IPM
Institute of Place Management

Manchester Metropolitan University

Proposing the lower bounds of area needed for individuals to social distance across a range of town centre environments

IPM Working Paper Series

This paper has been created by independent experts on behalf of the High Streets Task Force. It is not intended as Government guidance, and we have not sought approval for it to be so.

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The Institute of Place Management is the professional body for people involved in making, maintaining and marketing places. As part of Manchester Metropolitan University, the Institute of Place Management is dedicated to supporting people who serve places, providing them with unbiased research, continuing professional development, qualifications, conferences, events and networking opportunities.

Authors

This working paper has been written by an interdisciplinary team of academics from the Institute of Place Management at Manchester Metropolitan University and Cardiff University.

Dr Christine Mumford, Cardiff University

Professor Cathy Parker, Institute of Place Management, Manchester Metropolitan University

Dr Nikolaos Ntounis, Institute of Place Management, Manchester Metropolitan University

Dr Maria Lorono-Leturiondo, Institute of Place Management, Manchester Metropolitan University

Professor Keith Still, Fellow of the Institute of Place Management, Manchester Metropolitan University.

Background

This paper was commissioned by the Professional, Research and Data Group, within the High Streets Task Force to explore the very practical problem of capacity for social distancing, in light of COVID-19, across a variety of typical town centre environments. The aim is to provide guidance for place managers and business owners as lockdown eases, and as establishments are allowed to reopen and footfall comes back to town centres.

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Status

The paper is currently under review by members of the Institute's Editorial and Standards Board.

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1.Introduction

In the UK, the path out of the lockdown caused by the COVID-19 pandemic was revealed on the 10th May 2020 and we now expect outdoor markets and car showrooms to reopen on the 1st June, and other non-essential retail on the 15th, subject to conditions required from the 'conditional approach'[1]. As there is still no cure or vaccine for this coronavirus, the UK Government public health messages requests us to 'stay alert, control the virus, save lives'. As the virus can be inhaled and picked up from objects, new Government guidance has been issued on 'Working safely during COVID-19'[2] stipulating the expected measures that retailers, and other workplaces, are expected to implement to limit the transmission of the virus.

The main route of transmission is from cough and sneeze droplets. These droplets fall on people in the vicinity and can be directly inhaled or picked up on the hands and transferred when someone touches their face.

Public Health England, January 2020

Limiting the transmission of the virus in all environments involves social distancing ensuring, that in the UK, people keep 2m apart, increased hygiene measures and, in environments where people may be in prolonged contact with the virus or may not be able to social distance, the wearing of face-coverings.

All three measures, social distancing, increased hygiene procedures and the wearing of face-coverings will become normal practices in our town centres and high streets. Since mid-March, the High Streets Task Force has been urging place managers to plan ahead for the gradual reopening of businesses, in line with Government policy[3]. Over the next weeks we will be developing advice to help place managers understand and implement all three measures.

Going forward, agreeing capacities across retail environments will help reassure visitors returning to high streets. The capacity levels maximise occupancy in businesses, whilst respecting social distancing requirements, which is important for public health and reopening the economy.

1.1 Social Distancing

With regards to retail, current GOV.UK guidance[2] asks employers to define: "the number of customers that can reasonably follow 2m social distancing within the store and any outdoor selling areas. Take into account total floorspace as well as likely pinch points and busy areas."

[1] https://www.gov.uk/government/publications/our-plan-to-rebuild-the-uk-governments-covid-19-recovery-strategy/our-plan-to-rebuild-the-uk-governments-covid-19-recovery-strategy

[2] https://www.gov.uk/guidance/working-safely-during-coronavirus-covid-19/shops-and-branches

[3] https://www.highstreetstaskforce.org.uk/covid-19-recovery

It goes on to say: "Shopping centres should take responsibility for regulating the number of customers in the centre and the queuing process in communal areas on behalf of their retail tenants."

However, no further guidance is given regarding how to calculate the number of people that can reasonably follow social distancing in these environments.

This is a complex issue that will also require the careful management of people once they are in a space, coupled with self-discipline and compliance from the public. As well as the size of the floorspace, the layout and positioning of goods, entrance and exit points, and point of sale arrangements will have a large impact on what the final capacity may be for an individual retail environment.

In addition to individual stores and shopping centres, most town centres consist of other types of environments where social distancing will also need to be managed. These include locations where retailers are located in other managed spaces – such arcades and markets – as well as the general town centre area; the streets, squares, and public spaces that make up a town centre. Of course, town centres also consist of other environments, such as transport hubs and greenspace – but these are outside the scope of this paper. Instead, we develop a methodology for establishing occupancy levels for three town centre environments:

- Typical high street store space (individual retailers under 500 square metres)
- Larger retailer or managed commercial space (individual retailers over 500 square metres or commercial space where a number of stores trade together)
- Public urban space

In this paper we:

- Obtain a lower bound[4] for the amount of space a single individual needs to be allocated to social distance, in dynamic space (in other words, space where people need to move around freely).
- Offer a definition of dynamic space, in each of the town centre environments
- Obtain a lower bound for the amount of space a single individual needs to be allocated to social distance, in static space (in other words, space which has been allocated to people who are staying more static, like in queues)

It is important to explain that our proposal cannot account for the specific characteristics and morphological characteristics of individual places. Those responsible for each of the environments must undertake their own assessment of their spaces. Instead, our paper proposes, theoretically, how much space a person needs in each of the three environments, as well as the space required to queue or remain static in an environment. Our analysis involves enclosing each person in a circular region, with a predetermined space in which

i) They can move independently of other people.
ii) They are held in queues or seated etc., and cannot move independently.

[4] We define lower bound here as the minimum amount of square meters needed in order to adhere to social distancing measures in a given situation.

2.Theoretical development

In common with most place management problems, which are of a very practical nature, theory needs to be drawn from a variety of disciples. Our problem is how to calculate the number of people that can reasonably be expected to enter retail environments, to enable social distancing. To solve this problem, we have found useful theory from retail space allocation, crowd dynamics, operational research and finally, ergonomics and biomechanics.

2.1 Retail space allocation

Retail space allocation has a long tradition of research as businesses try to improve the performance of their stores. Two of the objectives of retail space allocation are to "attract the optimum number of shoppers into the store" as well as "balance the need for profitable trading with the concern for the needs and wants of the shopper" (Buttle, 1984, p.5/6). These fundamental principles of retail space allocation have guided our approach as we solve the problem from both the retailer perspective (who will want to optimise the use of their store space) and the consumer perspective (who will want to social distance safely while still enjoying a pleasant retail experience).

2.2 Crowd Science

Crowd science offers a systematic approach to risk analysis and safety in places of public assembly, when crowds are likely to be present (Still, 2004). Whilst the focus of much research in this area has been on major events, such as sports or music festivals, many of the techniques developed can be applied to the problem of social distancing in town centre environments and at a more limited spatial scale, such as store environments. Of particular relevance is the identification of two types of space – dynamic, where people need to move freely – such as around shops, shopping centres, markets and high streets/town centres; and static spaces, where people's movement is restricted, such as if they are seated or standing in queues.[5]

2.3 Operational research

Operational research is concerned with the organization and adaptation of establishments (e.g. stores) to conform with the habits of consumers and to raise business efficiency. How to fit objects efficiently into a given space is a well-researched, yet very challenging, branch of operational research, within a more general classification of "cutting and packing" problems (Dyckhoff, 1990). Although such problems can be different in nature and arise from very different areas of practice, they belong to the same logical structure, including *cutting* stock (e.g. cutting windows from a large stock sheet of glass, or finding the best layout for a dress pattern to conserve material), to *packing* goods into boxes for delivery, or loading containers for shipment. In the context of social distancing in light of the COVID-19 pandemic, however, our interest is focussed on a subset of problems concerned with "tessellation": an arrangement of shapes (e.g. people) that are closely fitting together. In order to apply this to everyday spaces, we explore the capacity of both types of space identified above; *fixed* space and *dynamic* space.

[5] http://www.gkstill.com/Support/crowd-flow/MovingDensity.html

Capacity in Static Space

Many shops are allocating space for queuing, internally and externally, using floor stickers, or temporary barriers, or a combination of both. In order to be 2 metres from the next individual, each person needs to be surrounded by an empty circle of area πr^2, with r = 1, as shown in Figure 1. UK Government guidance is currently to keep 2m away from people of different households. However, this differs from the WHO guidance, and guidance in other countries (for example in Germany it is 1.5m). Nevertheless, the equation remains πr^2 and r can be substituted with any social distance guidance (in metres) divided by 2.

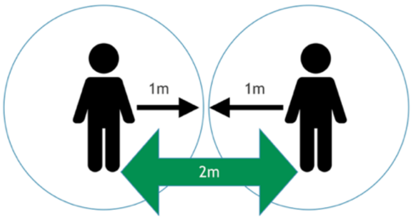

Figure 1: Social distancing of 2m between two individuals

For this configuration to work, it is necessary for people to move in unison, otherwise if the person on the right, for example, moves towards the person on the left they reduce the social distancing space to less than 2m (see Figure 2).

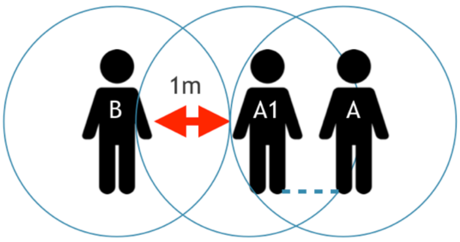

Figure 2: Person A moves towards Person B (from position A to position A1), reducing social distancing space to 1m.

The idea that people will move in unison is completely impractical in dynamic space, considering the different movement choices by individuals making their way through, for example, a supermarket – but is possible in static space, if the space is clearly marked out and managed, and people do not need to move around.

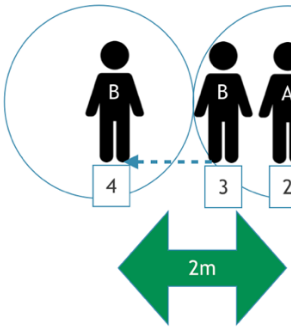

Figure 3: Person A moves towards Person B, from queue spot 1 to queue spot 2. Person B moves from queue spot 3 to queue spot 4. 2m of social distancing space is maintained.

The demarcation of this space in this scenario is likely to follow some form of square or rectangular tessellation (Figure 4), where people are held in individual straight rows, parallel rows or 'snaking rows' (Figure 5).

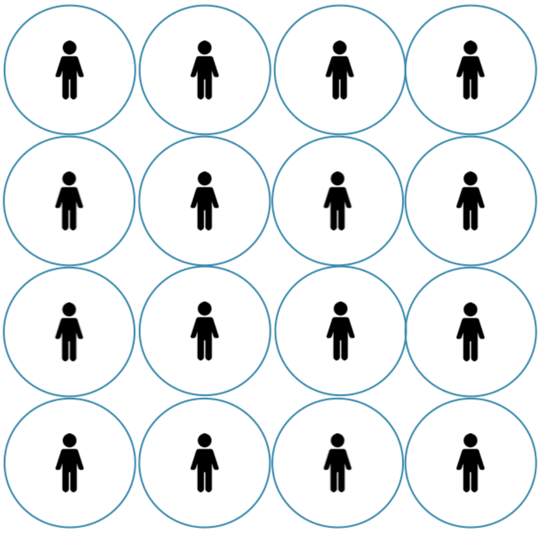

Figure 4: A square tessellation

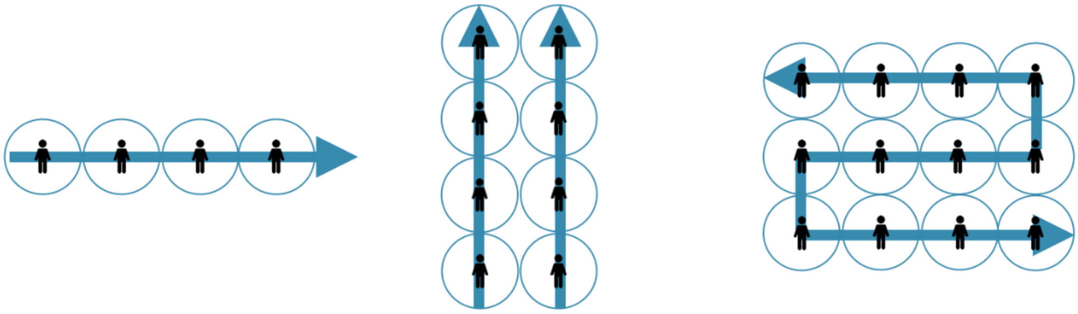

Figure 5: Queuing configurations based on square or rectangular tessellations.

In square or rectangular tessellations, the density of the circles[6] is 0.7854 (Williams, 1979, p. 49). In other words, 78.5% of the space can be utilised.

Based on a square tessellation, in fixed space each person will require a space of $\pi(r)^2/0.7894m^2$ ($3.9797m^2$ when r = 1m) for the square or rectangular tessellation.

However, this gives no room for independent movement without encroaching on another's space. We now introduce the importance of independent movement, which is a key characteristic of the dynamic space of retail and town centre environments.

Capacity in Dynamic Space

In relation to COVID-19 the term "packing" (i.e. fitting elements in a space in the most efficient way, in relation to the aforementioned "cutting and packing" problems) is somewhat at odds to the aim of "distancing". Nevertheless, this branch of theory within operational research still offers us a useful starting point for our analysis of capacity in dynamic space, as it did for static space. In order to identify the most efficient way of allocating space to people, retailers, shopping centre and market managers - as well as place managers - are going to want to optimise the floorspace they have available in the more dynamic spaces, where people need to move around freely (e.g. establish a maximum number of people they can safely allow into their space).

In the following discussion, we use a different method of 'packing' circles, known as a hexagonal tessellation. This is because square or rectangular packings tend to take up more space, even though they are the most likely arrangements in fixed space (people are going to be held or seated in rows). Therefore, if we assume retailers and other place managers will want to optimise the space they have available, we continue our analysis using the hexagonal packing of circles. Of course, in practice, dependent on the individual characteristics of the space in question, a hexagonal packing may not be

[6] We calculated the density of the circles in a given space based on circle packing theory, meaning that all arrangements of circles inside a given boundary do not overlap. Tessellations correspond to particular circle packings (Williams 1979, pp. 35-41) that are subject to the layout of space. Circle packing is used here in a way that allows the optimal use of space (meaning the maximum amount of space that can be covered in a store/public space/street when all obstacles and other parameters are calculated).

possible. The purpose of this paper is to establish the lower bounds of space needed to social distance, in different environments, not the particular occupancy levels in individual spaces.

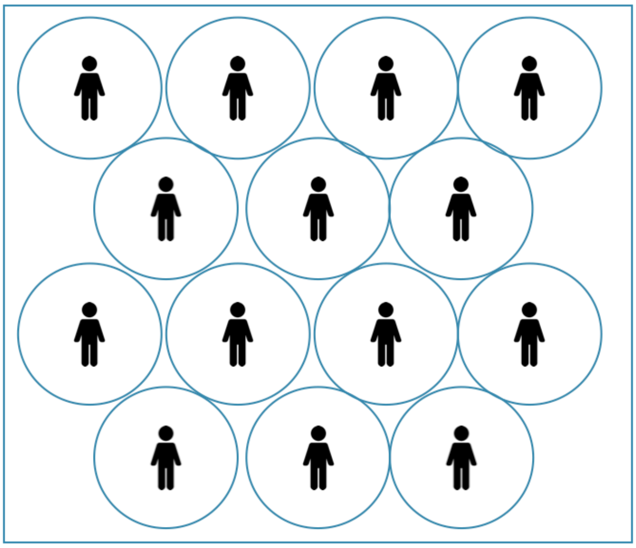

Figure: 6 A hexagonal tessellation

With a hexagonal packing or a hexagonal tessellation, the density of circles in Figure 6 is approximately 0.9069 (Steinhaus, 1999, p. 202), compared to that in Figure 4 is 0.7854 (Williams, 1979, p. 49). In other words, the proportion of the available space that the packed circles occupy is 90.7% with a hexagonal packing, compared to 78.5% with a square or rectangular packing. However, the same restrictions of movement still apply in a horizontal packing, if the distance between people is only 2m (see Figure 7)

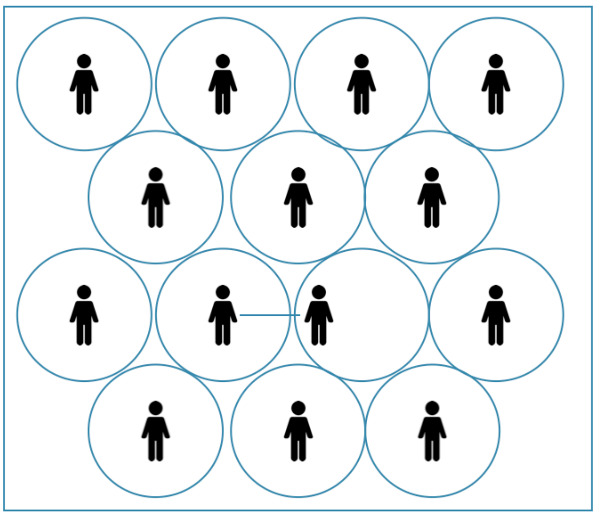

Figure 7: Violation of 2m social distancing space caused by movement when r=1

To overcome this problem, we start to model the space required by an individual person in a different way, to balance free movement with social distancing as people do not stand still or move in unison in dynamic space.

To do this, we give each individual partial freedom to move independently from each other. We can represent this situation by drawing an inner circle within an outer circle, as shown in Figure 8. A person can move independently within the inner circle, and the outer circle will ensure correct social distancing is maintained. The size of the radius inner circle, ***x*** must be determined according to the freedom of independent movement required.

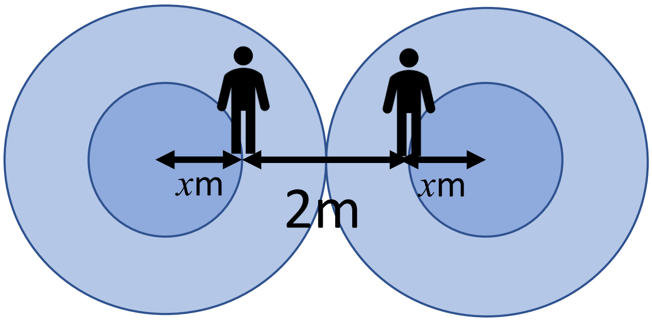

Figure 8: Social distancing with some freedom for independent movement. A person can move anywhere within the inner circle of radius *x* without reference to neighbours.

Based on a hexagonal tessellation, each person will require a space of $\pi (x + 1)^2/0.9069m^2$ ($13.856m^2$ when $x = 1m$).

The question now is, how much freedom of movement do people need in order to carry out their usual shopping (and other) activities that require them to move around?

2.4 Ergonomics and biomechanics

Our analysis so far has built on the principles of allowing retailers to optimise the space they have available and giving individuals freedom of movement with a social distancing 'buffer'. The question now is how much freedom of movement is required?

In order to answer this question, we have reviewed theory in both ergonomics and biomechanics, which investigates people's walking behaviour. In particular we are interested in walking speeds in our different town centre environments. In smaller retail environments (that we define to be individual retailers with a floorspace of under 500 square meters), people will walk the slowest as they are likely to be looking around and space will be more constrained – here we assume people will walk at 1.3m/s (Finnis and Walton, 2008).

In larger retail settings (above 500 square meters), or in managed commercial space, such as shopping centres, markets or arcades, people may walk a little quicker, as many typically bypass a proportion of the available walking space to arrive at the particular area or retailer where they are starting their shopping. In these environments we assume a walking speed of 1.46m/s (Finnis and Walton, 2008). This is the typical walking speed of adults.

Finally, in public urban space we have to assume that many people are entering to get from A to B. Therefore, to err on the side of caution, we assume a walking speed of people commuting which is 1.57m/s (Finnis and Walton, 2008).

To calculate the freedom of movement we should allow in each retail environment it was assumed that people will need 0.5s to stop walking (Tirosh and Sparrow, 2004).

Calculating areas needed for individuals to social distance across a range of retail environments:

Setting the value of x, the radius of the inner circle giving freedom of movement for the individual

We set the value of x, the radius of the inner circle giving freedom of movement, as walking speed / stopping time. This gives us the following values for x in the different town centre environments

- Typical high street store space (individual retailers under 500 square metres): 0.65m
- Larger retailer or managed commercial space (individual retailers over 500 square meters or commercial space where a number of stores trade together): 0.73m
- Public urban space: 0.79m

Establishing area per person for social distancing in different retail environments

Using our equation $\pi(x + 1)^2/0.9069m^2$, we propose the following lower bounds of space for people to social distance in different retail environments. In each one we round up to the nearest square metre. We present areas associated with alternatives distances in Appendix 1.

- Typical high street store space (individual retailers under 500 square metres): each person requires $10m^2$ of dynamic space
- Larger retailer or managed commercial space (individual retailers over 500 square meters or commercial space where a number of stores trade together): each person requires $11m^2$ of dynamic space
- Public urban space: each person requires $12m^2$ of dynamic space

Although these capacity figures are less than operators and place managers are used to, it is important to get some perspective and recognise that they will still allow trade and visitation. For example, any of these capacities would enable at least 200 people to move around and socially distance in an area the size of one third of a footfall pitch.

We appreciate that it will be difficult to estimate usable space in some environments, and we are looking at tools and templates to help managers do this. Ultimately, it is important that whoever is responsible for the space understands it, as this is part of the COVID-19 risk assessment process that all businesses should do, and that managing social distancing is also an expectation of local authorities and other managers of public space.

3. Defining “dynamic space”

Whilst it is common to measure the floorspace of retailers and managed commercial areas, such as shopping centres and markets, this total area does not equate with the total walkable space for people. Shops are full of merchandise and other ‘obstacles’ when it comes to practicing social distancing. In addition, they have other areas which are not accessible, such as space behind tills, storerooms and toilets etc. There are also areas of fixed space to be considered, where people are queuing for example, and these needed to be subtracted from the dynamic space available.

Similarly, all public urban space cannot be assumed to be 'usable – there will be areas given over to carparking, and traffic etc. as well as other, more aesthetic obstacles, such as flowerbeds, fountains and statues etc.

In all environments we define dynamic space as the space that is accessible and can be used for social distancing. The dynamic space will be different in every environment and those responsible will have to measure the areas that are open and accessible to the public, subtracting the areas that are not accessible/usable for social distancing or are given over to fixed space.

We believe that a pragmatic approach is best in these circumstances, as it makes the manager of the different environments responsible for agreeing available space and number of people for safe social distancing and, at the same time, it encourages managers to make the most of the dynamic space available in their environments. That may mean taking out some gondolas or merchandise in some retail environments, reducing the number of traders in some markets, or 'barrows' in shopping centres, and pedestrianising areas or reducing kerb-side parking in town centres, for example. The aim will be to provide an optimal mix of attractions and space for social distancing.

4. Conclusion and future papers

This paper has allowed us to propose lower bounds for people to social distance across a number of retail environments and in two types of space – static and dynamic. We hope this will be a useful first step for retailers, shopping centre managers, market managers and place managers who will need to calculate the numbers of people who can social distance in their environments.

It is important to stress that the lower bounds that we propose, on their own, will not enable managers to calculate 'capacity'. Each individual environment will need to be assessed to establish the amount of fixed space, dynamic space, and also take into account other factors, such as entrance and exit arrangements, pinch points etc. We hope to offer further insight here, in future papers, based on published academic research.

Crowd dynamics involves understanding the behaviour of groups of people, monitoring and management (Still, 2000). Services management and marketing, in a retail environment, involve redesign of layout and processes, staff training, clear signage, clear communications with customers, and other interventions (Baron et al., 2009). This will involve managing people at entrances and exits and other places, such as at tills or collection points. In larger environments it may involve controlling the flow of pedestrians around the store or space. At pinch points, such as narrow aisles, where people cannot safely pass, it may mean floor or other signage to encourage people to walk in one-direction.

These changes are in addition to the other interventions to stop the transmission of the virus (increased hygiene, the wearing of face-coverings in some environments). Getting all this right is especially important during the COVID-19 crisis, to keep the rate of transmission down and ensure customers, and staff, feel safe.

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Appendix 1 – Lower bounds of areas needed for individuals to social distance across a range of retail environments, using alterative distances (in metres)

Social distance (in metres)	Type of space	Area required per person (to nearest m^2)
2	Static space	4
2	Retail under 500 m^2	10
2	Retail or managed commercial space over $500m^2$	11
2	Public urban space	12
1.5	Static space	2
1.5	Retail under $500m^2$	7
1.5	Retail or managed commercial space over $500m^2$	8
1.5	Public urban space	9
1	Static space	1
1	Retail under $500m^2$	5
1	Retail or managed commercial space over $500m^2$	6
1	Public urban space	6

Static space – relates to space where people are 'fixed', for example, in seating or in queues

Retail under $500m^2$ – relates to retail outlets where the total floor area is under $500m^2$

Retail or managed commercial space over $500m^2$ – related to retail outlets where the total floor area is over $500m^2$. It also apples to shopping centres, arcades and markets or other managed 'collections' of retailers and service providers.

Public urban space – relates to the footpaths, squares, streets, car-parks or other areas common in town and city centres, where the local authority is responsible for management, often in partnership with other agencies.

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