Distancing, Density and Flow

in the

one-and-a-half-meter society

a

brief illustrated guide

(Working Paper v1.3)

Bert Bruyninckx

Pg Dip. Crowd Safety & Risk Analysis

bert.bruyninckx@360-solutions.eu

linkedin.com/in/bertbruyninckx

+32 492 93 42 58

02/03/2021

Table of content

List of Tables

List of Figures

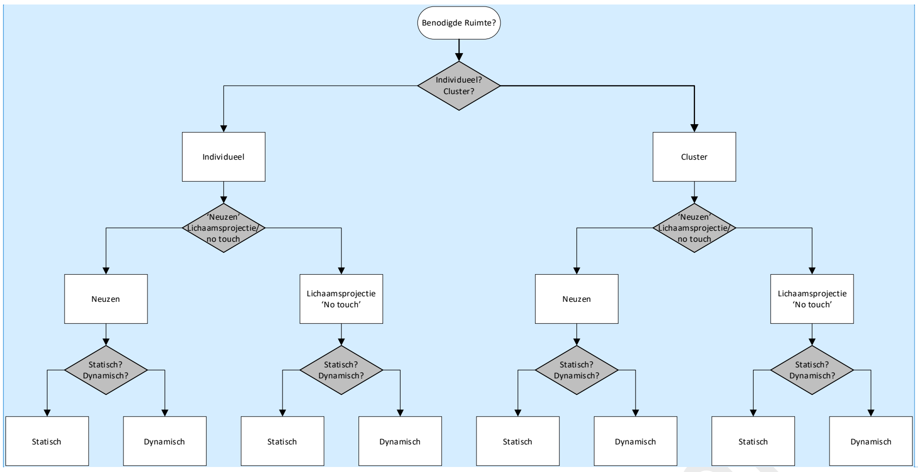
1 Introduction

Physical distancing is one of the basic pillars of resuming public life and safely organizing events (FOD Binnenlandse Zaken, 2020a; Mumford et al., 2020). The concept of physical distancing is further quantified into "visitor density". In relation with crowd safety, a distinction is made between static and more dynamic zones (Fruin, 1971; Still, 2000; Oberhagemann, 2012). After all, density determines both the capacity of a place and the flow rate of a passageway or pedestrian flow route. The same applies to the approach to physical distancing (Bruyninckx, 2020a; Mumford et al., 2020), a person in motion simply needs more space than a static person (Fruin, 1971; Still, 2000). This is also included as such in the Covid Event Risk Model (CERM) (Event Flanders et al., 2020; Flemisch Government et al., 2020), the Code of Conduct (CoC) (ACC et al., 2020) and the Exit protocol Event sector (Belgian Event Industry, 2020) for the event sector in Belgium.

The space required per person, the Personal Area Module (PAM) (Fruin, 1987) or per cluster of people (CAM) and per type of zone static or dynamic, depending on the 1.50 meter distancing (D), can be approached and calculated in two different ways (Bruyninckx, 2020a; SGSA, 2020), (1) the 'nose' method and (2) the 'body projection' or 'no touch' method.

This document is based on a study of international academic literature related to crowd management, crowd dynamics and the use of density as a means to facilitate distancing. An overview is offered of the different ways to approach and calculate density and the associated parameters. In addition, the flow capacity of a "high street" under physical distancing is examined more closely.

In addition, a proposal for an approach to density based on clusters is made. Density and the safe and common values in function of crowd safety and smooth flow and operation were in the past and under "normal" circumstances each time approached from the individual. In the context of physical distancing, however, it may be useful to approach this from a cluster of people who do not have to keep a distance, the close contacts or the household (FOD Binnenlandse Zaken, 2020b).



Commented [BB1]: Translate this Figure

Figure 1:Different approaches to calculating required space and density

2 Basic data

Throughout the document, we assume the distancing standard of 1.50 meters as applicable in Belgium (FOD Binnenlandse Zaken, 2020a). For the line of thought and calculations, where the body projection is taken into account, the study assumes a rectangular body projection (Dridi, 2015) of 0.50 meters by 0.30 meters, in accordance with the findings of Weidmann (1993) and the average used by Prof. Still (2000). This is an overestimate of the average Belgian values, but slightly less than the 95th percentile from the same study by Motmans (2005). The visuals also depict the corresponding "Body Ellipse" (Fruin, 1987; Weidmann, 1993). The figures below show the body projection of a standing person.

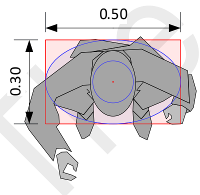


Figure 2: Standing 0.50 x 0.30 meters

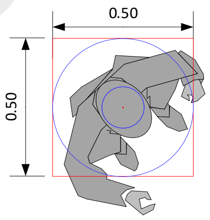


Figure 3: Standing turning circle

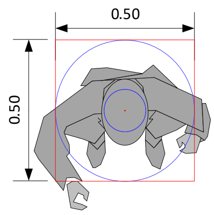


Figure 4: Standing representation

The same dimensions can be kept for a seated person (SGSA, 2020) as shown in the figures below.

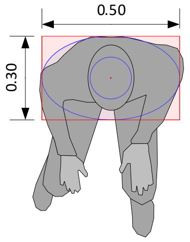


Figure 5: Seated 0.50 x 0.30 meters

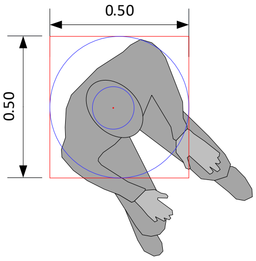


Figure 6: Seated turning circle

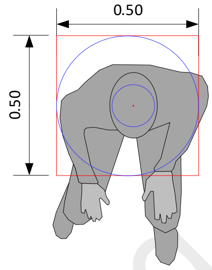


Figure 7: Seated representation

3 Density: the individual approach

In the individual approach, all visitors are considered individually, and the distancing standard (D) is applied to each individual.

3.1 The 'nose to nose' method

This first method is based on the distance from the center point of one body to the center point of the other body. Measurements are taken, say from nose to nose (Bruyninckx, 2020b; Mumford et al., 2020; SGSA, 2020). Note that physical contact is still possible for adults at this distance. Despite the fact that the effective space occupied by the body for standing or dynamic persons (0.6 m) is slightly larger compared to seated persons (0.50), the British Sportsground Safety Authority (SGSA, 2020) makes no distinction within the "nose" method.

Mumford et al. (2020) determine in their study, conducted within the Institute of Place Management (IPM), affiliated with Manchester Metropolitan University, the minimum distance required to achieve physical distancing in dynamic zones as a function of D. This study is based on the 'nose' method.

In the visualization the Personal Area Module (PAM) is represented by a circle, square or hexagon whose inscribed circle has a radius equal to distancing value D. The center of the PAM is centrally located on the head of each individual.

3.1.1 Static zones

With regard to static zones, seated or standing, a zone is demarcated per individual with a radius of half the distancing value. When we consider this Personal Area Module as a circle, not all the space is used, the circles of different individuals cannot be densely packed. On the other hand, it can be noted that when the PAM is represented with the circumscribed square of the circle, apparently too much area is allocated per person. There is a difference of about

20% between the area of the square PAM and the circle PAM. This is due to the way the space is filled and the individuals are packed. In the circle approximation, gaps arise between the circles that are not used by any individual.

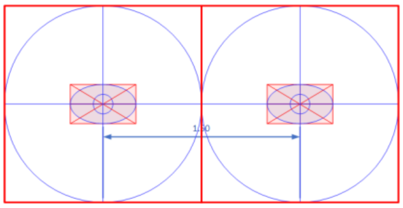


Figure 8: Unused space between individuals in circular PAM representation

In the approach with the circumscribed squares in a checkerboard pattern, that space is not there between the squares, but the squares cover more area (± 20%) than necessary to guarantee the distance.

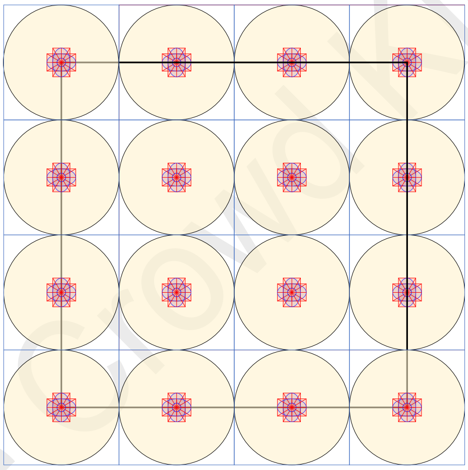


Figure 9: Approach with square PAM representation in a checkerboard pattern

When we want to "stack" the individuals as efficiently as possible, we arrive at a supported triangle stacking as shown in figure 10.

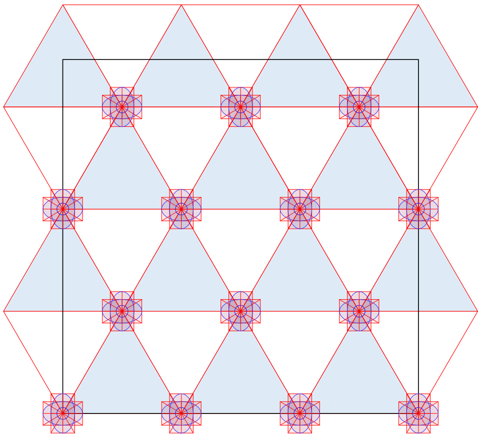


Figure 10: Triangular packing

The most correct way to represent the necessary space per individual is based on the circumscribed hexagon of the PAM circle, figure 10/11, determined by the distancing norm D.

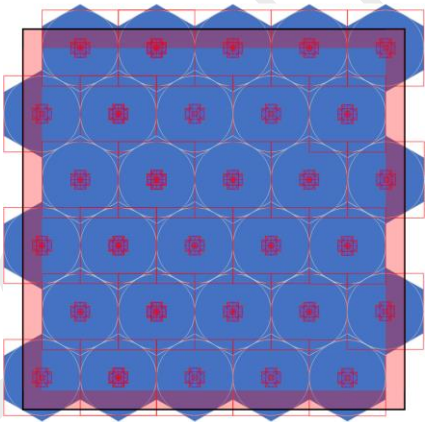


Figure 11: Supported triangular packing with circumscribed hexagon and voronoi tessellation

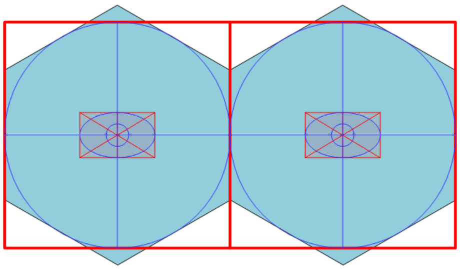


Figure 12: Circumscribed hexagon

When we apply the Belgian distancing standard of 1.50 meters, the necessary space covers the area of the circumscribed hexagon:

$$A = \left(\frac{3\sqrt{3}}{2}\right)[(2\tan 30)r]^2$$

at which:

$$r = \frac{1}{2}\,Distancing\ Norm$$

$$r = \frac{1}{2} \times 1.50m$$

$$r = 0.75m$$

thus:

$$A = \left(\frac{3\sqrt{3}}{2}\right)[(2\tan 30)0.75m]^2$$

$$A = 1.95\ m^2$$

When we look at the different approaches, we find that the hexagonal approach, which forms the voronoi tiling and tesselation, fills the space "completely" even though it does not result in the most use of space per individual (Steinhaus, 1983). Table 1 summarizes the results and Figure 13 illustrates the PAM. With regard to capacity calculation, it is recommended to follow the square approach (SGSA, 2020).

D = 1.50	PAM	Density
Cirkel	1.77	0.57
Vierkant	2.25	0.44
Zeshoek	1.95	0.51

Table 1: PAM and Density for individual approximation of the static zone with the "nose to nose" method

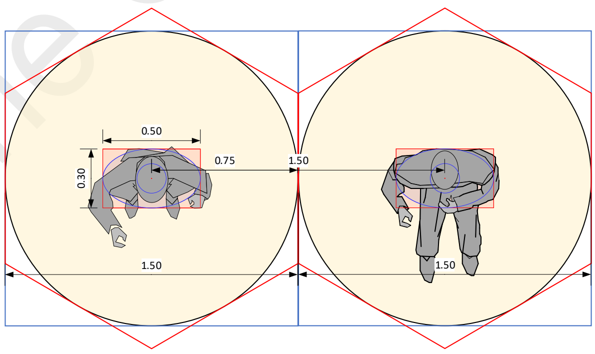


Figure 13: Method 1 "Nose to nose" - Personal Area Module for Static Zones (Standing / Seated)

The ratio of a circle to its circumscribed square and circumscribed hexagon are constants (Mumford et al., 2020). The ratio of a circle with radius r relative to the circumscribed square is 0.7854, relative to the circumscribed hexagon the ratio is 0.9069.

When we "project" the PAM on a podium or theater setup, as in figure 14, the side-to-side space between two seated persons equals 1.00 m, about two seats (chair, seat, seat…). In case of a checkerboard pattern, the rows should also be spaced 1.50 m apart, measured from the center of the seat in one row to the center of the seat in the next row.

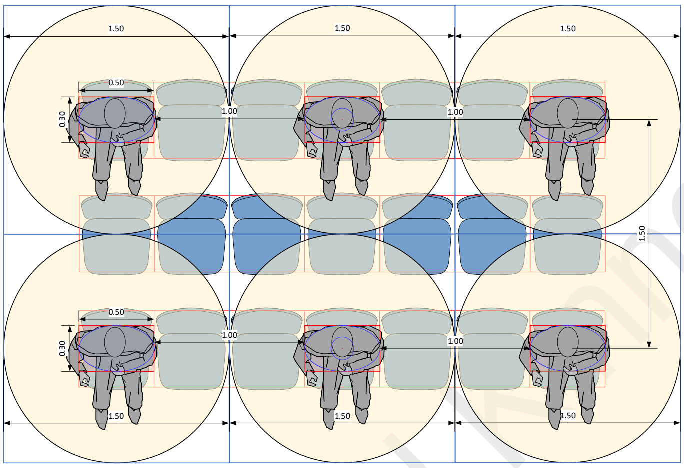


Figure 14: Method 1 "nose to nose" - side-to-side distance seated persons (seats, grandstand, theater)

3.1.2 Dynamic zones

3.1.2.1 SGSA

For the dynamic zones, the SGSA maintains the same values as for the static zones shown in Figure 15.

D = 1.50	PAM	Density
Circle	1.77	0.57
square	2.25	0.44
Hexagon	1.95	0.51

Table 2: PAM and Density for individual approximation of the dynamic zone with the "nose to nose" method

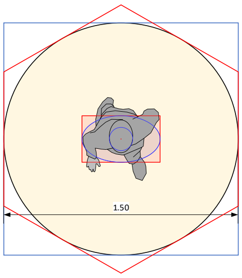


Figure 15: Method 1 "noses to nose" - Personal Area Module for Dynamic Zones SGSA

3.1.2.2 *Institute of Place Management*

Mumford et al. (2020) approach dynamic zones with the idea that the dynamics and movement make that more space per person is required. Not only because a body in motion needs more physical space, but also because a person in motion needs space in relation to other individuals in motion (or static) to maneuver, start and stop. When 100 people are each set up in a checkerboard pattern with a square PAM of 2.25 m^2, movement in compliance with physical distancing is only possible when all individuals move in sync in the same direction.

The equation (method) below (Mumford et al., 2020) is suggested to determine the minimum hexagonal space required per person in terms of dynamic zones.

$$Required\ space = \frac{\pi(x + \mathbf{1})^2}{0.9069} m^2 \ \ with\ x = walkingspeed * stoptime$$

Equation 1: Dynamic Zones Formula from Mumford et al. (2020)

The equation is based on the area calculation of a circle, in the numerator of the equation. Here an "inner circle" is defined within which an individual can move. This "inner circle" has radius "x". The x value is based on walking speed and stopping time (see Equation 1). Half of the distancing norm is added to the x value to obtain the radius of the outer circle. In the UK, where the method has been developed, this standard is 2 meters, so 1 meter is added to x in the equation.

Mumford et al. (2020) calculate the necessary space within the UK context for the three situations as shown below. The respective x values are based on research by Finnis and Walton (2008):

1. ‘individual retailers "<500 m^2, in what they call a" typical high street ", say" small "shop in a shopping street;
2. ‘large retailers or managed commercial space’ > 500 m^2, larger stores or shopping centres and;
3. ‘public urban space’, public open space, the shopping street.

The denominator of Equation 1 "compensates" for the inefficiency of circle stacking (Mumford et al., 2020). The ratio of a circle with radius r to the circumscribed square is 0.7854, to the circumscribed hexagon the ratio is 0.9069.

For the sake of completeness, the approach in this document includes the calculation for the circle, the circumscribed square and the circumscribed hexagon. The circular approach therefore does not use the "denominator" from Equation 1. Which comes down to a calculation according to Equation 2. Equation 2 also includes the Belgian distancing value of 1.5m.

$$Required\ \text{circle}\ space = \pi(x + \mathbf{0.75m})^2 \quad with\ x = walkingspeed * stoptime$$

Equation 2: Required circle space in dynamic zone, based on the circle approximation, adaptation of Equation 1, at D = 1.50m

The literature does not provide walking speeds at events or event conditions necessary to determine the x value. However, we can say that walking speeds at a fair or event are comparable to those in a smaller shop where people look around and have a high(er) interaction with their environment, such as in a highstreet store (Mumford et al., 2020). As a result, we can compare the minimum space required to facilitate distancing at an exhibition and event with that in an "individual store" in a high street.

When we apply this method and use Equation 2 with the Belgian 1.5-meter distancing standard, the minimum required area values as shown in Table 3 and illustrated in Figure 16 are obtained.

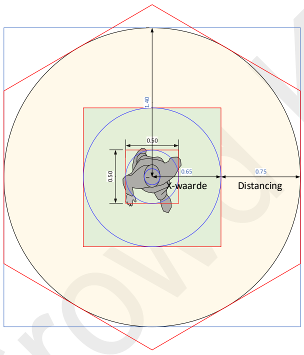


Figure 16: 'Nose to nose' method - dynamic with x-value (small shop) and D.

Situation	x value	Circle		Square		Hexagon	
		PAM m²/p	Density p/m²	PAM m²/p	Density p/m²	PAM m²/p	Density p/m²
Small shop	0.650	6.16	0.16	7.84	0.13	6.79	0.15
Larger shop	0.730	6.88	0.15	8.76	0.11	7.59	0.13
Public place	0.785	7.40	0.14	9.42	0.11	8.16	0.12

Table 3: "Nose to nose" Minimum space required in dynamic zone at 1.5m distancing

3.2 The ‘no touch’ or body projection method

This method takes into account the projected body surface area (bellies) of 0.30 m by 0.50 m (Weidmann, 1993; Still, 2000; Bruyninckx, 2020a). The distancing value is added to the body projection dimensions. Measurements are taken, say from belly to belly (Bruyninckx, 2020b, 2020a). In contrast to the first method, contact between persons is not possible within this no-touch method. The SGSA does make a distinction within this method between static and dynamic zones.

Mumford et al. (2020) do not look at this way, however, we can integrate the previously cited formula (Equation 2) into this method.

In the visualization, the center of the PAM is centrally located on the head of each individual and is represented by a circle, square or hexagon whose inscribed circle has a radius of the length of the distancing value D plus the assumed shoulder width of 0.50 meters. Please note that for the dynamic zone the SGSA (2020) takes into account 0.60 m.

3.2.1 Static zones

Applying the body projection method for static zones, seated or standing, results in a PAM of 4.00 m² (square), 3.14 m² (circle) and 3.46 m² (hexagon) as shown in figure 17.

D = 1.50	PAM	Density
Circle	3.14	0.32
Square	4.00	0.25
Hexagon	3.46	0.29

Table 4: PAM and Density for individual approximation of the static zone with the "no touch" method

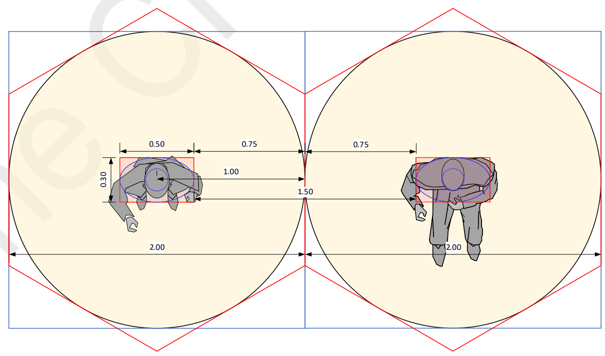


Figure 17: Method 2 "no touch" - Personal Area Module for Static zones (standing / sitting)

This brings the side-to-side space between two seated persons at 1.50 m, approximately three seats (chair, seat ...), see figure 18. In case of a checkerboard pattern, the rows should also be 1.50 m apart. measured from the front of the seat in one row to the back of the seat in the next row. The figure also shows the difference between the circle approach and the square approach for the PAM and density, with regard to capacity calculation it is recommended to follow the square approach (4.00m²/p)(SGSA,2020).

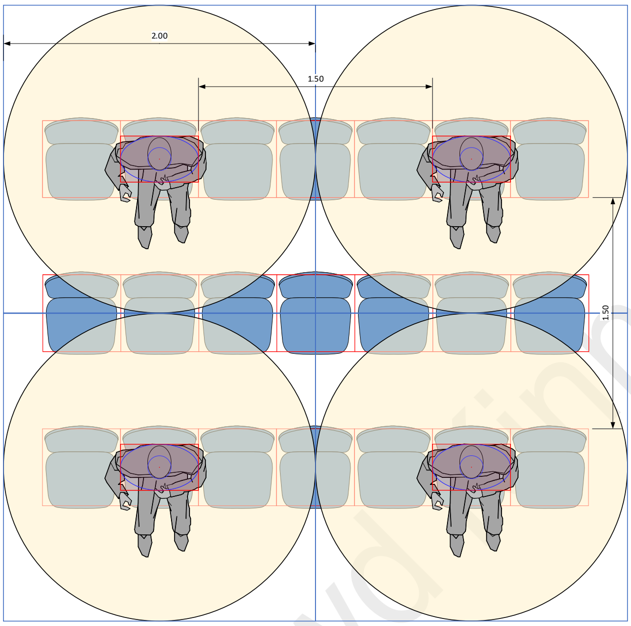


Figure 18: Method 2 "no touch" - distance between seated people (seats, grandstand, theater)

3.2.2 Dynamic zones

3.2.2.1 SGSA

With regard to the dynamic zones, the SGSA takes into account a body projection with a width of 0.60 m. Taking into account the Belgian 1.50 m distancing rule, this results in a PAM of 4.41 m² (square), 3.46 m² (circle) for the dynamic zones and 3.82 m² (hexagon) as shown in Figure 19.

D = 1.50	PAM	Density
Circle	3.46	0.29
Square	4.41	0.23
Hexagon	3.82	0.26

Table 5: PAM and Density for individual approximation of the dynamic zone with the "no touch" method

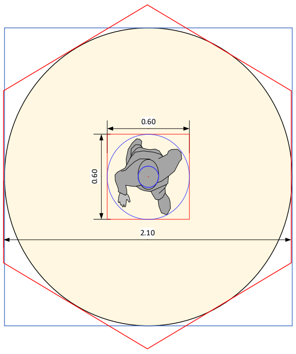


Figure 19: Method 2 "no touch" - Personal Area Module for Dynamic zones SGSA

3.2.2.2 Institute of Place Management

When we integrate the previously cited formula (Equation 2) of Mumford et al. (2020) into this method, the radius that will determine the final PAM should be composed of the x value, half the D value (1/2 * 1.50 m) and half the body width (1/2 * 0.50m). This sum makes up the entire radius.

$$Required\text{ circle }space = \pi(x + \mathbf{0.75m} + \mathbf{0.25m})^2 \ with\ x = walkingspeed * stoptime$$

Equation 3: Required circle space in dynamic zone in the body projection method, based on the circle approximation, adaptation of Equation 1, at D = 1.50m

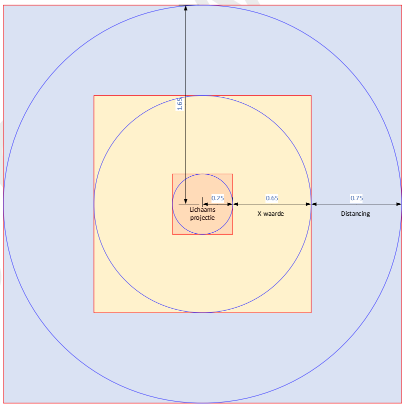


Figure 20: No Touch method - dynamic IPM

When we apply this method and use Equation 3 with the Belgian 1.5-meter distancing standard, we arrive at the minimum required surface area values as shown in Table 6.

Situation	x value	Circle		Square		Hexagon	
		PAM m²/p	Density p/m²	PAM m²/p	Density p/m²	PAM m²/p	Density p/m²
Small shop	0.650	8.55	0.12	10.89	0.09	9.43	0.11
Larger shop	0.730	9.40	0.11	11.97	0.08	10.37	0.10
Public place	0.785	10.01	0.10	12.74	0.08	11.04	0.09

Table 6: "No touch" Minimum space requirement in dynamic zone at 1.5m distancing

As mentioned earlier with the 'nose to nose' method, we equate an event situation with a small shop, this brings, as far as Belgium is concerned with a physical distancing of 1.50 meters, the PAM to 6.16 m²/p (circle), 7.84 m²/p (square), 6.79 m²/p (hexagon).

4 Density: the cluster approach

4.1 General

The cluster approach is based on keeping clusters of visitors together, while guaranteeing the physical distance norm between the clusters. In some cases, such as on stands, at an event with theater setup or other seated events, visitors are often held together per cluster of close contacts. Distancing does not have to be maintained between these persons; it is also unlikely that these persons will keep 1.50 meters apart. In order to make optimal use of the space, it seems sensible to adopt an approach in which clusters are thus kept together and the physical distance between the different clusters is guaranteed.

4.2 Principle

When we start from the cluster approach, it must first be determined how the individuals within the cluster relate to each other, as it makes a difference whether the individuals are on a straight line or 'random' on the surface, this includes the distance between the members of the cluster as a determining factor.

This approach adds two additional (unknown) variables to the equation:

1. The number of people per cluster;
2. The distance between the members of the cluster, the space that the cluster itself needs/gets in static standing and dynamic zones. For a seated event, the seats and their arrangement are decisive. There is of course a relationship between this variable and the number of people per cluster.

This approach also brings us to a theoretical visual representation of a circle in which a central individual is the centre, and the radius is determined by the maximum distance that the cluster members are allowed to keep from the central individual, "R". The members of the cluster are free to move within the cluster circle, as the maximum distance to the central individual is never exceeded. It should be noted that any change in the distancing standard has no influence on the R value, as this distancing distance should not be kept within the cluster.

4.3 The 'Nose to nose' method

We assume the "nose to nose" method and measure from the center point of the central individual.

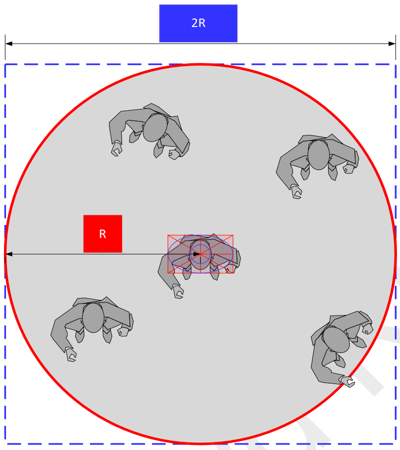


Figure 21: Cluster circle with radius R and circumscribed square with side 2R

4.3.1 Static zones

4.3.1.1 Standing persons

When we consider the cluster circle (gray in figure 21), in a static zone, in relation to other cluster circles, the physical distance norm in Belgium states that a distance of 1.5 meters must be maintained. The necessary space must thus be increased by half the distancing value, 360° all around. In the case of the cluster circle, this comes down to a Cluster Area Module (CAM), the purple circle in Figure 22, with a radius of R + 1 / 2D. The circumscribed square has a side of 2R + 2 (1 / 2D) or 2R + D.

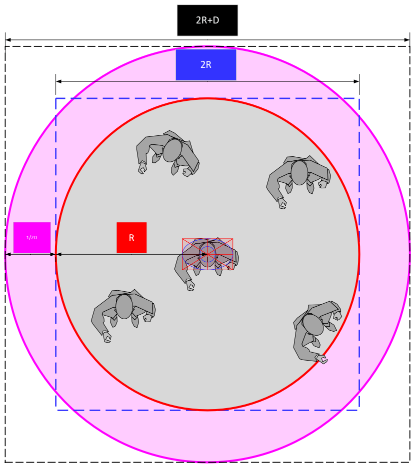


Figure 22: Cluster Area Module with radius R + 1 / 2D and circumscribed square with side 2R + D

For example (figures 23 and 24) with an R value of 1.00 meters and a distancing standard of 1.50 meters, the surface of the Cluster Area Module (the purple circle) is 9.62 square meters. In parallel with the individual approach, we can approach the CAM as a square and a hexagon, based on the compound radius that was also used for the circle. Figure 23 illustrates this, and Table 7 summarizes the values. Transferring the surface of the CAM to a density is not obvious unless a maximum number of people per cluster is assumed. Note that the number of people per cluster must be proportional to the R value, in other words the number of people must also physically fit in the cluster circle. In the example, the cluster contains 5 persons, this value is included in the density calculation, which is expressed as p/m².

Radius = 1.00 + 0.75	CAM	Density*
Circle	9.62	0.52
Hexagon	10.61	0.47
Square	12.25	0.41
* based on 5 people in a cluster at 0.15 m² / p per person		

Table 7: CAM at Circle, Hexagon and Square approximation

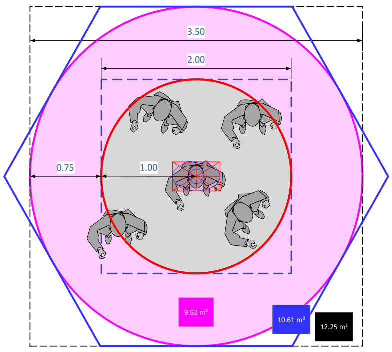


Figure 23: Cluster Area Module in static zones at R = 1.00m and D = 1.50m

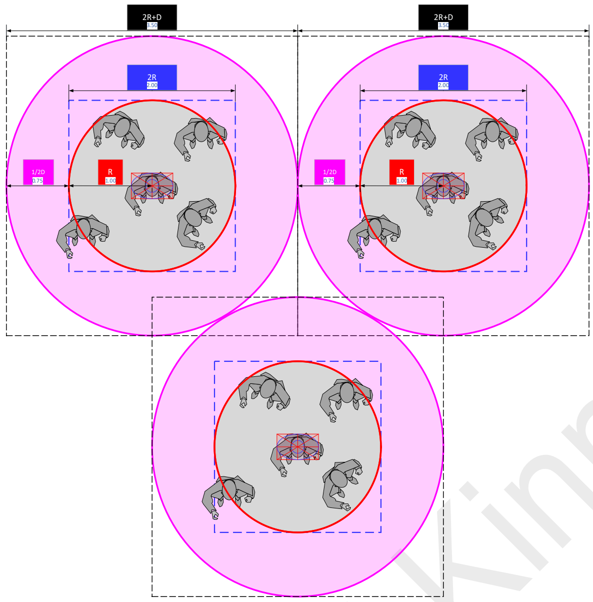


Figure 24: Cluster Area Module in static zone in triangular stack - R = 1.00m and D = 1.50m

4.3.1.2 Seated persons: stands, theater layout…

In case of clusters seated in the same row (stands, theater ...), the following must be taken into account:

1. The distance between the clusters in the same row, two empty seats are sufficient when the 'nose' method is used, in case of the 'no touch' method three seats are necessary.
2. With the "nose to nose" method, the distance to the next used row, one unused row between the clusters is sufficient (figure 25).

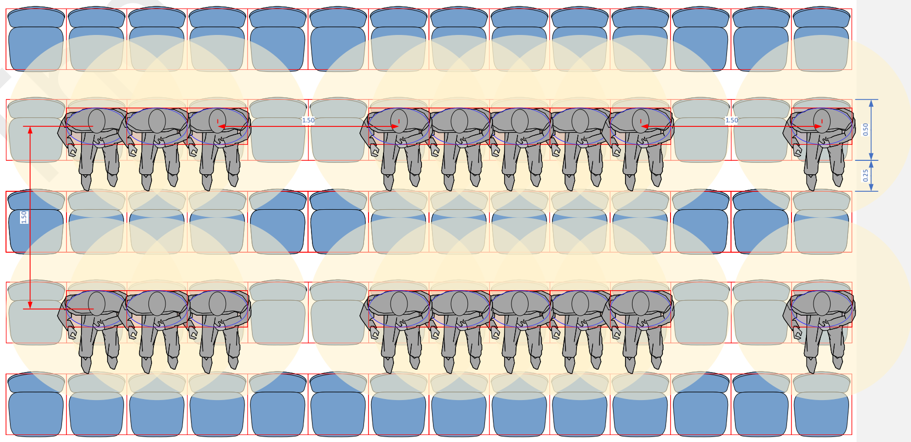


Figure 25: cluster approach on the stand with the 'nose to nose' method - 2 empty seats

4.3.2 Dynamic Zones

With regard to dynamic zones, we base ourselves on the line of thought from Equation 3, furthermore, the rationale from the static zone is kept. When we integrate the x value (Mumford et al., 2020) here we arrive at the space needed in dynamic zones.

$$Required\ circle\ space = \pi\left(x + \boldsymbol{R} + \frac{\mathbf{1}}{\mathbf{2}}\boldsymbol{D}\right)^2 \quad with\ x = walkingspeed * stoptime$$

Equation 4: Dynamic Zones Formula for Clusters

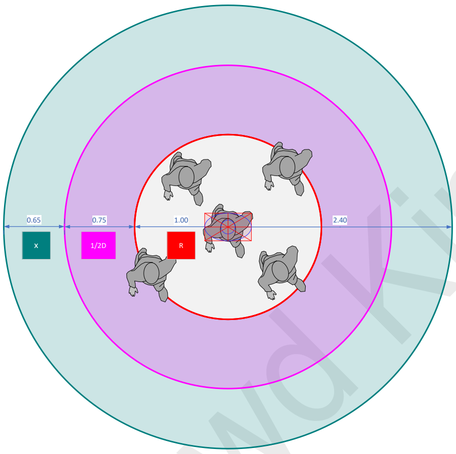


Figure 26: Basis for calculation CAM (circle)

With the values from the example from the static zone (R = 1.00 m and D = 1.50 m) and using the x values of Mumford et al. We can calculate the minimum space required to facilitate distancing using Equation 4, we assume 5 people in the cluster. Figure 26 illustrates this and Tables 8 and 9 summarize the values.

	Situation	x value	D	R	CAM	Density*
BE	Small shop	0.650	1.50	1.00	18.10	0.19
BE	Larger shop	0.730	1.50	1.00	19.32	0.18
BE	Public place	0.785	1.50	1.00	20.19	0.17

*** based on 5 people in a cluster at 0.15 m² / p per person**

Table 8: Calculation CAM dynamic zone

Radius = 1.00 + 0.75 + 0.650	CAM	Density*	Ratio*
Circle	18.10	0.28	4.14%
Hexagon	19.95	0.25	3.76%
Square	23.04	0.22	3.26%

* based on 5 people in a cluster at 0.15 m² / p per person

Table 9: CAM at Circle, Hexagon and Square approach in Dynamic zones

4.4 The 'no touch' method

4.4.1 Static Zones

4.4.1.1 Standing persons

For the "no touch" method, the cluster circle is measured from the body projection, which means that a distance of 0.25 m (half the body projection) is added to the total radius of the CAM.

Radius = 0.25 + 1.00 +0.75 = 2.00 m	CAM	Density*	Ratio*
Circle	12.57	0.40	5.97%
Hexagon	13.86	0.36	5.41%
Square	16.00	0.31	4.69%
* based on 5 people in a cluster at 0.15 m² / p per person			

Table 10: CAM at Circle, hexagon and square approach with the "no touch" method

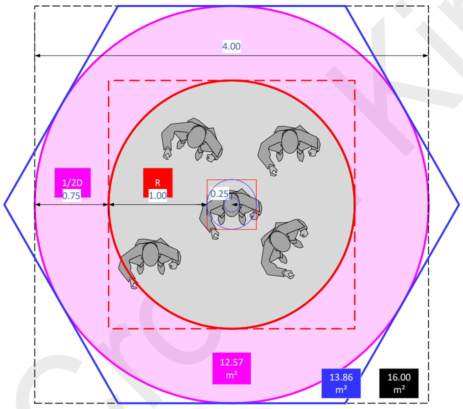


Figure 27: Cluster Area Module in static zones at R = 1.00m and D = 1.50m and "no touch" method

4.4.1.2 Seated persons: stands, theater layout…

In case of clusters seated in the same row (stands, theater...), the following must be taken into account:

1. The distance between the clusters in the same row, two empty seats are sufficient when the 'nose' method is used, in case of the 'no touch' method three seats are necessary;
2. The distance to the next row used, with the "no touch" method, three seats are necessary to respect the distancing.

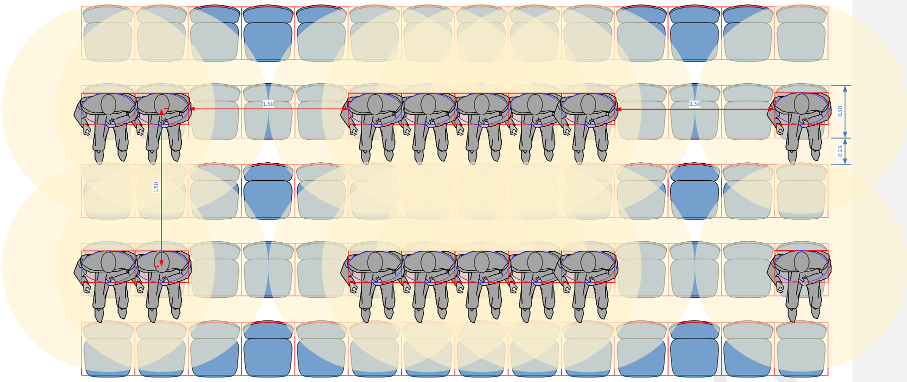


Figure 28: Cluster approach in the grandstand with the 'no touch' method - 3 empty seats

4.4.2 Dynamic zones

Also for dynamic zones 0.25 m is added to the basis of the calculation.

$$\mathit{Required\ circle\ space} = \pi\left(x + \mathbf{0.25} + \boldsymbol{R} + \frac{\mathbf{1}}{\mathbf{2}}\boldsymbol{D}\right)^2 \quad \mathit{with}\ x = \mathit{walkingspeed} * \mathit{stoptime}$$

Equation 5: Formula Dynamic zones for Clusters with "no touch" method

Using the values of the example from the static zone (R = 1.00 m and D = 1.50 m) and using the x values of Mumford et al. We can calculate the minimum space required to facilitate distancing using Equation 5, we assume 5 people in the cluster. Figure 29 illustrates this and Tables 11 and 12 summarize the values.

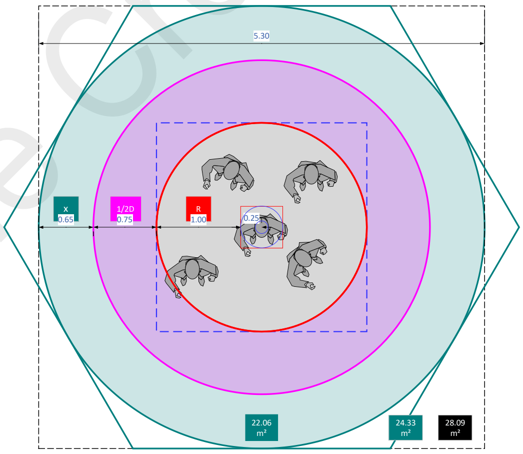


Figure 29: Cluster Area Module in dynamic zones at R = 1.00m and D = 1.50m and 'no touch' method

	Situation	x value	D	R	CAM	Density*
BE	Small shop	0.650	1.50	1.00	22.06	0.23
BE	Larger shop	0.730	1.50	1.00	23.41	0.21
BE	Public place	0.785	1.50	1.00	24.37	0.21
* based on 5 people in a cluster at 0.15 m² / p per person						

Table 11: Calculation of CAM dynamic zone with "no touch" method

Radius = 0.65 + 0.25 + 1.00 +0.75 = 2.65 m	CAM	Density*	Ratio*
Circle	22.06	0.23	3.40%
Hexagon	24.33	0.21	3.08%
Square	28.09	0.18	2.67%
*** based on 5 people in a cluster at 0.15 m² / p per person**			

Table 12: CAM at Circle, hexagon and square approach with the "no touch" method

5 Density: Summary

The table below summarizes the space required per person for each of the methods and approaches in a "small shop" situation.

Ruimte per persoon		Individual approach				Cluster approach (5p)			
		Nose		No Touch		Nose		No Touch	
		PAM m²/p	**Density** p/m²	**PAM** m²/p	**Density** p/m²	**CAM** m²/c	**Density** p/m²	**CAM** m²/c	**Density** p/m²
Static	■	2.25	0.44	4.00	0.25	10.61	0.47	12.57	0.40
	●	1.77	0.57	3.14	0.32	9.62	0.52	16.00	0.31
	⬢	1.95	0.51	3.46	0.29	12.25	0.41	13.86	0.36
Dynami SGSA	■	2.25	0.44	4.41	0.23				
	●	1.77	0.57	3.46	0.29				
	⬢	1.95	0.51	3.82	0.26				
Dynamic IPM	■	7.84	0.13	10.89	0.09	23.04	0.22	22.06	0.23
	●	6.16	0.16	8.55	0.12	18.10	0.28	28.09	0.18
	⬢	6.79	0.15	9.43	0.11	19.95	0.25	24.33	0.21

Table 13: Summary of methods and values

6 Combination with other measures

In the UK, wearing a proper mouth mask is seen as a reason to reduce the UK distancing standard of 2 meters under certain circumstances (SGSA, 2020) to 1 meter as determined by the WHO (2020). This is de facto what is done in Belgium in the basic protocol culture (Fabre, 2020) and where 1 seat between close contacts is allowed at events.

7 Flow capacity of a "high street" - Individual Approach

The flow capacity of a street or passage can be calculated based on the required space and speed of people. After all, flow capacity is the product of (average) speed and (average) density (Fruin, 1987). With regard to a street or passage, the flow capacity can be obtained in the following steps:

1. Divide the street or passage into "channels", with a width based on the PAM, we start from the hexagon projection. Obstacles must be subtracted from the useful width.
2. Determine flow per channel based on walking speed and PAM. For the walking speed we assume 1.57m/s (Mumford et al., 2020) for the PAM we use the hexagonal projection.
3. The sum of the flows of the different channels determines the total flow capacity.

The table below shows the Flow per Channel for the different Density determination methods.

Methode	Channel (m)	PAM (m²/p)	Flow (p/m/min)	Flow/Channel (p/min)
Nose				
SGSA	1.50	1.95	48	72
IPM	3.07	8.16	12	37
No Touch				
SGSA	2.10	3.82	25	53
IPM	3.57	11.04	8.5	30

Table 14: Flow capacity - Individual approach

When dividing the street into channels, the following Channel types can be distinguished:

1. Flow in one direction, these can be multiple channels.
2. Flow in the other direction (opposite), these can be multiple channels.
3. Queue to shop, this channel may not be included in the flow calculation.
4. Display area, this channel may not be included in the flow calculation.

In principle, channels must be extended over the entire length of the street (route); it is the narrowest passage that will determine flow.

The example below, Figure 30, shows a street with a width of 10.2 meters. In the example we use the nose method and the values of the SGSA. The street has shops on both sides, so there are queues and parking zones on both sides. In addition, there are 4 channels of 1.5m wide in this one-way street. The street furniture creates a strip that is not usable. The total flow capacity on these assumptions is 288 people per minute.

The same principle can be applied among other assumptions regarding distancing, density, or walking speed. The principle of dividing into channels is retained.

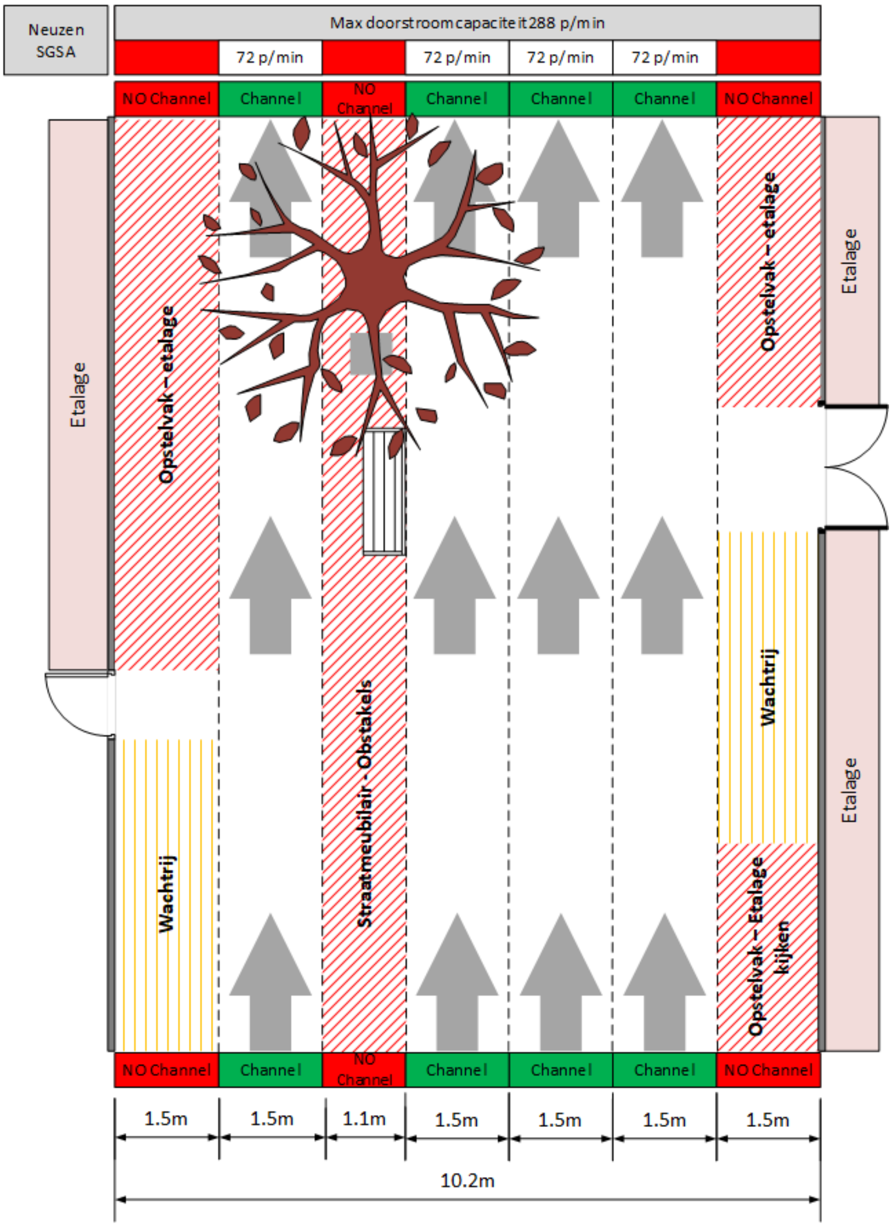


Figure 30: Example of High Street with Channels

8 References

ACC, BECAS, BESA and FEBELUX (2020) 'Code of Conduct CERM.' Alliance of Belgian Event Federations.

Belgian Event Industry (2020) 'Exitprotocol Eventsector.' FOD Economie, KMO, Middenstand en Energie.

Bruyninckx, B. (2020a) '"Density" and "Capacity" as COVID-19 Exit Strategy Parameter for Events in Belgium.' 360 Solutions.

Bruyninckx, B. (2020b) *Technopolis Capaciteitsbepaling.* Aarschot: 360 Solutions, p. 19.

Dridi, M. H. (2015) 'List of Parameters Influencing the Pedestrian Movement and Pedestrian Database.' *International Journal of Social Science Studies*, 3(4) pp. 93–105.

Event Flanders, Visit Flanders, Karel de Grote Hogeschool, ACC Belgium, BESA, BECAS, and Febelux (2020) 'COVID Event Protocol versie 29.06.2020.' Vlaamse Overheid.

Fabre, R. (2020) 'Basisprotocol Cultuur - Basiskader voor de cultuursector tijdens de CORONA-pandemie Versie 24.10.2020.'

Finnis, K. K. and Walton, D. (2008) 'Field observations to determine the influence of population size, location and individual factors on pedestrian walking speeds.' *Ergonomics*, 51(6) pp. 827–842.

Flemisch Government, Alliance of Belgian Event Federations and Karel de Grote Hogeschool (2020) *COVID Event Risk Model*. COVID Event Risk Model. [Online] [Accessed on 21st July 2020] https://www.covideventriskmodel.be/.

FOD Binnenlandse Zaken (2020a) *Ministerieel besluit houdende dringende maatregelen om de verspreiding van het coronavirus COVID-19 te beperken (18 oktober 2020)*.

FOD Binnenlandse Zaken (2020b) *Ministerieel besluit houdende wijziging van het ministerieel besluit van 28 oktober 2020 houdende dringende maatregelen om de verspreiding van het coronavirus COVID-19 te beperken (20 december 2020)*.

Fruin, J. J. (1971) 'Designing for Pedestrians: A Level of Service Concept.' *In*. Washington DC: Highway Research Board.

Fruin, J. J. (1987) *Pedestrian planning and design*. Alabama: Elevator World.

Motmans, R. (2005) *Volwassenen lichaamsafmetingen*. DINBelg. [Online] [Accessed on 8th November 2019] http://www.dinbelg.be/volwassenentotaal.htm.

Mumford, C., Parker, C., Ntounis, N., Lorono-Leturiondo, M. and Still, K. (2020) 'Proposing the lower bounds of area needed for individuals to social distance accros a range of town centre environments.' *Not published Version REVIEW-3*. (IPM Working Series).

Oberhagemann, D. (2012) *Static and Dynamic Crowd Densities at Major Public Events*. Altenberge: Technisch-Wissenschaftlicher Beirat (TWB) der Vereinigung zur Förderung des Deutschen Brandschutzes e.V.

SGSA (2020) 'Supplementary Guidance 02: Planning for Social Distancing at Sports Grounds.' Sports Grounds Safety Authority.

Steinhaus, H. (1983) *Mathematical snapshots*. Oxford [Oxfordshire] ; New York: Oxford University Press.

Still, G. K. (2000) *Crowd Dynamics*. PhD. University of Warwick.

Weidmann, U. (1993) 'Transporttechnik der Fussgänger.' *Schriftreihe des IVT*, 90 p. 110.

World Health Organization (2020) *WHO Director-General's opening remarks at the media briefing on COVID-19 - 25 March 2020*. [Online] [Accessed on 11th April 2020] https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---25-march-2020.