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Connectivity of public open space: its meaning for different functions

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ABSTRACT
Melbourne, Australia's fastest growing city, developed more rapidly to its south and east than to the north and west. This presents planning challenges where differences in the meaning of connectivity have emerged. To the north and west, there are demands to subdivide undeveloped land for housing, but there are also demands for connected public open space (POS). This paper defines connectivity in relation to its function and measured unimpeded connected POS for travel by foot, wheelchair, skateboard, scooter, rollerblades or bicycle. Distances ranged from 0.5 to 20 km. Connectivity was measured as distance travelled without retracing the course in the same direction.

Introduction

The term connectivity is commonly used in urban planning but there appears to be a lack of clarity as to what it means. The concept of connectivity when linked to accessibility and proximity in some planning contexts can lead to confusion as happened in recent discussions about the planning of public open space (POS) and suburban development in the city of greater Melbourne, the capital of the State of Victoria. This paper examines the meaning and measurement of connectivity in POS.

Melbourne is Australia's fastest growing metropolis (ABS 2018). The city, dating back to 1835, has experienced various growth spurts associated with gold mining in the 1850–60s and a migrant-fuelled boom after World War II, but the current rate of growth is unprecedented. Its population exceeds 5 million and its growth rate is in the top five fastest in the developed world (Bagshaw 2018). It is an affluent city that is regularly rated in the top three of the world's most liveable cities by the Economist Intelligence Unit's Global Liveability Index. The city developed more rapidly to its south and east than to the north and west, but it is these parts that now are expanding most rapidly. This uneven directional growth has thrown up some interesting challenges and opportunities for those planning development. The city's limits to the south and east extend to 60 km and beyond from the city centre, but to the north and west of Melbourne there is land within 20–30 km of the central business district (CBD) that is undeveloped and demands for its subdivision for housing are being made, but so too are demands for POS,

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recreational space and suburbs that can cope with climate change. It is recognized that there is a once in a century opportunity to plan for these parts of the city.

In Melbourne, parts of the eastern and southern suburbs have a long history of urban development and the capacity for creating new POS and connecting these spaces is limited. But to the north and west, which are historically the lower socio-economic status (SES) sectors of the city, opportunities still exist for creating and connecting POS. The current populations of these parts of the city have lower household incomes, shorter life spans and high rates of diseases related to high blood pressure, heart health conditions and type-2 diabetes, all of which are related to a lack of physical fitness and reduced rates of active and passive recreation compared to populations in other parts of the city (DHHS 2015; Astell-Burt and Feng 2016). Thus, provision of POS and accessible recreational facilities are important parts of planning for the future of these sectors of the city.

Public Open Space (POS)

The definition of POS varies with country and in the United Kingdom, POS means any land laid out as a public garden, or used for the purposes of public recreation, or land which is a disused burial ground (Town and Country Planning Act 1990). In the United States of America, POS is any land area in public ownership zoned for open space, or any land which would conserve and enhance natural or scenic resources, protect streams or water supply, promote conservation of soils, wetlands, beaches or tidal marshes, enhance the value to the public of abutting or neighbouring parks, forest, wildlife preserves, nature reservations or sanctuaries, enhance recreation opportunities or preserve historic sites or preserve visual quality along road corridors or scenic vistas; or retain in its natural state tracts of land not less than one acre situated in an urban area and open to public use by the granting authority (US legal 2019).

In Victoria and for the purpose of this paper, open space is land that provides recreation and leisure benefits and POS is land in public ownership and/or under public management that provides recreation and leisure benefits, while private open space is land that is privately owned and provides recreation and leisure benefits (DWELP 2015). Different types of POS are known to have different levels of value to different user groups and what communities value in POS may change over time (Bates and Santerre 2001; Brander and Koetse 2011; Carmona 2014). Not all POS is green space, but green POS is often more highly valued by users (Braubach et al. 2017; Lamb et al. 2019). The value of POS can also be enhanced for some users by a perception of solitude, the presence of wildlife, a higher level of biodiversity or even the ownership of the space. In many communities, publicly owned space is more highly valued than privately owned open space (Bates and Santerre 2001; Geoghegan 2002; Mansfield et al. 2005; McConnell and Walls 2005). This paper explores aspects of recreational activities that take place within POS, much but not all of which is green and which might be defined as public recreational space: a subset of POS.

For the past few years, the issues of POS accessibility and connectivity have been prominent in discussions concerning urban planning for a rapidly expanding Melbourne. There seems to be an encouraging commitment to accessibility and connectivity in the urban planning processes, but there are disconcerting differences in the use of the terminology and their intended meanings (Saelens, Sallis, and Frank 2003; Dill 2004;

Brander and Koetse 2011; Wang, Mateo-Babiano, and Brown 2013; Mehta 2014). Urban planners have long understood the need to consider open space as a whole that forms a closely linked system (Abercrombie and Forshaw 1943). Often the terms accessibility, proximity and connectivity are used to describe similar, if not identical, concepts in one context and then these same terms are used to define very different concepts in other contexts (Costa and Soares 2009).

At the heart of many of the major cities of the world are public parks that provide large POS. Central Park in New York, the Englischer Garten in Munich and the Tiergarten in Berlin readily come to mind. These are sufficiently large to provide opportunities for diverse passive and active recreational activities and showcase POS, often giving the impression, especially to occasional visitors and tourists, of a green and leafy city, but on a regular basis they are only accessible to those who live close by. They are so large that they do not need to be connected to other POS. The Royal parklands of London and the string of 'Emerald necklace' parks in Boston (Figure 1) are also inner city parks, but are a connected group of parks rather than one large entity. They provide access points over a much longer linear distance and so are accessible to more people. The Tan Track (walking and running) and Yarra River trail of central and the inner east of Melbourne fulfil a similar role to these latter parks with an extended and connected POS of about 20 km (Figure 2).

Too often, however, the most impoverished sectors of societies are the most disadvantaged in their access to and use of POS, which in turn is associated with problems such as obesity, poor physical and mental health and social disadvantage (De Vries et al. 2003; Gies 2006; Maas et al. 2006; MacIntyre, MacDonald, and Ellaway 2008; DHHS 2015; Butler

Figure 1. Part of the 'Emerald necklace' park system consisting of a 1,100 acre (450 ha) chain of linked parks and waterways in Boston and Brookline, Massachusetts, USA designed by Frederick Law Olmsted, who conceived it as a linear park of walking paths along a gentle stream. There are opportunities for cutting short longer walks if the need arises. There is excellent connectivity under the bridge on both sides of the stream. The paths on both sides are paved, but note the parallel desire line tracks made by runners and walkers. In other places, roads and low bridges obstruct the connectivity of this POS.

Figure 2. Part of The Tan running and walking track that provides 3.8 k of connected walking and running space around the Royal Botanic Gardens Melbourne, Australia. The sand track provides a low impact surface for users, and is illuminated for early morning and late night use. This track also provides access to an extensive system of city trails, but only after a major road is crossed.

2016; Braubach et al. 2017; Lamb et al. 2019). Even when POS is available in sectors of cities of lower SES, it may be less frequently used by residents due to perceptions of danger, poorly maintained or vandalized POS or a lack of social cohesion and networking (Bates and Santerre 2001; Astell-Burt and Feng 2016; Braubach et al. 2017). There is also evidence that greater health benefits may accrue to lower SES communities from the provision and use of POS and that provision of POS could be a mechanism for addressing SES related inequality (Gies 2006; Mitchell et al. 2015; Braubach et al. 2017). Connected POS over a longer linear distance provides increased proximity and greater accessibility to the space and opportunities for a more diverse range of activities. The public health issues and lower SES affecting the northern and western regions of Melbourne place added burdens on the public health system, particularly as the population ages, which add to the importance of the provision of connected POS in these parts of the city (DHHS 2015; ABS 2018; Lamb et al. 2019).

The proximity to open space influences its use and the recreational, health and other benefits that people can derive from using the space (Ahendt 2004; Giles-Corti et al. 2005; Cohen et al. 2007; Astell-Burt and Feng 2016). For the purposes of this paper, the term proximity describes a simple concept which is nearness in space and it can be quantified by a simple linear measurement of the closeness of a site (home, office or school) to POS – it is not to be confused with connectivity. There is little doubt that most people want to have proximity to open space (Ahendt 2004; Giles-Corti et al. 2005; Cohen et al. 2007), which usually means that they want to be able to access POS by foot within 500–1000 m of their home, and preferably without major obstacles such as freeways, waterways or railway lines blocking access (Giles-Corti et al. 2005). Well planned and connected POS may contribute to both the proximity and accessibility of the open space and facilitate its greater use.

Proximity, accessibility, connectivity and POS

While this paper focuses on the physical aspect of connectivity, the impact of accessibility and proximity on connectivity are acknowledged. There is considerable research on aspects of proximity, accessibility and connectivity to POS showing that they are related and interconnected. Accessibility is a multidimensional construct, not just a matter of physical distance from open space that is affected by variables such as SES, educational background and population density among other factors (Wang, Mateo-Babiano, and Brown 2013; Mehta 2014; Lamb et al. 2019). Connected POS only achieves its purposes and functions when people access and use it and so the Victorian Department of Health has a policy that involves increasing the rate of active and/or passive recreation by between 1 and 2%, which will reduce the State's annual health costs by AUD$234 million (Dedman 2010). To achieve this aim, one of the department's goals is to provide appropriate shaded POS and there is a particular focus on the disadvantaged parts of Melbourne's north and west (DHHS 2015).

The term connectivity has a variety of meanings in different disciplines and contexts. In ecology, the term niche, which includes but is much broader than the concept of habitat, is impossible to define completely, while habitat is relatively easily defined and measured as the physical space that an organism occupies (Ricklefs and Miller 2000). Similarly, when dealing with open space, accessibility is a broader concept that includes proximity, but also evokes all of the factors such as education and SES, personal health and population density that affect a person's use of POS. Accessibility is very difficult to define and measure completely, but connectivity can be readily defined and measured (Wang, Mateo-Babiano, and Brown 2013; Mehta 2014).

The biological and ecological use of the term connectivity relate to the web of interconnected habitats and ecosystems and to claims that connected systems are more sustainable and managed more efficiently than isolated systems (Taylor et al. 1993; Hilty, Lidicker, and Merenleder 2006; Coutts 2012). However, in this context too defining precisely what connectivity means has proved difficult and various measures have been developed. Patch cohesion index (no units but increases with greater connection), connectance index (expressed as a percentage with 100 being when all patches are connected), and wildlife corridors (classified by their width in metres or by the width: length ratio with wider corridors being utilized by more species) have been used to express connectivity. In landscape ecology, connectivity may also pertain to biodiversity, cultural or natural values (Costa and Soares 2009). At the level of the individual, different people may connect with POS in many ways and an individual may connect to POS in multiple ways.

Transportation Network analysis also uses a connectivity index, which measures the relative connectedness within a transportation network. It is a measure of connectedness within a system regardless of distance with a high index value meaning there is high accessibility and low isolation. The higher the index value for a node within a transport system the more connected it is. Like the measures of ecological connectedness, it is useful for its specific purpose by those expert in the discipline, but it has little relevance to planning connected POS to achieve a specific function. These measures of connectivity in other disciplines often involve complex calculations and are difficult for multi-disciplinary users to comprehend or for decision-makers such as government officials to interpret.

The confusion as to what is meant by connectivity in urban landscapes can be illustrated by the following definition used in a planning context: the directness or ease of travel between two points that is directly related to the characteristics of street design (Saelens, Sallis, and Frank 2003). Sometimes the term connectivity is used to include ingress, but people gain access to POS in various ways. Some people will enter the POS through designated entry points but others may ingress by jumping a fence or following a waterway. Some people will connect with the POS from their vehicles as they drive to work and a lucky minority might gain access from their kitchen windows as they prepare a meal. The fact that connectivity can have a variety of meanings in an urban landscape context means that it is possible that multiple objectives, such as those related to ecology, culture, recreation or human health may be realized intentionally or by chance, if such places are properly planned and managed (Wang, Mateo-Babiano, and Brown 2013).

It is clear that users of connected space are aware of connectivity and that extensive connected open space encourages greater usage and is given as a reason as to why people use the space (Coutts 2012). The perception of a more extensive connected open space can also contribute to the user's sense of satisfaction with the space and increase both the frequency and extent of use of that space (Wang, Mateo-Babiano, and Brown 2013; Mehta 2014). Therefore, in the urban planning context, the term connectivity may be considered to be multidimensional too, embracing ecological, social, economic or environmental values (Wang, Mateo-Babiano, and Brown 2013; Mehta 2014; Braubach et al. 2017; Lamb et al. 2019).

While this paper appreciates and addresses some of the issues that are related to the use of the terms accessibility and proximity as necessary, its focus is upon physical connectivity in relation to POS, and more particularly the connectivity of parks, gardens, linear parks along rivers and streams and remnant forests, and their role in human recreational activity. It considers the wants and needs of people who are already using POS. It takes this approach due to a particular interest in recreational use of POS and the needs that such use place upon a more extensive and uninterrupted connected POS than often currently exists. It defines connectivity and relates its meaning to specific functions and activities and the length of connected POS to fulfil those functions allowing better use of the space. In taking this approach, it is hoped that planners will anticipate the needs of future generations for connected, functional POS rather than having to adopt expensive retro-fitted connections.

In this paper, the word connectivity is used to provide a measure of uninterrupted and unimpeded connected POS for travel by foot, wheelchair, skateboard, scooter, roller blade or bicycle. There are no obstructions to those using the connected pathways and the degree of connectivity can be measured linearly as the maximum distance that can be travelled without retracing your steps or the course in the same direction. Units of measurement are important as they can influence human perception and understanding of distance (Tischendorf and Fahrig 2000). For example, the unit of measurement for proximity should be the metre, as it indicates that access to POS should be over a relatively short distance. On the other hand, the unit of measurement for connectivity should be the kilometre as it conveys the need for an extended and interconnected space.

Methods

The desired degree of connectivity should not be determined arbitrarily, nor should it be the result of using available space that has been left after other uses and functions have been fulfilled. The concept that business structures should relate to their function has been extended to other aspects of human endeavour, so if enterprises are to succeed then structure should follow function (Chandler 1962; Galbraith 2012). Thus, the structure of connectivity should relate to its function, and so will vary according to the different needs and wants of users. However, it is not difficult to determine what some of these might be both now and for the future. In general, the minimum distance of connected open space for a particular function should not be less than half that required to perform the function for an out and back course (Connected Distance = 0.5 x Distance required to meet function).

In relation to walking, 20 people were timed walking over distances from 2–5 km. Walkers were recruited as they walked in Brimbank Park – a large park situated in Keilor a suburb located in the west of Melbourne – which contains a number of walking and cycling paths and circuits. All walkers were adults and there was an even mix of genders. Most but not all walkers came from the western region of Melbourne. Twenty people were chosen as this gave a good estimate of walking speed and an indication of surface preference. While walking speed varied according to height, age and distance among other factors, the average speed was just under 5 km per hour which was rounded to

5 kmhr^{-1}. Participants in this part of the work were asked how long they intended to walk for or what distance they wanted to cover and whether they had a preferred surface for walking. Nearly all walkers suggested a time as their goal, but a couple suggested distances. The most common durations nominated were half an hour or a full hour and the distances were from 2–5 km. These data allowed a calculation of the minimum connected space required for a walk that did not require retracing the course.

The same questions were put to 20 parents using connected POS for walking with infants and toddlers. The parents were recruited by contacting five different families from different regions of Melbourne with children under 2 years of age and then asking for information from four members of their friendship groups also with children under two. Twenty people were chosen for the same reasons as for the walkers, but there were more responses from females than males. It is worth noting that parents taking babies for a walk or a sleep in prams/strollers were often looking at a period of activity of between one and one and a half hours rather than at a distance to be traversed. They were generally walking at slightly below average walking speed of 4 kmhr^{-1}and preferred an option of cutting the circuit short if the need arose. Walking with young children (toddlers) was a more difficult calculation as walking in a circuit might not be what eventuates, but since walking speed was approximately halved some estimates of distance travelled were made.

For those using connected POS for running, 30 participants were asked the same questions as for the walkers about time, distance and preferred surface. All runners surveyed were registered with the Victorian (Australia) State Athletics Association and their abilities ranged from near elite to average regular running level. They came from different regions across Melbourne with a majority from the northern and western regions of the city, and 30 were sought because of a wider range of speeds. The times and distances nominated by these athletes varied according to their competition interests and training requirements. For most non-elite runners, the pace may be time and distance dependent, with the longer and further the distance the slower the speed and so an average pace of 10 kmhr^{-1}was utilized in this study. The estimates of distances and durations required provided a good indication of the connectivity of POS needed to meet the demand.

The variations in cycling for distance and duration were too great to be considered in detail in this paper. Accordingly, the needs of road and mountain cycling, which are better catered for elsewhere than in urban POS, were not considered, but recreational level cycling needs were modelled. Distances of 20–40 km were nominated by 30 recreational cyclists at a pace of 20 kmhr^{-1}which would be a safe average speed of travel but some suggested a faster pace and so 30 kmhr^{-1} was also modelled. The cyclists were recruited through their contact with members of a large athletic club situated in the western suburbs of Melbourne, but were not competitive cyclists and 30 were sought for the same reasons as the runners.

For skateboarding, the range of speeds was wide as there were commuting, recreational and speed focused skateboarders. The same variation in speed applied to those using scooters and roller blades, but typically scooter speeds were up to three times faster than walking. The estimates of speed for everyday, as opposed to elite or competitive users of skateboards, scooters and roller blades ranged from 15–30 kmhr^{-1}. Twenty participants were sampled equally from Brimbank Park in Melbourne's west and from the Yarra River Trail in Melbourne's east.

There is a temptation to think that if you meet the longest need for connectivity then you automatically meet all needs. However, this is not necessarily the case. Long, linear loops such as those along rivers, canals or in some instances freeways and railway lines need to have crossing points. The crossing points should also be located, where possible, at distances that are appropriate to the shorter requirements. To facilitate an understanding of the connectivity that can be achieved by the permutations available in multiple connected figure-eight type circuits, the combinations of up to six connected loops were calculated.

Results

The average pace for walking of 5 km/hr meant that if people wished to walk for half an hour, a circuit of 1.25 km would suffice and to walk for an hour a 2.5 km circuit would be required (Table 1). People walking with prams/strollers and toddlers would need a minimum circuit of about 4km, preferably with the option of cutting the circuit short if the need arose. The walkers expressed a strong preference for paved over unpaved surfaces, but did not distinguish between paved surfaces (Table 2).

For runners, both the pace and distance varied (Table1). A distance of 5 km or a half an hour of running at 10 km/hour requires an out and back circuit of 2.5 km, while for a marathon of 42.2 km, a 30 km training 'long run' requires a 15 km circuit (Table 1). Although unsolicited, several of the runners requested an accurate 400 m circuit for speed work or interval training. The runners had a mixed view of surfaces. Many had a preference for a paved surface with bitumen preferred over concrete, but for those running in excess of 20 km, and in particularly those over the age of 50 years, a smooth but softer unpaved surface was preferred (Table 2).

The connected POS requirements for three cycling distances and durations were calculated (Table1). The surface preferences of cyclists (Table 2) were for a smooth all season path and while a paved surface was preferred by most, some preferred an

Table 1. Length of connected open space required for a range of activities.

ACTIVITY	Distance (km)	Time (hr)	Pace (kmhr^{-1})	Required connected length (km)
Walking	2.5	0.5	5	1.25
	5.0	1.0	5	2.5
Walking with toddlers	1.0	0.5	2	0.5
	2.0	1.0	2	1.0
Walking pram/stroller	2.0	1.0	4	1.0
	6.0	1.5	4	3.0
Running recreational	5.0	0.5	10	2.5
	10.0	1.0	10	5.0
Running half marathon	20.0	2.0	10	10.0
Running marathon	30.0	3.0	10	15.0
	40.0	4.0	10	20.0
Cycling	20.0	1.0	20	10.0
	30.0	1.0	30	15.0
	40.0	2.0	20	20.0
Skateboarding/roller blading/scooter	15.0	1.0	15	7.5
	30.0	2.0	15	15.0
	15.0	0.5	30	7.5

Table 2. Surface preferences (%) of users of connected open space required for a range of activities, (N is the number of participants).

		Surface preferences				
			Paved			
ACTIVITY	N	Smooth	Bitumen	Concrete	None	Unpaved
Walking	20	75	15	15	45	25
Walking with toddlers	20	100	15	25	60	0
Walking pram/stroller	20	100	40	40	20	0
Running recreational	30	80	13.3	6.7	60	20
Running half marathon	30	75	20	13.3	33.3	33.3
Running marathon	30	60	40	6.7	13.3	40
Cycling	30	90	30	26.6	33.3	10
Skateboarding/roller blading/scooter	20	100	35	35	30	0

Table 3. Variations on multiple connected circuits of a figure 8 type.

Number of loops	Number of variations	Notes on circuits using the formula 2^n, where n is the number of connected loops.
1	2	Travel in reverse direction
2	4	Travel in reverse direction in different combinations
3	8	Travel in reverse direction in different combinations
4	16	Travel in reverse direction in different combinations
5	32	Travel in reverse direction in different combinations
6	64	Travel in reverse direction in different combinations

unpaved surface. For skateboarding, scooter use and roller blading, the wide range of speeds made it impossible to consider all of the possible permutations. So high speed and lower speed scenarios over two different distances were modelled (Table 1). All 20 participants nominated their preference for a smooth paved surface (Table 2).

Multiple figure-eight or looped configurations increased the number of different possibilities enormously. The general formula for the number of variations that can be obtained from interconnected circuits is 2^{n}, where n is the number of loops. So for a single circuit there are only two variations based on travelling in different (opposite) directions, but for four connected loops there are 16 variations possible (Table 3).

Discussion

Provision of connected POS

While the distances required to effectively undertake the activities explored in this paper (Table 1) seem unattainably long, they are required for populations living in cites now, but even more importantly in the future. The average pace for walking of 5km/hr was consistent with other calculations of walking speed (Bohannon 1997; Carey 2005) and people tend to walk slower under an increased load such a walking with a pram/stroller or carrying a young child (Kong and Chua 2014). For the other activities there is a much wider range of paces and distances to consider. Skateboarders can reach speeds in the vicinity of 100 $kmhr^{-1}$ (Fang 2018) and typically scooter speeds can be up to three times faster than walking (Anonymous 2015). For these and other activities, such as running and cycling, there is also the likelihood that the faster you go, the shorter the circuit required. Long distance runners and cyclists require longer circuits (Table 1), but fortunately their needs are similar – a circuit of between 10 and 20 km.

Figure 3. A connected POS of approximately 2 k in Shenyang, China. The bridge in the distance is a crossing point, but the road crossing it represents an obstruction as it prevents access to a similar circuit on the other side of the road, which would double the connected POS circuit.

Figure 4. An old cast iron traffic bridge re-purposed as a user-separated crossing point for bicycles (centre) and pedestrians (paths on either side).

Recreational and health needs are not going to diminish in the years ahead; indeed, they are likely to increase. The impetus for increased connected open space is likely to be economic – the increased health costs of populations where obesity is already a major problem, compounded by the effects of an ageing population (Astell-Burt and Feng 2016). The question that immediately arises is, 'How can such lengthy POS connectivity be achieved?'

One of the more obvious places for providing long and unimpeded connectivity would be along waterways by making sure that there is access for passive recreation as part of any and all bridges that span the river for roads or railways (Figure 3). This can be relatively easily and cost-effectively done at the time of construction or renovation (Figure 4), but it is very difficult and often prohibitively costly to do retrospectively (Figure 5). Similar opportunities exist along some freeways and railway lines, especially when there are bridges present for roads or waterways. Their value, particularly in terms of cycle and long distance running access, should be fully realized as the energy savings and health benefits associated with more accessible cities for cyclists, runners and pedestrians become established (Dill 2004). It is far more cost effective to implement the connection of POS in anticipation of need rather than being forced to retro-fit under the pressure of subsequent demand.

One common and sometimes recurring obstruction to connectivity for some users is steps which are not a barrier to all walkers, but can be to cyclists, runners and skateboarders, roller bladders and scooters (Figure 6). In many places over recent years, ramps have been incorporated into designs for disabled access and these could afford opportunities for runners, cyclists and skateboarders, but frequently the design accommodates only a single purpose or user group. With a little more thought, all users could be satisfied. When retro-fitting into older, perhaps historic sites, it is interesting to note that when a portion of the step system is ramped to allow people to push bicycles up and down the steps, the ramps are used by cyclists, runners and skateboarders. While there are obvious

Figure 5. A retro-fitted pedestrian/bicycle tunnel under a major urban road linking two sections of public open space previously obstructed by the road, Essendon, Victoria Australia. The cost of providing the tunnel was many times higher than if it had been built at the time of road reconstruction, approximately 20 years earlier.

Figure 7. Part of the Capital City Trail, Melbourne, showing directional pedestrian and cycle lanes and barrier protection near the river where the trail curves under an old road bridge. The trail provides over 20 k of connected open space without obstruction and has many crossing points as it follows the river.

Figure 6. The possible obstruction of connected POS by steps on the banks of the Spree River in Berlin is relieved by a ramp on part of the steps. This is a simple, cheap and effective way of dealing with obstruction to connected open space for some user groups.

safety issues associated with the use of such ramps, runners and skateboarders argue that using the ramps is safer than using the steps.

Other limitations to the use of even well-connected open spaces can be the absence of basic facilities such as toilets and access to drinking water which present an effective barrier to the use of the whole connected POS. When considering hydration, variables such as age, gender, weight, ambient temperature and exertion need to be considered (Position Stand 2007). However, a general recommendation that an exercising athlete such as a runner may need hydration every 20–30 min (Position Stand 2007), suggests that in warmer climates, provision of drinking water every 5 km for an extended connected open space would be sensible. Proper signage and distance markers are also required, as many users need to know not only the distance that they have traversed but the distance available in front of them so that they can plan the length of their activity and estimate the time that it is likely to take. The presence of shade over hot summer months can also improve the experience of using the open space by lowering the ambient temperature and so expand both the extent and frequency of use of the space (Butler 2016).

While there are a number of features which allow connected POS to be enjoyed by all users, the separation of activities utilizing connected open space needs to be considered. Unnecessary separation can be costly and so while shared use is often both desirable and practical, it is not always preferred or perhaps possible for the full length of the connected space (Figure 7). The benefits of shared use include lower cost, higher usage rates and a greater sense of safety due to the 'safety in numbers' phenomenon. Separating cyclists from pedestrians and those going in the opposite direction is often easily done with a dividing line on a paved surface, or by the rules of keeping to the right/left. However, if there is a need to separate cyclists from pedestrians and skateboarders most of the risks and hazards can be dealt with by separating traffic in key places, such as sharp bends, atop rises, through tunnels and across bridges (Dill 2004).

Circuits and surfaces

The materials from which the paths of POS are made vary depending on climate, soil type, usage and risks such as fire or flooding. Different surfaces may either facilitate or act as a barrier to use. Surfaces need to be durable, long wearing and non-slip, but the same surface does not necessarily meet the needs of all users. A softer material such as gravel or granitic sand (sometimes mixed with the site soil) is often preferred by runners as it has a lower impact than concrete or bitumen paving and is less likely to cause knee and ankle injuries. Long distance runners will often travel considerable distances to take their 'long run' on these softer tracks. In parks and along pathways, it is interesting to see how often there are desire-line tracks parallel to paved surfaces made by runners with a view to avoiding the harder surfaces and in some cases shortening the route (Figure 8). They are testament to the need for walkers and runners to have a softer surface, and to the fact that this need is unmet. Such surfaces may also be preferred by cyclists who ride to a mountain or trail bike format, but harder surfaces are preferred by skateboarders and road/track cyclists.

Other users may prefer paved surfaces of bitumen or concrete for all season usage. In some places, such as along rivers and streams or along railway lines, it may be possible to meet both requirements by paving one side of the river or tracks and leaving the other unpaved. It is worth noting which surfaces last longest and are the least expensive to maintain (Figure 9). While there are too many variables at play to generalize about such matters in this paper, in one case study of a Melbourne riverside pathway which had concrete, bitumen and compacted granitic sand sections. Bitumen proved superior to concrete, as the latter tended to lift and crack due to the reactive clay soils of the region and occasional flooding events. For parts of the track that were exposed to several flooding

Figure 8. Unofficial "goat" tracks may reflect user desire lines, but they can also express user preference for a softer surface, especially for running – Englischer Garten, Berlin, Germany.

Figure 9. A smooth transition from a concrete to a granitic sand trail that forms part of the River Trail along the Maribyrnong River, Melbourne.

Figure 10. A popular riverside path blocked by poor drainage after heavy rain. The same can occur after flash flooding of paths.

incidents, the granitic sand track survived best and was restored to full use quickly with relatively inexpensive grading.

Connected circuits have the advantage that you can take them in different directions. It is amazing how different the user experience can be when the same path is taken, but from the opposite direction. New things are seen, view points are different and there is even a different sense of distance travelled. The multiple sections of the 'Emerald necklace' system of parks in Boston, increases the number of different possibilities enormously. The formula 2^{n}, where n is the number of loops, shows how readily different configurations can be achieved and such circuits meet the needs of parents who are pushing prams/strollers or walking younger children and who may need to shorten their activity.

It is also worth considering other aspects of useful amenity when developing a system of extensive connected open space. Provision of benches for resting at appropriate distances, especially for younger and older users, and in numbers suitable for the volume of user traffic will facilitate use (Astell-Burt and Feng 2016). Lighting can both extend the time of usage and greatly improve the sense of user safety early in the morning or later into the night. The widespread availability of mobile phones has greatly reduced the need for emergency telephone access in most urban settings, but there are still places where mobile reception can be poor.

Extreme weather events, either seasonal or occasional; may also need to be considered. Flash flooding can impose a barrier to connected POS and pose considerable danger, especially to children. Drainage that prevents flooding and improves user safety is often a necessity (Figure 10). In some hotter climatic zones, the possibility of wild fires occurring in connected POS must be considered for user safety and as a potential risk of fire spreading from the POS and posing a hazard to life and property.

While it is beyond the scope of this paper to discuss the width of paths and tracks in detail, width does vary according to intended use. In this paper which considers individual, as opposed to mass participation event use, the minimum width of paths should be 2.0 m which allows for safe and comfortable passing by foot, wheelchair, skateboard, scooter, roller blading or bicycle (Austroads 2009). The minimum width, however, also depends on the number of users and the speed of travel and so widths of between 2.4 and 3.0 m are common (Austroads 2009). In Melbourne, width of paths is often 2.4–3.0 m which allows emergency vehicle, particularly fire fighting appliance, access. The width of paths used in this study varied with some being as narrow as 1.5–2.0 m; sometimes due to poor maintenance. For mass participation events such as 10 km, half marathon and full marathon runs or cycling races the required width depends on participant numbers with many events conducted on roads. For up to 1000 participants a minimum with of 7.0 m is required for the first 1.0km, but thereafter 3 m will suffice. In Australia 7.0 m is the minimum width of a two-way street Austroads (2016). For running events of greater than 1000 participants or which involve cycling and higher speed, wider paths are required for safety (Austroads 2016).

Conclusion

In many other disciplines, connectivity is a term that is clearly defined and used with a metric. This paper proposes that for recreational POS, connectivity should refer to linear distance that is unimpeded or unobstructed, which is measured as linear kilometres and that long circuits of up to 20 km are required to meet user needs. In urban planning, a key objective of POS should be aiming for improved and extensive connectivity for specific purposes for future generations of city dwellers. Planning must also aim to achieve the maximum possible connectivity for new urban works and when renovating older infrastructure where connectivity has not been previously considered.

For future generations, the health needs of urban populations are going to be major drivers of urban design and planning. The capacity for increased and meaningful active and passive recreation over long distances will be the hallmarks of sustainable and liveable cities. Appropriately long circuits of connected POS are going to be essential urban infrastructure under conditions of increased urban populations and climate change, not as a luxury for a privileged minority, but as a vital component of a sustainable economy for the majority and a right of all citizens. Connectivity of POS is not an option but essential as societies cannot afford it to be otherwise!

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