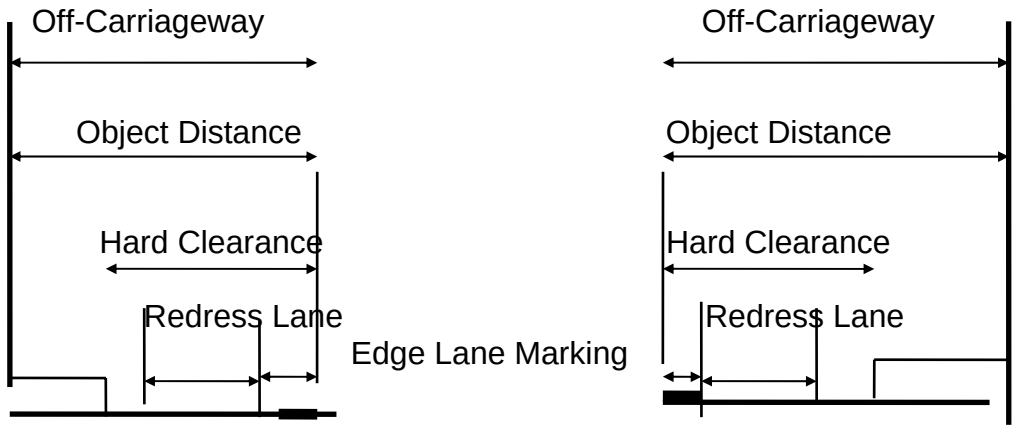

Figure 6-1: Elements and functions of off carriageways in case of walkways

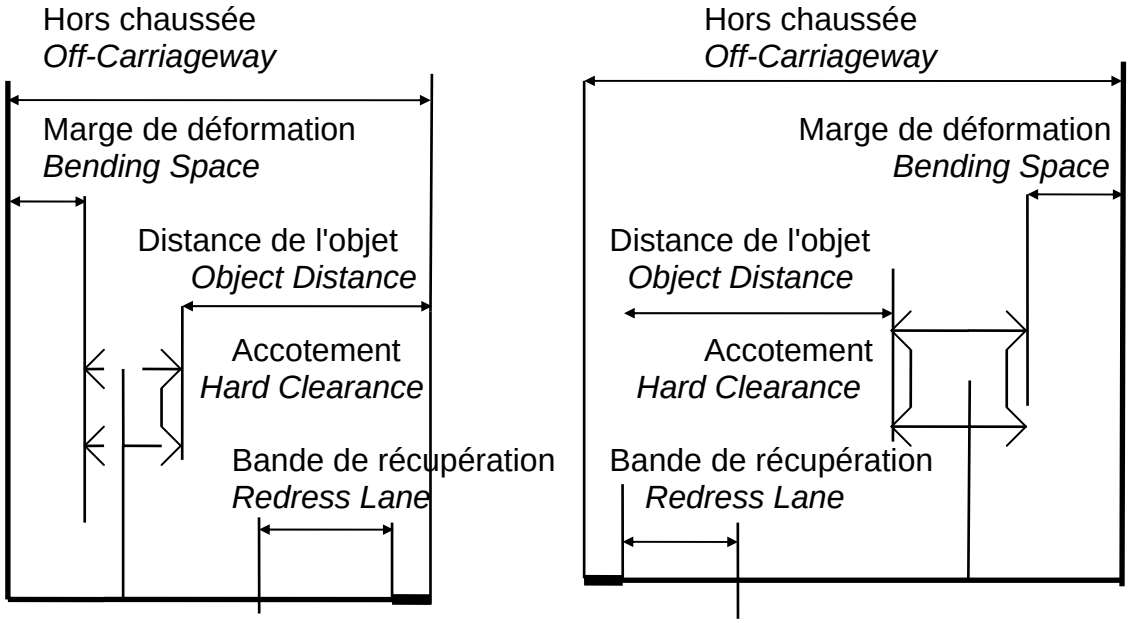

Figure 6-3: **Éléments et fonctions des zones hors chaussée avec glissières de sécurité /**
Elements and functions of off carriageways in case of flexible guard rails

Table 6-1: **Dimensions of Off-Carriageways adjacent to the Driving Lane in the absence of Emergency Lanes (for straight sections)**

Country and name of guidelines or other source	**Design Speed [km/h] (profile nr)**	**Width of hard clearance [m]**	**Width of walkway [m] or safety barrier (sb)**	**Width of off-carriageway [m]**
Austria RVS 9.232	80 - 100	> 0.25	1.00	> 1.25
Denmark (practice)	90 - 120	0.50	1.00	1.50
France CETU	80 - 100	1.00 0.30#	0.75	1.75 1.05#
Germany RABT'94/RAS-Q 1996	70-100 (26 t) 70-100 (26Tr)	0.25 1.75#	1.00 1.00	1.25 2.75#
Japan Road Structure Ordnance	80 - 120 60 - 80	1.00 0.75	0.50 0.25	1.50 1.00
the Netherlands ROA	120 90	1.50 (0.80*) 1.00 (0.50*)	sb sb sb sb	1.50 + sb (0.80*)+ sb 1.00 + sb (0.50*)+ sb
Norway Design Guide Road Tunnels	80 - 100	0.30	0.75** 1.25***	1.05 1.55***
Spain Instruction 3.1	90 - 120	1.00	0.75	1.75
Sweden Tunnel 99	70 90 110	2.00 2.00 2.75	sb sb sb	2.00 + sb 2.00 + sb 2.75 + sb
Switzerland	80 - 120	-	1.00	1.00
UK TD27(DMRB 6.1.2)	110	1.00	0.70	1.70
USA AASHTO	n.s.	0 - 1.50	0.50 - 0.70	0.50 - 2.20

: in exceptional cases
* : usually applied and allowed
* *: the elevated walkway is separated from the carriageway with a rollover kerb stone.
***: in short tunnels (< 500 m)
n.s.: not specified

Table 6-2: Dimensions of Off-Carriageways adjacent to the Driving Lane in the presence of Emergency Lanes (for straight sections)

Country and name of guidelines or other source	Design Speed [km/h] (prof.nr)	Width of hard clearance [m]	Width of walkway [m] or safety barrier	Width of Off-carriageway [m]
Austria RVS 9.232	80 - 100			
Denmark (practice)	90 - 120	3.00	1.00	4.00
France CETU	100	2.00	sb	2.00 + sb
Germany RABT'94/RAS-Q 1996	100 (26T) 110 (29,5T) #	2.50 3.25#	1.00 1.00	3.50 4.25#
Japan Road Structure Ordnance	80 - 120		-	2.50
the Netherlands ROA	120 90	3.95 3.95	sb sb	3.95+ sb 3.95+ sb
Norway Design Guide Road Tunnels	80 - 100	no emergency lanes		no emergency lanes
Spain Instruction 3.1	90 - 120	2.50	0.75	3.25
Sweden Tunnel 99	70 90 110	2.00 2.00 2.75	sb sb sb	2.00+ sb 2.00+ sb 2.75+ sb
Switzerland (rectangular tunnels)	80 - 120	3.00	1.00	4.00
Switzerland (oval tunnels)	80 - 120	no emergency lanes		no emergency lanes
UK TD27(DMRB 6.1.2)	110 (urban m.w.)	3.30 2.00	0.70 (0.10 + 0.60)	4.00 2.70
USA AASHTO	n.s.	3.00	0.70	3.70

: in exceptional cases

Table 6-3: Dimensions of Off-Carriageways adjacent to the Overtaking Lane (for straight sections)

Country and name of guidelines or other source	Design Speed [km/h] (prof.nr)	Width of hard clearance [m]	Width of walkway [m] or safety barrier (sb)	Width of off-carriageway [m]
Austria RVS 9.232	80 - 100	> 0.25	1.00 (0.30 + 0.70)	> 1.25
Denmark (practice)	90 - 120	0.50	1.00	1.50
France CETU	80 - 100	0.50 0.30#		0.50 0.30#
Germany RABT'94/RAS-Q 1996	100 (26T) 100 (26 Tr) 70 (26t) 110 (29,5T)	0.50 0.25 0.25 0.75	1.00 1.00 1.00 1.00	1.50 1.25 1.25 1.75
Japan Road Structure Ordnance	80 - 120 60 - 80	1.00 0.75	0.50 n.s.	1.50
the Netherlands ROA	120 90	1.50 (0.80*) 1.00 (0.50*)	sb sb sb sb	+ sb (0.80* + sb) 1.00 + sb (0.50* + sb)
Norway Design Guide Road Tunnels	100	0.25	0.75	1.00
Spain Instrucción 3.1	90 - 120	1.00 0.50#	0.75	1.75 1.25#
Sweden Tunnel 99	70 90 110	1.00 1.50 2.00	sb sb sb	1.00+ sb 1.50+ sb 2.00+ sb
Switzerland (rectangular tunnels)	80 - 120	-	1.00	1.00
Switzerland (oval tunnels)	80 - 120	-	1.00	1.00
UK TD27(DMRB 6.1.2)	110	0.30	0.70 (0.10 + 0.60)	1.00
USA AASHTO		0 - 1.50	0.50 - 0.70	0.50 - 2.20

: in exceptional cases

* : more often applied and allowed

Table 6-4: International comparison of dimensions of walkways

Country and name of guidelines or other source	Height of walkway [m]	Width of Walkway [m]	Width of safety margin [m]	Width of walking lane [m]
Austria RVS 9.232	0.18	1.00	0.30	0.70
Denmark (practice)	-	1.00	-	1.00
France CETU	max. 0.25	min. 0.66 (at foot level)	0.06	0.60 (at foot level)
Germany (RQ26) RABT 94/RAS-Q 1996	0.07	1.00	-	1.00
Japan Road Structure Ordnance	0.25	0.25 or 0.50	-	0.25 or 0.50
the Netherlands ROA	-	-	-	-
Norway Design Guide RoadTunnels	0.10	0.75	-	0.75
Spain Instruction 3.1	0.15 - 0.20	0.75	-	0.75
Sweden Tunnel 99	-	1.00	-	1.00
Switzerland (rectangular tunnels)	0.18	1.00 minimum	0.30	0.70
Switzerland (oval tunnels)				
UK BD78	0.075	1.00	-	1.00
USA AASHTO		0.50 - 0.70	-	0.50 - 0.70

VI.2. Functional aspects of off-carriageways and hard clearance

In this paragraph all functions of off-carriageways and in particular of the hard clearance will be dealt with. The functional requirements of walkways will be treated more detailed in chapter 7.

The potential functions of the off-carriageway/hard clearance adjacent to the overtaking lane will be described first. The functions of the off-carriageway/hard clearance adjacent to the driving lane generally are the same but have to be extended, mainly due to the requirements of broken down vehicles and cases of emergency.

VI.2.1. Off-Carriageways, general

1. Off-carriageways on roads in general help to increase the *traffic lanes capacity*. As was shown in chapter IV, the capacity of the road depends on the width of the lanes and the distance between obstacles and the roadway, the *object distance*. According to the Highway Capacity Manual the optimal object distance is 1.80 m, reduction to 0.60 m decreases capacity by 2% to 5 % and reduction to 0.00 m decreases capacity by 10 to 25 %.

   In the case of tunnels it is questionable whether object distance is determined by the distance between the inner side of the edge lane marking and: a) the kerb of walkways, b) the front of safety barriers or guardrails, or c) the tunnel sidewall. There is general agreement that in case low level walkways are employed the distance to the tunnel wall is a good measure. When no walkways are present the distance to the base or to the top level of the safety barriers has to be considered.

   Especially in tunnels drivers prefer a certain distance to the wall (or walkway, guardrail of safety barrier) due to smaller movements of the eye-angle when fixed on objects. Experience shows that where object distance in tunnels is smaller than on the adjoining road motorists change course to keep distance from the tunnel wall.

2. In many countries off-carriageways contain walkways. In a separate paragraph the functions of the walkway will be discussed.

3. If vehicles crossing the edge lane marking cannot be redirected in time then the *consequences of collision with the wall must be minimised*. This can be achieved by means of safety barriers or guard rails. Safety barriers require less space then guard rails. When vehicles collide with safety barriers at small (acute) angles they can be guided back in the direction of traffic and there is a chance of preventing major accidents. When vehicles collide with safety barriers at large (obtuse) angles the results of the collision may be more serious. Guardrails are not as effective as safety barriers at correcting/redirecting errant vehicles, however they cause less damage in a collision at an obtuse angle. That is why safety barriers are to be preferred in case of narrow hard clearances and guardrails in case of broad hard clearances. As guardrails require bending space this would mean extra width of the tunnel, which in many cases is not feasible from an economic point of view. Safety barriers perform well especially at restricted speed. Moreover barriers need less maintenance.

4. Although this report deals with straight sections of tunnels it is of importance to point at the possible need to increase the width of off-carriageways in bends to provide enough *stopping sight length*.

VI.2.2. Additional functions of hard clearances adjacent to the overtaking or fast lane

1. **Edge lane markings** are included within the hard clearance and vary in width internationally typically from 0.1m to 0.25m. Experiments in Japan and Spain have shown that the edge lane marking is crossed less frequently when made more highly visible or made to create a noise (rumble strip) when crossed.

2. **A Redress lane** may be included in the hard strip allowance and this is designed to allow drivers who inadvertently cross over the edge lane marking to make a safe correction. Measurements have indicated that edge lane markings of narrow traffic lanes are crossed over four times as much as those associated with normal traffic lane widths. The Dutch guidelines (ROA) specify a redress lane width of 0.60 m for design speed (Vd) of 120 km/h and 0.30 m for Vd = 90 km/h.

3. **Traffic Fluidity** is enhanced by the provision of wider hard clearances *by enabling traffic to more easily pass stranded vehicles* particularly in case of stranded cars *on or alongside the driving lane*. From tables 6.1 and 6.3 it can be seen that France, Sweden and the UK prescribe broader hard clearances adjacent to the driving lane than adjacent to the overtaking lane. This is logical because in the majority of cases of broken down vehicles the vehicle will stop on the side of the driving lane. (In heavily congested tunnels in Norway, however, many of the motorists in difficulty on the fast lane do not succeed in changing lane and break down in the fast lane). Also for this function a pavement capable of bearing vehicles is required. It is not required that this pavement is flat over the whole width. Low kerbs (not more than 7 cm) may be mounted to allow the parking of stranded vehicles.

   In the French design guide the width of the hard clearance along the overtaking lane is based on the requirement to allow traffic to flow past a broken down vehicle and depending on: a) the desired passing speed, b) the traffic volume and c) the percentage of HGV in the traffic composition.

   The case of stranded vehicles is dealt with in more detail in the section on hard clearances adjacent to driving lanes.

4. **Fixtures** *such as ventilation fans and traffic signs* on the tunnel sidewalls are afforded protection by the hard clearance from collisions with vehicles. A safety margin between the inner side of the edge lane marking and the equipment is required in many guidelines. For Germany this distance is 0.50 m (when crossfalls are significant this distance must be increased).

5. **Tunnel maintenance** activities both planned and unplanned may be facilitated by provision of adequate hard clearance thereby allowing traffic management to permit traffic to cross the edge lane markings and either facilitate bi-directional traffic flow or closure of all or part of a traffic lane. It is now common for maintenance work of short duration that at least one driving lane has to be closed completely. In the ideal situation it should be possible in case of maintenance of long duration to arrange 4 lanes with counter flow (4-0 system).

6. **Walkway** provision may be allowed in the hard clearance. Walkways are designed to be used by drivers in emergency, e.g. vehicle breakdown or fire and usually lead to safe havens, tunnel escape routes, tunnel cross passages, etc. Swedish and Dutch Guidelines recommend walkways at carriageway level without a separating kerb which is considered to be a hazard. The French Guidelines do not require a walkway where the hard clearance is greater than or equal to 2m in width. In the UK it is recommended, should the crossfall so require, to provide a low height kerb and walkway on the overtaking lane side to protect escaping pedestrians from hazardous spill, also where the second tunnel bore is the primary place of safety then a sufficiently wide walkway must be provided to allow passengers to pass traffic stopped in the overtaking lane.

7. **Protective barriers** opposite cross passage exits are included in the hard clearance and are required to prevent conflict between tunnel users escaping from one tunnel with traffic in the second tunnel.

8. **Gravity Drainage** provisions are sometimes included in the hard clearance to accommodate drain inlets and gullies. In tunnels where transport of dangerous goods is allowed the capacity and sealing of the inlets and drains is of particular importance.

VI.2.3. Additional functions of hard clearances adjacent to the driving or slow lane

Functional requirements of hard clearances adjacent to the driving lane are essentially the same as mentioned in the above section. On “open” roads of the motorway type generally adjacent to the driving lane an **emergency lane** is provided. Due to the costs the provisions in tunnels to park broken down vehicles generally are less. In this paragraph a listing is given of the reasoning of different countries with respect to alternatives for emergency lanes and its functions.

1. In many countries, due to costs, the width of the hard clearance is too small to **park a vehicle** adequately. Therefore at certain distances **lay-bys** are provided. However, in Norwegian and Spanish experience only 40 % of the broken down vehicles effectively reach or use the lay-bys. This demonstrates that lay-bys cannot completely replace emergency lanes. Studies have shown that the provision of emergency lanes on “open” motorways reduces accidents by 10% to 20%. In this context it is interesting to take notice of a German study [4], which indicated that traffic safety is not affected by the omission of an emergency lane from an economical point of view. A proposal was presented for a guideline in order to establish a tunnel cross section which is most favourable economically. The additional annual costs of the cross section with an emergency lane in comparison with the cross section without an emergency lane for the construction authority can be compared with the traffic costs which are saved correspondingly. Not only different tunnel lengths, construction procedures and difficulty classes but also the mean longitudinal inclination, the average daily traffic and the mean proportion of HGV traffic are taken into account in this respect.

2. The hard clearance should give the possibility to park a stranded car outside the carriageway. Therefore the width measured from the **outer** side of the edge lane marking should be at least the width of a passenger car (1.75 m) plus a width of 0.50 m to enable motorists to descend, resulting in a hard clearance of 2.45 m. In case also heavy trucks should be parked outside the carriageway a width of (2.50 + 0.50 + 0.20 =) 3.20 m is required (NL).

3. If the width of emergency lanes should be such that cars wanting to enter or exit the emergency lane can do this **without hindering the traffic** on the driving lane a width of 3.25 m from the outer side of the edge lane is necessary. This is the width of a traffic lane at design speed of 90 km/h. This makes the width of the hard clearance 3.45 m (incl. the edge lane marking) (NL). If adjacent to the emergency lane a clearance of 0.50 m for passengers to descend from the vehicle is required a total width of 3.95 m is obtained.

4. Emergency lanes can also be used by **police and rescue teams** to pass queues in case of incident or accident. For this purpose a width of 3.25 m is needed. This results in a width of the hard clearance of 3.45 m. If emergency lanes are too small this may prevent fast operation of rescue teams, vehicle hauliers, fire brigades, etc.

5. However, in expensive tunnel constructions such as bored and lined tunnels in the Netherlands wide hard clearances are employed only to safeguard for a future **increase in the number of traffic lanes**.

6. In the French design guide [11] the width of the hard clearance on both sides is derived from the possibility to **maintain traffic flow** during a car break down depending on desired speed (in the occasion of the car breakdown), traffic volume and percentage HGV guidelines. The French design guide discerns “normal”, “prudent” and “slow ” velocities.

   The **“normal” velocity** is the velocity when there is no broken down vehicle in the tunnel or when it is desirable that traffic moves on at the same speed when there is a broken down vehicle;

   The **“prudent” velocity** is the speed when there is a broken down vehicle and it is desirable that traffic moves on at moderate speed;

   The velocity **“at a footpace”** may be acceptable for roads with low traffic volumes.

7. Table 6-5 gives the necessary widths in m for the types of vehicles and the velocities considered.

Table 6-5: Width in m required by vehicles at different velocity modes according to French guidelines

vehicle type	**velocity mode**			
	normal	prudent	at a footpace	standstill
Passenger Car	3.00	2.70	2.30	2.15
Heavy Vehicle	3.50	3.25	3.00	2.85

In the table the last column gives the width necessary for cars at a standstill. Depending on the choice of the width of the broken down vehicle, the choice of the type of vehicles in the other rows of traffic and the chosen velocity mode the total width of the roadway is determined. Given the width of the traffic lanes (3.50) and a number of prevailing standard measures of hard clearances (0.30 m, 0.50 m, 1.00 m and 2.00 m) the width of the hard clearance on each side is determined.

7. According to the French guideline a general rule is that the width of the hard clearance along the driving lane should **not lie between 1.00 and 2.00 m** in order to ensure that drivers do not consider the off-carriageway as an emergency lane and feel safe to stop.

8. In the German guidelines for the cross section with emergency lanes, indicated with RQ26T, the hard clearance adjacent to the driving lane has a width of 2.50 m of which 2.00 m is considered as an emergency lane. The traffic lanes are 3.50 m wide and the hard clearance adjacent to the overtaking lane 0.50 m. In special circumstances where traffic management during maintenance and repair requires four lanes, the width of the hard clearance adjacent to the driving lane is 3.25 m, of which 2.50 m is attributed to the function of an emergency lane. This profile is indicated as RQ29,5T.

   In the minimum cross section without emergency lanes, which is indicated as RQ26T, the width of the hard clearances is only 0.25 m. In this cross section broken down vehicles have to park in lay-bys (if tunnel length exceeds 700 m). A special solution in case of using a tunnel boring machine (TBM) is the cross section RQ26Tr. Here the hard clearance is 1.75 m. This cross section so far has not been employed in Germany.

9. In Norwegian tunnels no wide hard clearances are employed to park broken down vehicles. Instead the walkways are provided with roll over kerbs.

10. The Swedish guidelines state that traffic operation in case of incidents is a factor to be taken into consideration when deciding on the requirement for emergency lanes.

VI.2.4. Functions of walkways

In this section all elements and functions of walkways are dealt with.

1. The main function of walkways is to provide for **pedestrians in special circumstances**: staff and maintenance personnel, tunnel users walking to telephone or to emergency points. The width (and clear headroom) necessary for this function (not taking into account safety margins) is determined by the designer using the national guidelines. The maximum height of the walkways is determined by the demand that doors of personal cars can easily be opened at the nearside (not more than 0.20 m).

   N.B. 1. In some guidelines a raised walkway is not necessary if there is an emergency lane (France).

   N.B. 2. In case there are good traffic monitoring, signalling and communication systems risks for pedestrians can also be minimised by closing one or all traffic lanes. Moreover in case of broken down vehicles flowing traffic along the walkways often is not possible over certain lengths due to the presence of the broken down vehicle.

   N.B. 3. Use of raised (narrow) walkways is not possible by wheelchairs.

   N.B. 4. A solution for this (the main) function is provided by high walkways (0.50 m or more). Staff and walking or waiting occupants of broken down vehicles are perfectly safe from ongoing traffic. Every 50 - 100 m access stairs are present. In this case the width of the roadway has to be enough to open doors of vehicles at the nearside. This solution is applied in some recent Japanese tunnels.

2. Walkways enable the **opening of emergency doors** without interfering with traffic.

3. If kerbs of walkways are designed to be a **barrier against vehicles** mounting on the walkway the front of the kerbs serves as the inner edge of a safety margin for pedestrians (tunnel staff or occupants of broken down vehicles). These pedestrians are assumed not to use this safety margin when walking on the walkway. The width of the safety margin is determined assuming that vehicles move with their tyres just touching the kerbs. A safety margin with respect to salient parts of vehicles (coachwork, mirrors, air flow) is determined. In this way the Austrian, French and Swiss safety margins are determined.

   N.B. When there is an emergency lane the safety margin can be disregarded (Austria)

4. From the point of view of traffic management and traffic safety walkways, and especially their kerbs, can be considered as **orientating lines** for motorists. Due to their salient character the attention of the motorist might be drawn better than edge lane markings do. The same effect could be reached by rumble strip edge lane marking and/or light reflecting edge lane markings and/or reflectors.

5. The kerbs of walkways can serve as a means to **prevent vehicles**, which have crossed the edge lane marking, from **colliding against the walls** of the tunnel. This is the same function as is attributed to safety barriers or guard rails. Their performance with regard to this function is, however, less effective. If walkways are applied mainly for this function guidelines of some countries (France, Japan) advise walkways with width of 0.25 m and kerbs with a height of 0.25 m or more.

6. The presence of walkways can **reduce traffic speed** to 90 km/h when the hard clearance between traffic lanes and walkways is very small.

7. Walkways can also be used to **park** broken down vehicles as close to the outside of the platform as possible in order to maintain traffic flow, in which case kerbs should be of the roll over type or kerb should be not higher than 0.15 m.

8. Also **rescue teams** can use walkways with roll over kerbs in case of queues on the carriageway.

9. If kerbs of walkways are considered as a warrant against violation of the walkways the front of the kerbs serve as the inner edge of a safety margin for **protection of tunnel equipment** (sensors, traffic signs, ventilator fans). This safety margin defines the limits of the space at higher levels in the cross section of the tunnel within which this equipment cannot be installed. Also, account has to be taken of a certain “overhanging” of heavy goods vehicles due to cross-falls.

10. A non-traffic related function of walkways is that they often provide a possibility to **install cables and ducts** outside of the roadway. Often this function is determining the width of the walkway. A disadvantage of the use of walkways for this function is that due to safety prescriptions for working people traffic is not possible on one or even two lanes in case of maintenance work at the cables and ducts. That is why some guidelines advise that cables and ducts be installed in separate accessible canals out of the traffic tube.

11. The kerbs of walkways can be **integrated with inlets** for drainage of leakage or cleaning water and especially for the collection of hazardous spills. (Also this function can be fulfilled by other means.)

12. In Sweden the walkway is part of the hard clearance to enable **wheelchairs** to reach emergency doors.

VI.3. Conclusions

- The width of off carriageways varies widely between countries.

- There is discussion on the question of emergency lanes. Many guidelines indicate that they should continue in tunnels. Due to costs normally a reduction of the width is applied.

- Guidelines not always address the possibilities of traffic management (for example the issues associated with shuttle flow or bi-directional flow in normally unidirectional tunnels).

- There is a variety of functions that can be attributed to walkways. It appears that national guidelines differ in the value assessment of the different functions.

- There are no scientific convincing arguments for a “best” (i.e. most safe) design of walkways.

VI.4. Recommendations

- In paragraph VI.2 comprehensive lists of functional requirements and data of research have been given. The designer of the cross section for a given tunnel is advised to consider and weigh all this and to justify and lay down his choices on paper. That document has to be confirmed by the responsible authorities.

- In heavy congested tunnels (e.g. in cities) the off-carriageways adjacent to the overtaking lane should be wide enough to enable safe parking of broken down vehicles.

- It is recommended to avoid sudden changes in characteristic features at the entrance of tunnels. And such changes should where required be introduced at a minimum distance of 150 m from the tunnel portal.

- It is recommended during maintenance work in one way tunnel tubes to close at least one lane for traffic adjacent to the place of action. This favours safety of maintenance workers more than walkways.

- It is recommended wherever possible to put cables and ducts outside the tunnel tube. Especially the connections which require most access should be separated from the traffic area. This decreases the need to close lanes during maintenance works.