Geospatial Automation of Ground Subjective Surveys

A Case Study of the Public Open Space Tool (POST)

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Abstract

Background: Public open space (POS) with high quality environments and amenities attract more people and provide many benefits. Hence, maintaining the quality of POS is important in order to provide a better environment for the local neighbourhood. There are different ways to measure the quality of POS such as, a needs-based approach, the Systematic Pedestrian and Cycling Environmental Scan (SPACES) instrument, Geographical Information System (GIS) and Remote Sensing (RS). However, each approach has limitations. To streamline the collection of POS measures, this paper illustrates a new remote-assessment approach using feature extraction techniques to provide a quick and relatively inexpensive measurement of the quality of POS.

Purpose: The aim of the study was to examine the feasibility of automating the Public Open Space Tool (POST) using high resolution aerial imagery and feature extraction technology to increase the efficiency of data collection for a large number of parks in the Perth Metropolitan Area. This paper has two objectives: (i) Develop a set of routines using geospatial technologies to measure attributes of POS as an alternative to the subjective POST audit; and (ii) Compare the accuracy of feature extraction techniques with on-ground applications of the POST.

Methods: 39 parks were selected from the City of Stirling, Perth, Western Australia to assess feature extraction techniques, measure attributes of POS and compare results with those obtained from on-ground assessment of the same parks.

Results: The on-ground assessment of 39 parks took approximately 6 days whereas feature extraction technique took approximately four days. This study shows that feature extraction technique can provide rapid and inexpensive measures of the quality of POS for a large number samples in a short period.

Conclusions: Feature extraction technique provides a new and novel approach for audits conducted across multiple sites, or over large geographic areas, providing researchers with a rapid, convenient, cost-effective, and reliable method of assessing the quality of public open spaces.

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1. Introduction

As a result of urbanisation, the world's population has become increasingly concentrated in cities [(1)]. The Australian Bureau of Statistics (ABS) forecasts that Australia's population will rise to 35.9 million by 2050 [(2)]. In Perth alone, populations are projected to increase by nearly 70% by 2031 [(3)]. Perth also has the fastest rate of suburban growth among any city in Australia [(3)]. This projected population increase will necessitate the provision of development to meet residential needs. As cited by Burgess *et al.* (1988), new housing, commercial and industrial redevelopment schemes can destroy valued green spaces and diminish the quality of social life and sense of community [(4)]. The built environment can also have a significant impact on a person's level of activity [(5).] There is a strong relationship between people's overall health (mental and physical) and regular physical activity as low levels of physical activity will increase the risk of obesity and related diseases including diabetes, cardiovascular disease and cancer [(6)]. A large body of research demonstrates that public open spaces are a fundamental health resource, particularly in terms of disease prevention. The built environment is directly associated with physical activity which is important in reducing risk factors for cardiovascular disease. Physical activity is not just about 'health' or 'sport and recreation' but it has a triple-bottom-line impact with overall social, environmental and economic for the community [(5)].

Various literatures suggested that physical activity is influenced by different features in the environment. The quality of public open space is essential in providing a better environment for the local neighbourhood. Based on this evidence, interventions such as increasing access to natural settings have been made to improve the quality of life in neighbourhoods and cities [(7)]. Public open space (POS) and recreation service are now becoming an important part of the healthcare system. That the natural environment is a key determinant of health is now recognised globally; in fact, when there are parks close to where people live, these encourage the physical activity and provide better health for residents [(8, 9)].

1.1 Definition and Importance of Public Open Space

The importance of open space is widely recognised as land use planning systems are now considering environmental, social, economic, and culture development [(10)]. Taylor *et al.* (2011, p. 106) defined POS as 'space that people can access legally, including vacant lots,

playgrounds, and public gardens'. According to Timperio *et al.* (2007, p. 336)[11], POS also comprises 'state government managed reserves, other managed reserve, parks with water reservoirs, reserves or parks, open space not officially recognised as a reserve or parks (including foreshores), scouting associations, and sporting or recreation spaces (including golf courses)'. More specifically, in Perth, Liveable Neighbourhood (Edition 2) from the Western Australia Planning Commission (WAPC) defined POS as 'land used or intended for use for recreational purposes by the public and includes parks, public gardens, foreshore reserves, playgrounds and sport fields' [12].

Despite the variety of definitions associated with POS, there are nevertheless commonalities. Overall, POS are identified as parks, public gardens, foreshore reserves, playgrounds, natural reserves and sporting fields that offer important opportunities for sport and recreation. The City of Stirling, representing a portion of the Perth metropolitan region and the study area for this research, defines POS in its Public Open Space Strategy as 'open developed and undeveloped areas, such as parks, reserves, wetlands, bushlands, coastal reserves and special purpose open spaces' [13]. It is this particular definition of POS that is used in this study.

In Australia, POS is the third single most utilised venue for physical activity after street and home [14]. In this regard, it is important to make sure that there are enough parks and POS in new housing development to provide a better environment for local neighbourhoods. WAPC mandates that ten per cent of the land in new housing developments must be allocated to public open space [12]. POS not only provides a location to engage in physical activity, but increasing empirical evidence indicates that the presence of public open space in urban contexts contributes to the quality of life in many ways such as reducing stress, enhancing contemplativeness and providing a sense of peace and tranquillity [15]. POS also plays multiple roles in making cities more sustainable and pleasant by providing environmental benefits, social benefits and economic benefits [16] (Figure 1).

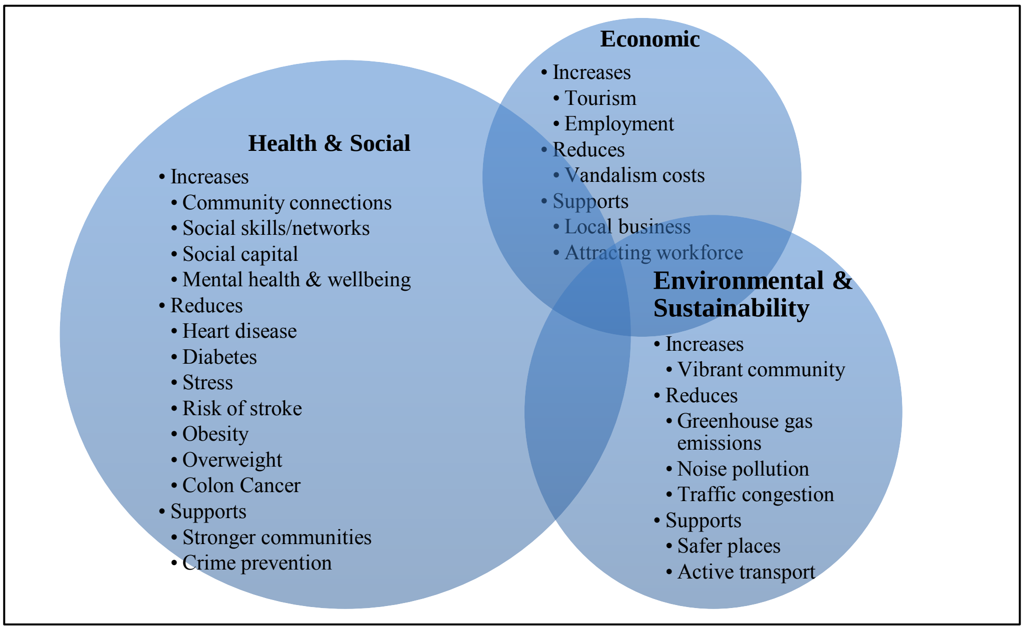

Figure 1 The triple-bottom-line benefit of POS [5]

1.1.1 Public Health Benefits

In Australia, nearly half of all Australians do not meet the daily recommendation of 30 minutes of physical activity [17]. Improving physical activity levels and the use of POS have been consistently identified as the top public health priority to reduce premature mortality and prevent chronic disease such as diabetes, obesity and hypertension [6, 18]. The active use of POS or parks may reduce stress, feelings of anger, frustration and aggression [15, 19]. Furthermore, exposure to natural environment can improve people's health and well-being by providing restoration from stress and mental fatigue and enhancing the feelings of social safety through reduction of actual rates of aggressive behaviour and criminal activity [19]. Consequently, POS plays an important role in encouraging physical activity, which leads to improvement in mental health, physical health and wellbeing.

1.1.2 Environmental Benefits

Environmental benefits of POS are provided through the attenuation of 'heat island' effects, air filtration, noise reduction, sequestration of carbon, and the attenuation of storm-water [16, 18, 20]. Trees within POS act as natural air conditioners keeping cities cooler, mitigating the effects of concrete and glass that increase heat under the summer sun [20]. Moreover, appropriately located POS can buffer the impact of humans on vegetation and wildlife by protecting habitats and breeding grounds [21].

1.1.3 Social Benefits

Aesthetically, POS provides a context for social interaction and serves as tangible reminders of childhood and memories of community life [22]. They also offer 'gateways' or opportunities for people to escape from the stresses of urban life, making inner-city neighbourhoods more liveable [4]. Access to POS has been strongly linked to reductions in crime and in particular, reductions in juvenile delinquency [20].

1.1.4 Economic Benefits

Recently, researchers found that POS also provides significant economic benefits by enhancing property values, increasing municipal revenue, and attracting homebuyers, workers and retirees [23]. In fact, many people are willing to pay high property prices for residences located close to parks or open spaces when compared to homes that do not offer this amenity [16, 20, 23]. POS often becomes one of a city's signature attractions and a prime marketing tool to attract tourists, conventions and businesses. Furthermore, organised events held in public open space or parks often bring substantial positive economic impacts to their communities, filling hotel rooms and restaurants and bringing customers to local stores [20].

1.2 Attributes of Public Open Space

Numerous factors influence the use of POS, including the quality and quantity of space; characteristics of potential users (such as age, gender, socioeconomic status and ethnicity); psychological factors (e.g. self-efficacy, perceived barriers); the match between park attributes and needs of local users; park maintenance; access to competing local facilities; and perceived safety [14, 24]. For example, litter, the sign of vandalism and lack of management can give the feeling that sites are potentially unsafe, which in turn, reduces public use [25]. Giles-Corti *et al.* (2005)[14] argued that distance from home to POS influences the frequency of use and type of usage. As work hours increase, it is important to provide easily accessible POS as people do not have time to visit remote regional parks for contact with nature [3]. Moreover, POS and parks are more likely to stimulate activity if they are aesthetically pleasing with tree-lined paths rather than empty expanses [6].

Badland *et al.* (2010)[24] argued that safer POS have more street visibility and greater surveillance from surrounding houses, lighting and controlled pedestrian crossings. In examining the relations between neighbourhood socio-economic status and features of

POS, Crawford *et al.* (2008)[26] found that POS in neighbourhoods with high socio-economic status possessed more amenities (e.g. drink fountains, picnic table), walking and cycling paths, trees that provide shade, water feature (pond, creek), lighting, and signage regarding dog access. Meanwhile, neighbourhoods with lower socio-economic status had a greater level of incivilities such as, litter, broken glass, evidence of alcohol use, and graffiti or tagging.

Golicnik & Thompson (2010)[27] argued the importance of understanding weather in relation to the individual's use of POS. Their study pointed out that weather condition (temperature, wind, dryness and sunshine) influenced the amount of people using the POS as people tend to stay indoors or restrict outdoor activities during higher temperatures. Hence, it is important to consider all attributes, such as material selection, use of vegetation, shade provisions and urban geometry when designing a public open space.

1.3 Measuring the Quality of Public Open Space

The quality of POS has traditionally been assessed through a needs-based approach. This approach considers the socio-economic and bio-physical characteristics in the surrounding area of the POS [16]. A needs based approach assumes that people will minimise travel costs (e.g. time, fuel cost and energy) by using the closest available resource [16]. The needs-based approach was based on detailed community surveys, focus group research, participant observation, ethnographic data, analysis of census data, and detailed assessments of existing parks [16]. However, this approach is considerably time consuming and resource intensive.

The School of Population Health, University of Western Australia developed an audit instrument called Systematic Pedestrian and Cycling Environmental Scan (SPACES). The SPACES instrument is based on features (the overall factors that summarise the physical environment); elements that influence each of those features (those factors that form the components of features); and factors that influence each element (i.e. those that have the potential to change or improve an element [28, 29]. The SPACES instrument was generally easy to use and was a reliable and practical instrument for collecting data. However, the usefulness of SPACES was limited by the need to visit each POS to observe and rate the physical environment. Clifton *et al.* (2007)[30] argued that the SPACES instrument was designed mostly for use in Australia because some of the features measured did not match the American context. For example, there is no differentiation between residential and

commercial driveways and there are no questions about the degree of enclosure or the setback of buildings on the street. In view of this, the question about number of road lanes was changed to include all driving lanes (turning lanes) in order to allow a better assessment of conditions at street crossings [30].

Focused on the study of SPACES, the Centre for Built Environment and Health (CBEH) designed an auditing mechanism called the Public Open Space Tool (POST) to assess the quality of public open space. The POST collects data from 46 questions with a total of 80 sub-questions in four areas – activities, environmental quality/aesthetics, amenities and safety [31]. The POST instrument is an improvement of SPACES and as noted by Pikora *et al.* (2002) [28], addresses the earlier limitations of SPACES which measured some items subjectively (i.e. the height of trees) and demonstrated poor reliability. As a methodological improvement, the POST has refined some of these earlier limitations by replacing items that were subjectively measured with those that could be obtained objectively, such as replacing tree height with canopy size [28]. However, using the POST required visiting each POS and individual assessment proved time consuming and subject to the interpretation of the data collector.

A new remote-assessment approach was introduced by Taylor *et al.* (2011) [32] to evaluate the potential of using Google Earth to provide fast and inexpensive measurement of the quality of POS. As a proof of concept, they used an area in the southwest of Sydney [32]. The study areas were assessed (with a shorter POST) with an initial viewing of satellite and aerial images of the entire space, followed by viewing of each successive Street View images around the edge of the space to assess visibility of its features. By using Google Earth, the time and resources required to conduct audits of POS were significantly reduced. However, whilst accuracy of attribute measurements was high, not every question in POST could be covered by using aerial image interpretation. As such, 14 items and one section of another item (i.e. visibility of surrounding houses from the centre of the POS) could not be assessed in this study reliably because of low image resolution. Some examples of the questions that had been removed relate to availability of dog litter bags and watering of grass. Furthermore, remote sensing using Google Earth is limited by the low image resolution. A further limitation is that the Google Earth images may be up to three years old which could affect assessment in spaces where redevelopment has occurred [32].

To address the limitations of the above method for measuring the quality of open space, this paper introduces a remote sensing technique of feature extraction to increase the efficiency of data collection for a large number of parks. In digital image processing, feature extraction use visual clues such as shape, size, pattern, tone (or hue), texture, shadows, site, association, colour, height (elevation) and depth to identify and characterise objects in an image [33-35]. Feature extraction is the process of generating features of interest which are used to computationally extract spatial objects from a remotely sensed image. Once extracted, each object is classified then allowing for the development of multiple layers of different objects for use in further GIS based spatial analysis [36]. The term 'feature' here refers to recognisable objects or structures in the image (e.g. vegetation types, urban materials, transportation features, land use/ land cover) with similar characteristics (whether they are spectral, spatial or otherwise) [23, 37-40]. Therefore, feature extraction aims to accurately retrieve these features and enhance the distinctness of surface materials based on their spectral characteristics [37, 38].

A particular range of the electromagnetic spectrum is sensitive to a particular feature on the ground, or a property of the atmosphere [41]. Table 1 lists the four spectral bands of imagery along with a brief summary of the intended principal applications of each.

Table 1 Spectral bands

Band	Wavelength µm	Nominal Spectral Location	Principal Applications
1	0.45 – 0.52	Blue	Designed for water body penetration, making it useful for coastal water mapping. Also useful for soil/vegetation discrimination, forest-type mapping, and culture feature identification.
2	0.52 – 0.60	Green	Designed to measure green reflectance peak of vegetation for vegetation discrimination and vigor assessment. Also useful for culture feature identification.
3	0.63 – 0.69	Red	Designed to sense chlorophyll absorption region aiding in plant species differentiation. Also useful for cultural feature identification.
4	0.76 – 0.90	Near Infrared	Useful for determining vegetation types, vigor, and biomass content, for delineating water bodies, and for soil moisture discrimination.

Source: (42)

As each object on the earth's surface has a particular spectral signature (Figure 2) and the whole electromagnetic spectrum is wider than the visible wavelengths seen by human, it is possible to produce images containing much more information than can be deduced with the naked eye [(43)]. The horizontal axis shows the wavelength of incident energy, which ranges from the visible into reflected IR spectral regions. The vertical axis shows the percentage of incident energy reflected at the different wavelength. The figure show that the spectral profile for sand is high throughout the visible bands (blue, green and red) while residential rooftop reflects relatively lower amounts if blue, green and red energy throughout the visible spectrum. The spectral profile for the golf-putting green exhibits all the characteristics of a well-calibrated hyper-spectral vegetation pixel. There is chlorophyll absorption in the blue and red portions of the spectrum and significant reflectance throughout the near-infrared region [(43)]. The reflectance in the middle-infrared bands in the region 1.55-1.75µm and 2.08-2.35µm is also strong. Remote sensing software uses classification algorithms to search all bands and classify things of interest [(41)]. Feature extraction techniques use the different reflectance of each type of land cover to classify forests, grasslands and urban developments [(41)]. Feature extraction techniques are not only rely on the spectral signal of individual pixels, but how pixels with a similar spectral signal are grouped together into recognizable features and how computer algorithms are refined to more accurately extract these features [(41)].

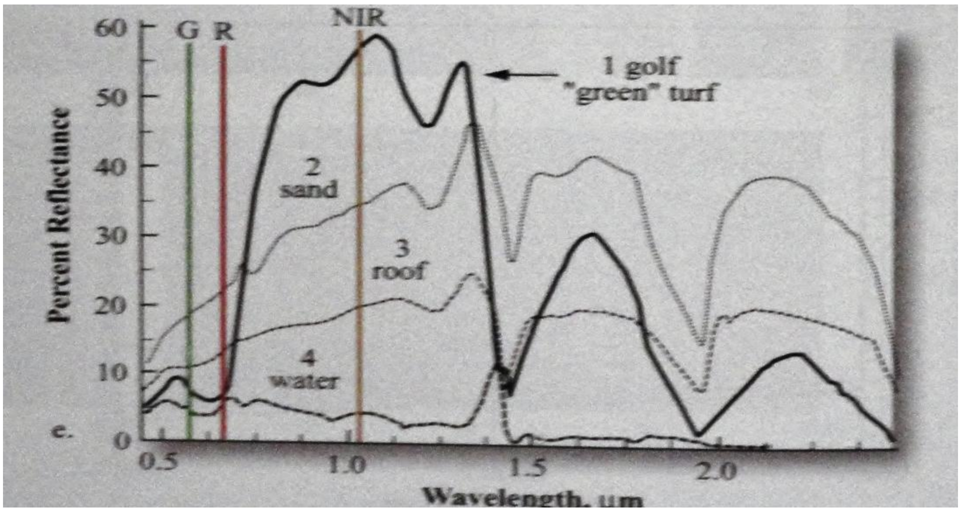

Figure 2 Spectral profiles of golf 'green' turf, sand, roof and water extracted from the bands of hyper-spectral data [(43)].

To achieve an effective analysis and information extraction of remote sensing data, it is important to rationally select features from various spectral channels in the optical

wavelengths of electromagnetic spectrum. Normalised Difference Vegetation Index (NDVI) is one of the most widely known remote sensing techniques used to examine vegetation health [43]. It is an important vegetation index that responds to changes in the amount of green biomass as the seasonal and inter-annual changes in vegetation growth and activity can be monitored and the rationing reduces many forms of multiplicative noise [43]. Therefore, the information quantity contained in a band is an important parameter in evaluating the band. There are several feature extraction techniques in remote sensing including Principal Component Analysis (PCA), Minimum Noise Fraction (MNF), the Independent Component Analysis (ICA), and Supervised Classification [37, 38, 44].

PCA transforms the original remotely sensed dataset into a substantially smaller and easier to interpret set of uncorrelated variables that represent most of the information present in the original dataset. It is very useful for reducing the dimensionality of hyper-spectral dataset [43]. MNF is a useful algorithm for reducing the dimensionality of hyper-spectral data and minimising the noise in the imagery [45]. MNF is used to determine the true or inherent dimensionality of hyper-spectral data, to identify and segregate noise in the data, and to reduce the computation requirements of further hyper-spectral processing by collapsing the useful information into smaller set of MNF images [43, 45]. ICA presents a linear transformation to obtain the independent components and each component will contain information corresponding to specific feature [37, 38].

Supervised classification is training closely controlled by the analyst. The identity and location of some of the land-cover types are known *a priori* through a combination of field-work, interpretation of aerial photography, map analysis and personal experience [37, 46]. In contrast to supervised classification, unsupervised classification is more computer-automated. The computer is required to group pixels with similar spectral characteristics into unique clusters according to some statistically determined criteria [46]. However, the quality of the classification is based on the analyst's understanding of the concepts behind the classifiers available and knowledge about the land cover types under analysis [42]. The approach (remote sensing technique of feature extraction) used in this study can overcome the problems of time-intensity and high cost of using the POST for both on ground audits and manual image interpretation using Google Earth. Once feature extraction rules have been developed, the approach can be applied in an infinite number

of parks (given image availability) in the time it takes to run the algorithm for each. Given the reduction in time, the approach could save considerable labour costs [47].

The quality of public open space is essential in providing a better environment for the local neighbourhood. To date, there had been several methods used to measure the quality of public open space, both manually and remotely – but each approach presents limitations. With advances in technology and the availability of high resolution multi-band imagery, there is an opportunity to improve current methods of assessing the quality of public open space. In acknowledgement of this emerging opportunity, this research aims to examine the feasibility of automating the Public Open Space Tool (POST) using high resolution aerial imagery and feature extraction technology to increase the efficiency of data collection for a large number of parks in the Perth Metropolitan Area. Towards this aim, this paper develops a set of routines using geospatial technologies to extract features from public open spaces as an alternative to subjective POST audit, and compares the accuracy of feature extraction techniques with on-ground application for the POST.

2. Methods

2.1 Study Area

The City of Stirling is dedicated to the good management of parks and reserves with mission of '**Creating quality lifestyle and sustainable development**' [13]. In 2008, the City developed the Public Open Space Strategy as part of a comprehensive strategic planning framework with the vision to create a network of resource efficient quality public open spaces across the City that will satisfy current and future recreational needs in an equitable and sustainable manner [13]. The City will establish a hierarchy of POS types of sufficient quantity and quality to meet community needs. To achieve this vision, the City is currently undertaking a program to develop a select group of parks to a suitable level for use by the local community [48]. The approach used in this study can help the City to overcome the limitation of time consuming and expensive labour cost in examining the quality of POS within the City.

2.1.1 Site Location

The City of Stirling (the subject site) is located approximately eight kilometres north of the Perth central business district (CBD), covering an area of approximately 100 sq kms and comprised of 31 suburbs (Figure 3). The subject site is bound by the Cities of Joondalup and Wanneroo in the north, the Cities of Swan and Bayswater in the east, the City of Vincent and Cambridge in the south with the Indian Ocean to the West. The City of Stirling is the largest local government authority in Western Australia, providing services and facilities for over 200,000 residents. It is predominantly residential, although industrial and commercial centres are contained within the City's boundaries. The population of the City has grown steadily over the last twenty-five years with an average annual growth rate of 0.91 per cent.

2.2 Selection of Public Open Space in Stirling

The City of Stirling contains more than 400 nature reserves and 50 major sporting facilities, which are more specifically classified as bushland, wetland conservation areas and coastal reserves [13]. The aerial imagery provided by Landgate is concentrated on the left of the City, defining the study area for this research (Figure 3). Of these, samples of 39 POS were selected from the 58 POS located in the study area.

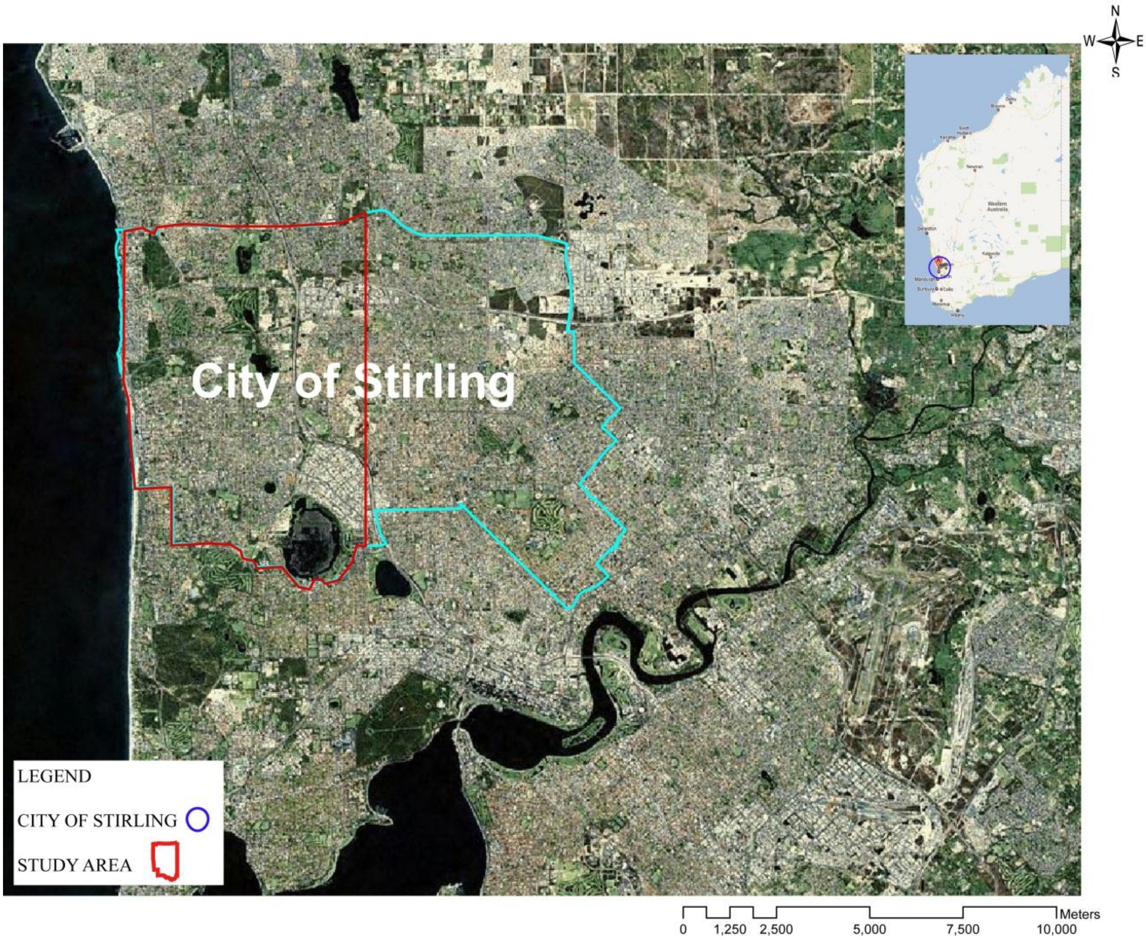

Figure 3 Map of City of Stirling and Study Area (Source: ERDAS Imagine)

A classification system has been developed to identify the different types of public open space within the City based on the Liveable Neighbourhood and Public Open Space Strategy (Stirling). The public open space has been classified into nine different categories (see Appendix B for details of classification and provision standards) with an average size of 21.3 ha (Standard deviation [SD] = 53.6). Table 2 provides a list of parks examined in this study classified according to the City of Stirling's POS classification system.

Table 2 Number of total and sample parks by category.

Classification	Total	Sample
Community	15	5
District	9	5
Foreshore Reserve/ Natural Conservation	5	5
Large Neighbourhood	9	6
Local	1	1
Medium Neighbourhood	13	11
Regional	3	3

Residual	1	1
Small Neighbourhood	2	2
Total	58	39

2.3 Data

2.3.1 POST

POST, an auditing mechanism, designed by the Centre for Built Environment and Health provided the basis for the feature extraction study. The POST, was designed with 49 questions – six concerning the identification of POS's location and 43 for examining the quality of the POS (see Appendix A for details). However, the POST was modified to enable use of aerial imagery in remote sensing technique of feature extraction. The extent to which each of the 43 questions in the POST could be collected by using remote sensing techniques of feature extraction was first assessed. There were 23 items that could not be assessed reliably because of the similarities of those types of features and the subtle differences that actually distinguish them apart cannot be inferred from the imagery (Table 3).

Elimination of these items resulted in a shorter POST instrument of 20 items (Table 4). Figure 4 presents the items used for each approach (e.g. on-ground assessment, Google Earth and feature extraction method). By using Google Earth auditing tool, 16 items were removed from the original POST. In this study, the remote sensing technique of feature extraction required the removal of 23 items; however, five of those items have been modified and two items have been added to the POST for use with aerial imagery. The time taken to rate the 39 parks was recorded from entry of work-space until departure from the computer work station.

Table 3 Items removed from the original POST and reasons for their removal.

Domain	**Feature Extraction**	**Reason (Feature Extraction)**
Activities		
1. Type of usage (tick all relevant)	REMOVED	
2. For what type of activities is the space designed? (tick all relevant) Tennis (grass/hard courts) Soccer Football Netball (grass/hard courts) Cricket Baseball Fitness Circuit Basketball/Netball Hoops Hockey Athletics Rugby	REMOVED *New item: Grassed Open Space*	Specific activities where undistinguishable
Environmental quality	**New item: Is the POS adjacent to bushland?**	
7. (a) Are there other aesthetic features in the POS?	REMOVED	
(b) Which of the following features are present? (Tick all relevant) Statues Gazebos/Rotunda Sculptures Bridge Rocks Ducks/Swans	REMOVED	These features cannot be distinguished from other similar features No way of reliably detecting wildlife through aerial imagery.
15. Are dogs allowed? (tick all relevant)	REMOVED	Dog access is usually shown on signage
16. Is access for dogs: Allowed for all areas Restricted from some areas Not specific	REMOVED	Dog access is usually shown on signage.
17. Is graffiti present?	REMOVED	Imagery provides a top down perspective and cannot distinguish features of vertical surfaces.
18. Is vandalism evident?	REMOVED	Difficult to collect with accuracy using aerial imagery.
19. Is there litter throughout the POS?	REMOVED	Difficult to collect with accuracy using aerial imagery.

Domain	Feature Extraction	Reason (Feature Extraction)
Amenities		
21. What items of play equipment are present? (tick all relevant)	REMOVED	It can visually be seen that one is there but cannot extracting it using image classification techniques. This is really due to the spectral heterogeneity of the features in a playground.
22. What is the playground surface? (Tick all relevant)	REMOVED	Very hard to detect reliably the difference between gravel or pebbles, woodchips and sand.
24. Are barbeque present?	REMOVED	Unable to extract these features due to the common spectral characteristics with other features
25. Are picnic tables present?		
26. (a) Are there parking facilities serving the POS?		
27. Are there public access toilets?	REMOVED	Difficulty in distinguishing difference between residential and public access toilet.
28. Is there a kiosk/cafe present?	REMOVED	It is possible to distinguish the buildings but hard to know what they are used for.
30. Is there seating present?	REMOVED	Does not have adequate resolution to determine the presence of this item.
31. Are there clubrooms/meeting rooms present?	REMOVED	It is possible to distinguish the buildings but hard to know what they are used for.
32. Are rubbish bins present?	REMOVED	Does not have adequate resolution to determine the presence of this item.
33. Are dog litter bags provided?		
34. In how many locations in POS are dog litter bags present?		
35. Are there taps or other water sources accessible for dogs?	REMOVED	Does not have adequate resolution to determine the presence of this item.
36. Are drinking fountains present?		

Domain	**Feature Extraction**	**Reason (Feature Extraction)**
Safety		
37. Is there lighting within the POS (i.e. not just street lighting)	REMOVED	Due to the spectral heterogeneity of the features, it can visually see that one is there but cannot extract it using image classification techniques.
38. Where is the lighting located? (tick all relevant)	REMOVED	Could be done if lighting could be extracted.
39. From the centre of the POS, how visible are surrounding roads? (Tick one)	MODIFIED *Number of roads within 20m buffer of the park*	Aerial imagery only provides a top down view of the park.
40. (a) From the centre of the POS, how visible are the surrounding houses? Clear visibility means you can clearly see windows, backyards, or front yards of houses overlooking the park? (Tick one)	MODIFIED *How many sides of the park are houses present*	Aerial imagery only provides a top down view of the park.
(b) How many of these houses overlook the park?	MODIFIED *Number of houses within 20m buffer of the park*	Aerial imagery only provides a top down view of the park.
(c) Is there any area of the POS where you are unable to clearly see surrounding houses?	REMOVED	Aerial imagery only provides a top down view of the park.
41. Are all rounds surrounding the POS minor roads or cul-de-sacs?	MODIFIED *How many sides of the park are roads present*	
42. (a) Does the major road/s have a zebra crossing to assist access to the POS? (b) Does the major road/s have a pedestrian crossing with signals to assist access to the POS?	REMOVED	Due to the speactral heterogeneity of the features, it can visually see that one is there but cannot extract it using image classification techniques.

Table 4 A condensed POST for use with feature extraction techniques.

Activity
1. For what type of activities is the space designed? (tick all relevant) Walking (only if path) Cycling Children's playground Grass Open Space
Environmental Quality
2. Is the POS adjacent to bushland?
3. Is the POS on the beach/river foreshore?
4. Are there water features in within the POS?
5. Type of water feature (tick all relevant)
6. Total water area of water feature
7. Estimate the percentage of the POS occupied by the water feature(s)?
8. Are there trees in this POS?
9. Estimate the approximate number of trees present
10. Where are the trees placed? (tick all relevant)
11. Are there gardens in this POS?
12. Are there walking paths within or around the POS? (tick all relevant) Shade along the paths?
13. Is there evidence that the grass is watered?
Amenity
14. Is children's playground equipment present?
15. Is playground shaded?
16. Is there access to public transport within one block of POS?
Safety
17. Number of roads within a 20m buffer of the POS
18. Number of houses within a 20m buffer of the POS
19. Are houses/roads present on all sides of the park? How many sides or the park are roads present? How many sides of the park are houses present?
20. How many houses are within a (e.g. 50m) buffer of the children's playground?

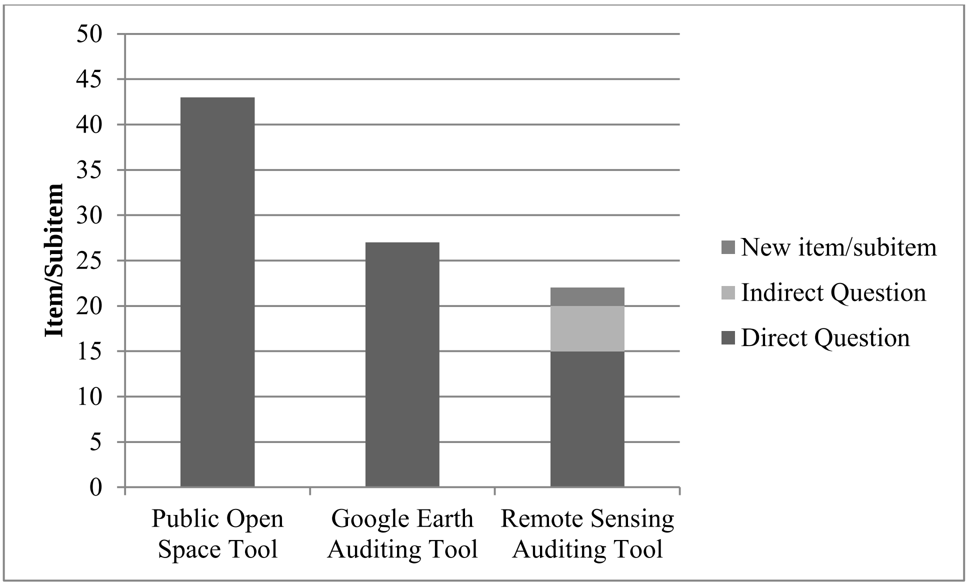

Figure 4 Number of items used for each approach.

2.3.2 Imagery

The feature extraction process used 4-band imagery with a resolution of 15 cm. Typically containing red, blue, green, and near infrared bands, 4-band imagery is multispectral [(49)]. A bright red colour in 4-band imagery is an indication of healthy vegetation. The spectral data in a composite image of Band 2, 3 and 4 can be used to distinguishing vegetation, water and urban areas.

2.3.3 LIDAR

LIDAR (Light Detection and Ranging) could generate large amounts of data about the physical layout of terrain and landscape features using laser pulses [(50)]. Two sources of LIDAR data - Digital Surface Models (DSMs) and Digital Elevation Models (DEMs) from the Department of Water (DoW) were used in this study. It was 2 meter post spacing and updated on the 21st February 2011. DEMs are three-dimensional digital representations of the ground surface topography that show the elevation of the landscape [(51)]. They represent a 'bare earth' model that excludes vegetation and buildings [(51)]. DSMs represent only terrain and buildings [(52)]. They are used to provide a fast, efficient and low cost algorithm for extracting 3D features in urban areas.

2.4 POS Measures

2.4.1 On-ground assessment of public open space tool

On-ground assessment of public open space was conducted by direct in-person observation directed by the POST Manual. During the on-ground assessment, the time taken to assess each parks was recorded as well as the time taken to travel from home to the suburb and to assess the POS once there (Appendix C). Figure 5 indicates the average auditing time spent on the different types of parks as classified by the City of Stirling.

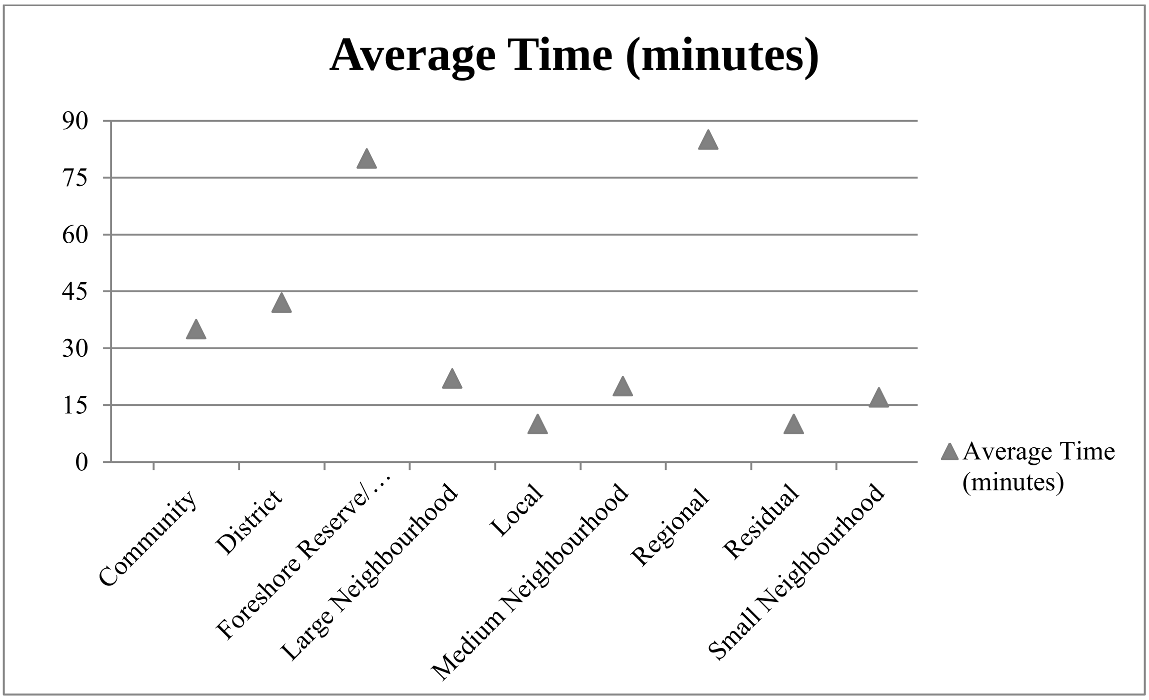

Figure 5 Number if parks assessed based on the City of Stirling's POS classification and the average audit time for each type.

2.5 Attribute Extraction

2.5.1 Feature Extraction – Imagery

In this study, ERDAS Imagine Objective was used to extract features such as road, walking path, playground, lake and green space from the aerial imagery. ERDAS Imagine Objective is modelled after the human visual system for image interpretation. This is accomplished by quantifying all the salient visual image interpretation cues for a feature, training machine learning components with these clues, then processing the imagery in a manner that these learned clues can be applied. The first step in the remote sensing method was to select training sites for each of the class categories (e.g. road, walking path, playground, trees, buildings, lake and green space). Spectral values for each pixel in a

training site were then used to define the decision space for that class. After defining the clusters for each training sites, the computer classified all the remaining pixels in the scene. Figure 6 provides an overview process of road extraction.

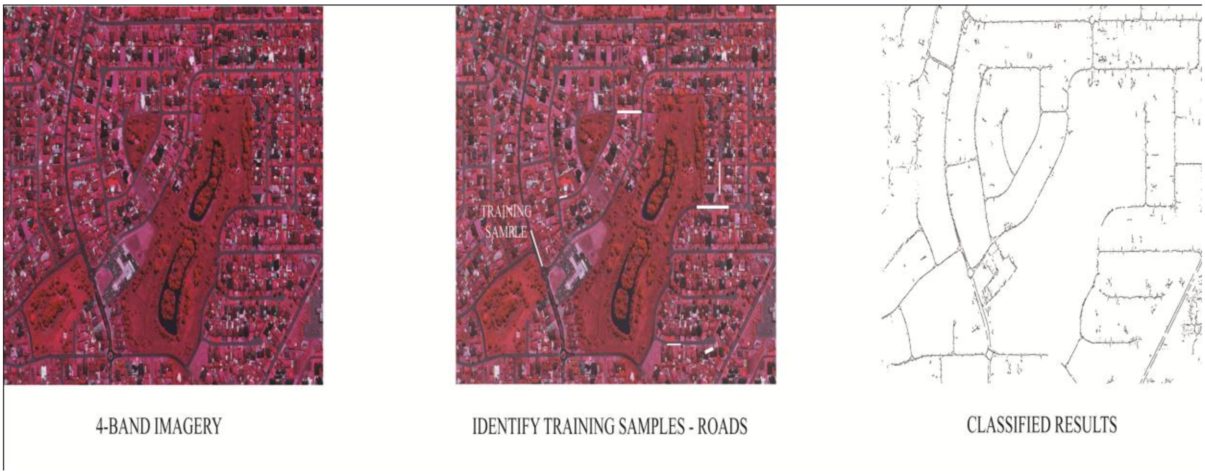

Figure 6 An overview process of road extraction.

2.5.2 Feature Extraction –LIDAR

In this study, the LIDAR Analyst software was used to extract buildings, trees and forest areas from the LIDAR data set. The software automatically extracted buildings, trees and forest features from LIDAR dataset. LIDAR Analyst provides 100% automation of the workflow for feature extraction of terrain (Bare Earth), buildings and trees from LIDAR datasets. Figure 7 is an overview of LIDAR analysis process and it shows the extraction of bare earth, building footprints and trees from the LIDAR data.

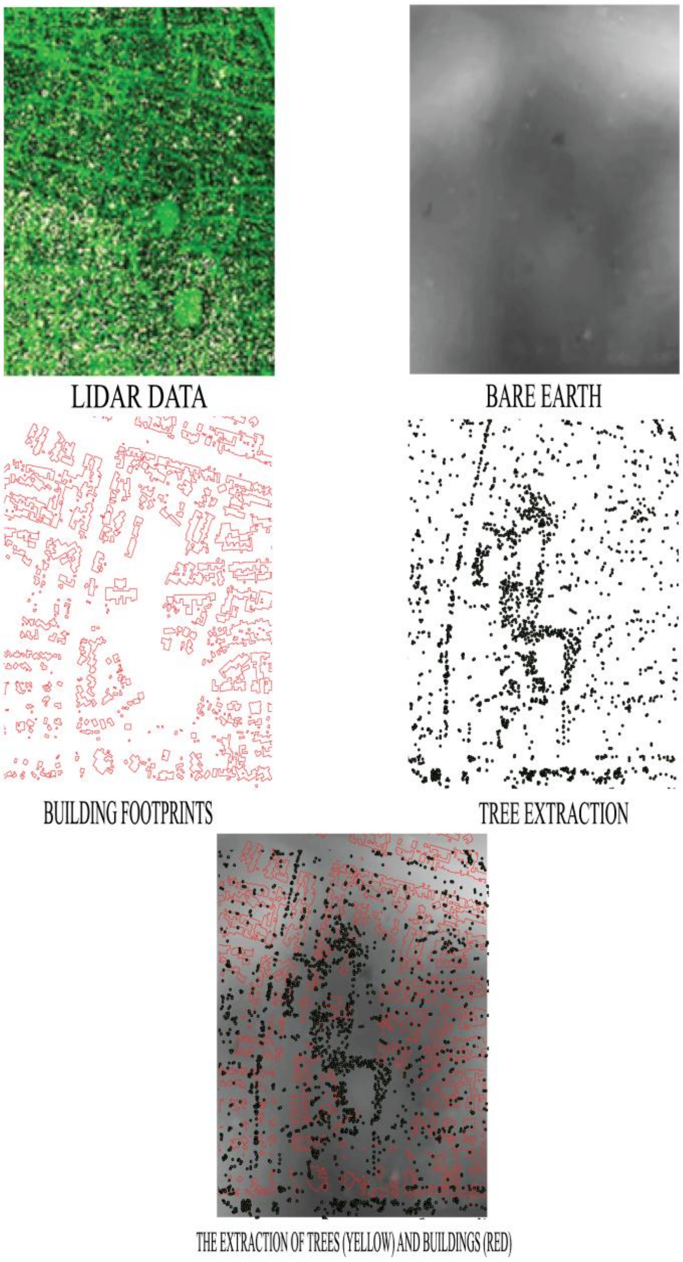

Figure 7 The overview of LIDAR analysis process. The images include the bare earth model, building footprints and trees extracted from the LIDAR data.

2.6 Statistical Analysis

Kappa statistics were used to test the reliability of feature extraction methods with on-ground assessment. Kappa is a measure of the observer agreement and expected agreement, standardised to fall on a scale from -1 to 1 [(53)]. A Kappa coefficient of 1.0 represents perfect agreement; Kappa coefficients equal to 0 represent agreement corresponding to that expected by chance; and Kappa coefficients less than 0 represent

agreement less than that expected by chance. Landis and Koch (1977)[54] have suggested the following benchmarks for interpreting Kappa:

Kappa Statistics	Strength of Agreement
< 0.00	Poor
0.00 – 0.20	Slight
0.21 – 0.40	Fair
0.41 – 0.60	Moderate
0.61 – 0.80	Substantial
0.81 – 1.00	Almost perfect

According to Landis and Koch (1977) [54], Kappa statistics between 0.61 and 0.80 indicate substantial agreement and Kappa statistics greater than 0.80 indicate almost perfect agreement.

2.7 Cost benefits Analysis

Cost benefit analysis is a technique for deciding whether to make a change. It compares the values of all benefits from the action under consideration and the costs associated with it [55]. An approach or programme having a high benefit-cost ratio will take priority over others with lower ratios [55]. In this study, the time and cost required for remote sensing techniques of feature extraction will be used in comparison with on-ground assessment and Google Earth.

3. Result

3.1 Attribute Extraction Approach

Residential rooftop, lake, trees, road, walking path, green space and playground were the primary focus of the extraction process. NDVI was used to measure the vegetation cover from the aerial imagery. Generally, healthy vegetation will absorb most of the visible light that falls on it and reflects a large portion of the near-infrared light [43, 56]. Unhealthy vegetation reflects most of the visible light and less of the near-infrared light [43, 56]. Bare soils reflect moderately in both the red and infrared portion of the electromagnetic spectrum [43, 56]. Therefore, the NDVI information can be derived by focusing on the satellite bands that are more sensitive to vegetation information (near-infrared and red). The NDVI algorithm subtracts the red reflectance values from the near-infrared and divides it by the sum of near-infrared and red band [43, 56]. Values for NDVI ranged from 1.0 to –1.0. Higher values indicated higher concentration of green vegetation. Lower values indicated non-vegetated features, such as water, barren land, ice, snow or clouds [43, 56]. The image was acquired during the summer, indicating that areas that are irrigated have values over 0.7 represent dense green vegetation. In this study, extreme negative values (-0.8) represent water and values around zero represent bare soil. Table 5 provides the description of method used to audit the new modified POST.

Table 5 Description of methods corresponds to the new modified POST.

Question	Methods	Description
Park boundary	GIS Editor Tool	The parks boundary was manually digitised.
Type of activities (e.g. grass open space, playground)	ERDAS Imagine Objective	Classify grassed open space pixels from the image by sampling and training green space pixels. The output is shapefile (.shp) representing the grassed open space.
Water feature within the POS	ERDAS Imagine Objective	Classify water feature pixels from the image by sampling and training water feature pixels. This produced a shapefile (.shp) representing the water feature.
Wetland / Lake	GIS Server – Interoperability Connection	Adding SLIP WFS servers Two sets of x and y coordinates (the south-western corner and north-eastern corner of the study area

		have been defined to obtain the features for the entire dataset.
Total water area	Raster Calculator	Total water area/POS area
Walking path	ERDAS Imagine Objective	Classify walking path pixels from the original image by sampling and training walking path pixels. A shapefile (.shp) representing the walking path was then produced.
Road	ERDAS Imagine	Classify road pixels from the original image by sampling and training road pixels. A shapefile (.shp) representing the road was generated.
Number of houses	ArcGIS Extension – LIDAR Analyst (building extraction)	1. First return was used to generate the Bare Earth model 2. Bare Earth model was used for extracting buildings. Building attributes of height, area, perimeter, average height and building roof type (pitched, simple, etc) were also automatically collected. 3. The number of houses within 20m buffer of the park was calculated.
Number of trees present	ArcGIS Extension – LIDAR Analyst (tree extraction)	Bare Earth model and building footprints was used for extracting trees.
Evidence that the grass is watered	NDVI	(Band 4 – Band 3) / (Band 4 + Band 3)
Public transportation	GIS Server – Interoperability Connection	Adding SLIP WFS servers. Two sets of x and y coordinates (the south-western corner and north-eastern corner of the study area have been defined to obtain the features for the entire dataset.
Cycling	GIS Server – Interoperability Connection	Adding SLIP WFS servers. Two sets of x and y coordinates (the south-western corner and north-eastern corner of the study area have been defined to obtain the features for the entire dataset.

3.2 Kappa Results

Overall, using geospatial technologies to extract feature from POS has proven to be reliable as all the items scores are above 0.40 (moderate agreement). The Kappa scores across the two methods (see Table 6) shows that eight items had moderate agreement (0.6 > k > 0.4); seven items had substantial scores and four items had almost perfect agreement. The items of perfect agreement were two of the aesthetic domain (presence of water features and distribution of trees) and one of the amenity domains (presence of public transport). On the other hands, items such as the presence of trees, the safety domain (e.g. building footprint) and one of the activity domain (activities available: grass open space) had Kappa values of 1.

Table 6 Kappa scores for agreement for each response item.

Item	Kappa	95% CI	
		Lower Limit	Upper Limit
ACTIVITY DOMAIN			
Activities available: Children's playground	0.497	0.160	0.835
Activities available: Walking	0.622	0.369	0.876
Activities available: Cycling	0.624	0.317	0.932
Activities available: Grassed Open Space	1.000		
AESTHETIC DOMAIN			
Is the POS adjacent to bushland?	0.753	0.484	1.000
Are there water features within the POS?	0.874	0.703	1.000
Lake	0.918	0.758	1.000
Wetland	0.614	0.255	0.972
Are there trees in this POS?	1.000		
Estimate the approximate number of trees present	0.582	0.372	0.792
Arrangement of trees			
Perimeter all side	0.826	0.591	1.000
Perimeter some side	0.587	0.332	0.842
Along walking path	0.449	0.155	0.744
Random placement throughout	0.567	0.248	0.886
Are there gardens in this POS?	0.519	0.261	0.776
Are there walking path?	0.622	0.369	0.876
Shade along the path?	0.419	0.166	0.671
Is there evidence that grass is watered?	0.804	0.539	1.000
AMENITY DOMAIN			
Is children's play equipment present?	0.497	0.160	0.835
Is playground shaded?	0.628	0.334	0.922

Is there access to public transport within 20m buffer?	0.885	0.730	1.000
SAFETY DOMAIN			
All houses surrounding the POS	1.000		
All road surrounding the POS	1.000		

3.3 On-Ground Assessment

The time taken for on-ground assessment was recorded and compared with the feature extraction technique. It took about 6 days to finish 39 parks for on-ground assessment while feature extraction only took about four days with the assessment involving more than 39 parks. The detail of time taken (traveling time and park audit time) for on-ground assessment is in Appendix C.

4. Discussion

4.1 Comparison of Feature Extraction results with Google Earth

4.1.1 Kappa

Kappa scores for the remote sensing technique of feature extraction were compared with remote sensing technique of Google Earth (Table 7). This result has further strengthened confidence that remote sensing technique of feature extraction could increase the efficiency of data collection for a large number of parks. This paper has obtained comprehensive results proving that the remote sensing technique of feature extraction is reliable. In general, feature extraction has a shorter POST compared to Google Earth approach but Kappa results would seem to suggest that some items (i.e. the presence of trees, arrangement of trees) have higher agreement.

Table 7 Comparison of Kappa scores between remote sensing technique of feature extraction and Google Earth approach.

Item	Feature Extraction	Google Earth
ACTIVITY DOMAIN		
Activities available: Children's playground	0.497	0.75
Activities available: Walking	0.622	0.65
AESTHETIC DOMAIN		
Are there water features within the POS?	0.874	0.85
Are there trees in this POS?	1.000	0.63
Estimate the approximate number of trees present	0.582	0.53
Arrangement of trees		
Perimeter all side	0.826	0.09
Perimeter some side	0.587	0.04
Along walking path	0.449	0.11
Random placement throughout	0.567	0.38
Are there gardens in this POS?	0.519	0.24
Are there walking path?	0.622	0.81
Shade along the path?	0.419	0.84
AMENITY DOMAIN		
Is children's play equipment present?	0.497	0.88
Is playground shaded?	0.628	0.66

4.1.2 Cost benefit

This study shows that comparable quality assessments of public open spaces can be obtained using a shorter POST and automated methods such as feature extraction, LIDAR Analysis and image classification as compared to direct-observation. This approach increased the accuracy of some items, such as the presence of public transport within 20m buffer of the POS and number of trees as these items could be easily extracted. The information of public transport is provided by the Public Transport Authority, authorised by Landgate and they endeavour to provide the most up-to-date and accurate spatial dataset. However, it is time-consuming to identify these items during on-ground assessment.

The current study evaluates the potential of feature extraction techniques for assessing the quality of open space to provide rapid and inexpensive assessment for studies involving a large number of spaces. The labour cost for on-ground assessment are quite substantial as it requires time for people to visit each public open space to directly observes and rate the physical environment. The time taken for 50 parks using remote sensing of Google Earth was 4 hours compared to 12 hours using feature extraction [32]. As shown in this study, the time taken for a larger number of parks is less when the numbers of parks increase by using feature extraction technique compared to on-ground assessment (Figure 8). With a large number of parks in each local government areas, the remote sensing technique using feature extraction can dramatically decrease the time and effort involved in assessing POS.

The longer timeframe required for on-ground assessment result in greater labour expenses (Figure 9). The remote sensing of Google Earth shortened the time required and resulted in cheaper labour cost compared to on-ground assessment. For a small number of parks, the cost for Google Earth approach is relatively cheaper compared to remote sensing approach of feature extraction in as much as feature extraction technique required the consideration of software and data (i.e. aerial imagery) costs. However, since most of the local governments in Perth acquire the imagery used in this study on an annual basis as part of their data acquisition budget, there is the potential of utilising this imagery to defray the cost of POS audit using remote sensing techniques.

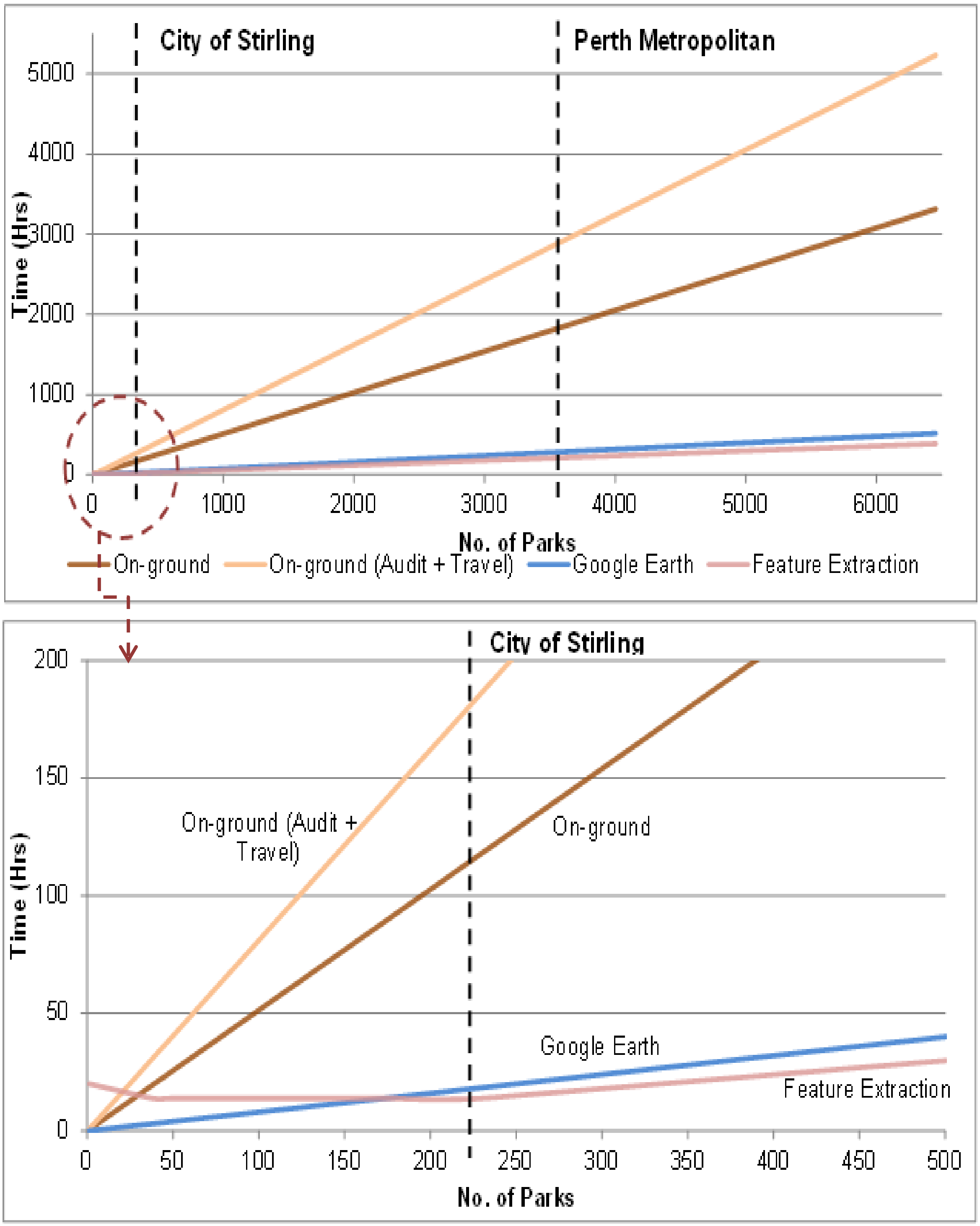

Figure 8 Analysis of time taken for auditing corresponds to the number of parks by each method.

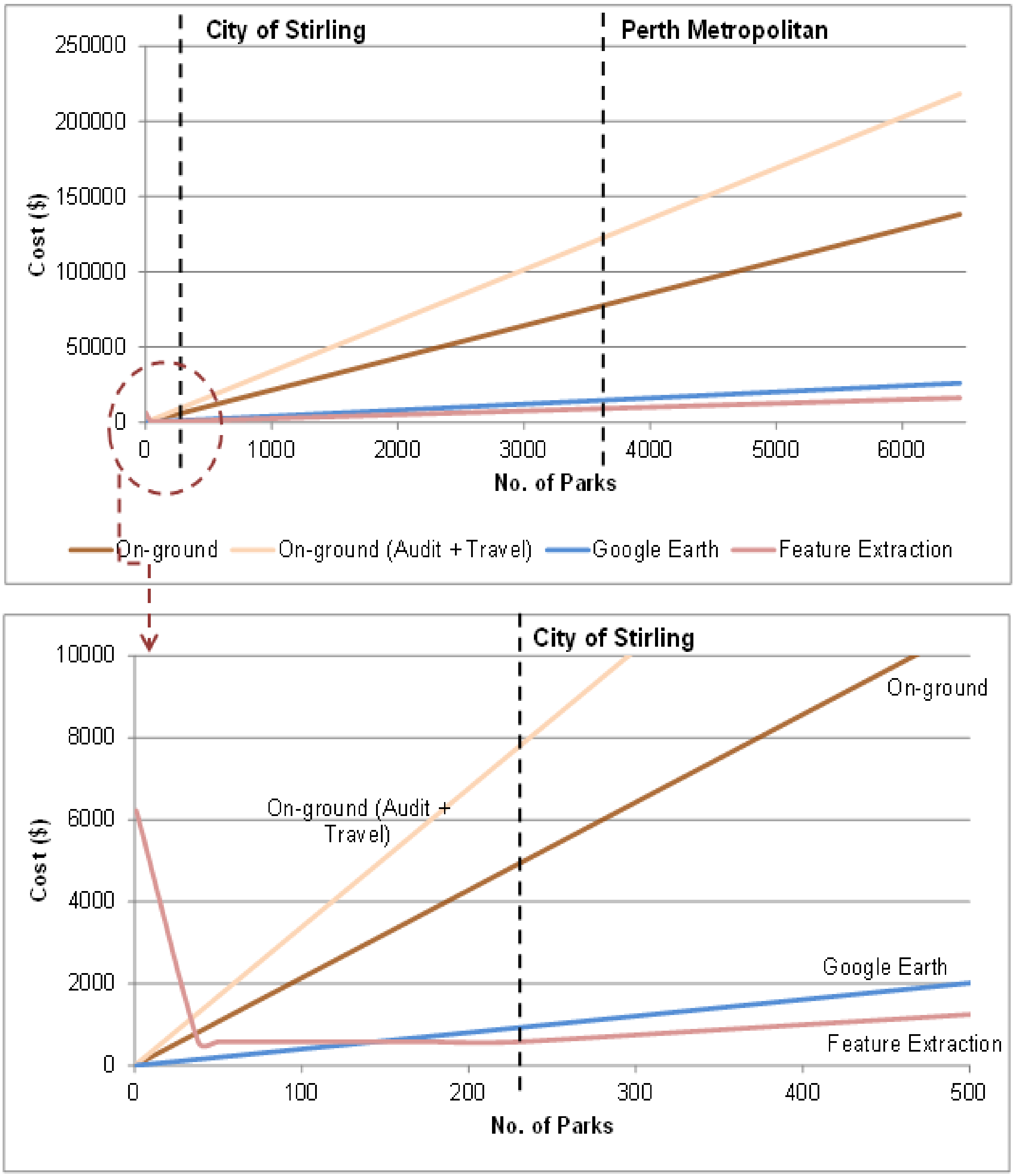

Figure 9 Comparison of cost required for park auditing in each method.

The advantages and disadvantages of each approach (on-ground assessment, remote method – Google Earth, and feature extraction method), dataset and expertise required for each approach, and the time and cost for each approach are detailed in Table 8. On-ground assessment is the easiest method as no dataset is required and it can be done by anyone. However, the time and cost taken for auditing a large number of parks are the highest. Remote sensing techniques of feature extraction on the other hand, require some basic GIS training. However, the cost and time taken for auditing a large number of parks

will be greatly reduced. This research paper shows that when auditing a small number of parks (i.e. less than 50), remote method (Google Earth approach) will be the best approach as feature extraction required certain software (i.e. ArcGIS and ERDAS) for auditing and thus will result higher cost compared to remote method which only required access to Google Earth (which can be downloaded at no cost). In general, park auditing is done by the local council to ensure that a better environment is provided to the community. Hence, feature extraction approach could help local council greatly reduce the time and cost required for auditing the park.

Table 8 Advantage and disadvantage for each approach.

Approach	Dataset	Expertise	Time required	Cost
On-ground assessment	None	None	Shorter time for small areas; longer time for large areas	Cheap for small areas, expensive for large areas
Remote method	Google Earth, Street View	Basic computer user	Shorter time for small areas; longer time for large areas	Cheap for small areas, expensive for large areas
Feature extraction	Aerial imagery, LIDAR dataset	Basic GIS user	Shorter time for large areas	Cheap for large areas

4.2 Limitations

The methods produced significant results and addressed most of the attributes of the POS. These included the presence of trees, the accessibility of parks with surrounding houses, walking path, cycling, trees that provide shade, and water feature (pond, creek). However, there were several problems associated with the method and the technology used that contributed to the error in the calculation of some variables. Some items, particularly those on the aesthetics and safety subscale, could not be assessed reliably due to the spectral heterogeneity of the features. Some of the items can be seen visually but could not be extracted using image classification such as seating, lighting, BBQ facilities and picnic table. Moreover, it is impossible to extract objects that are under trees and bushes as they are obstructed from view. Hahn and Craythorn (1994) [(57)] found that despite the popularity of walking, a disproportionate amount of community POS is zoned for organised sports rather than for informal activities such as walking or jogging. However, feature extraction techniques could not be used to identify the type of activities within the POS (e.g. tennis, cricket, soccer, football, rugby and etc.) because of the grassy issue. It can distinguish grass open spaces with buildings but it could not identify the type of

activities within the POS. This method can distinguish buildings but it is impossible to identify the use of the building.

It is very hard to avoid error in digitising. Some paths or roads may have been obliterated due to misinterpretation of aerial photograph. The tree canopies often obstructed the view of walkways, resulting in missed classifications during extraction (Figure 10). Playground equipment is often located under the canopies of the tree, or under sails resulting in missed playground. Shadows are another issue that compound digitising error. However, this issue could be overcome by removing the shadow through band ratio[1].

Figure 10 Limitation - missing road.

[1] A band ratio is calculated by dividing the pixels in one band by the corresponding pixels in a second band. Band ratio can help distinguish the difference between the spectral reflectance similar surface types (ERDAS 1999)

5. Conclusion

In the studies of physical activity and overall health, it is very important to examine the quality of built environment, and tools such as the remote-method approach used on this study could lead to a better understanding of the relationship between health and public open space. Feature extraction represents a toolkit for local council in their development. Through feature extraction, local councils could examine the quality of the parks easily and make improvement on the parks to meet the community needs. To date, there had been several methods used to measure the quality of public open space, both manually and remotely – but these instruments have their own limitations (i.e. SPACES is time-consuming, GIS and remote sensing is limited by image of low resolution). With advancements in technology and the availability of more detailed mapping software packages, there is an opportunity to provide a more cost effective method of assessing the quality of public open space. Feature extraction technique holds particular potential for audits conducted across multiple sites, or over vast geographic areas, providing researchers with a rapid, convenient, cost-effective, and reliable method of assessing the quality of public open spaces. Overall, the time, labour cost and resource required to conduct audits of public open spaces could be greatly reduced through feature extraction techniques and this method could be expanded to access the quality of urban decay, school grounds, urban change, scenario of natural hazard affecting the population and other physical environmental attributes.

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Appendix A Public Open Space Tool

On-ground assessment

Reference Number = ______________________
Address = ______________________
Area (hectares) = ______________________
Postcode = ______________________
Geocode = ______________________
Year of Establishment of POS = ______________________

Activities

1. Type of usage (tick all relevant)

   Active-formal
   Active-informal
   Passive only

2. For what type of activities is the space designed? (tick all relevant)

   Tennis (grass/hard courts)
   Soccer
   Football
   Netball (grass/hard courts)
   Cricket
   Baseball
   Walking (only if path)
   Cycling
   Fitness Circuit
   Basketball/Netball Hoops
   Hockey
   Athletics
   Rugby
   Children's playground
   Other

Environmental quality

3. Is the POS on the beach/river foreshore?

4. Are there water features in within the POS?

5. Type of water feature (tick all relevant)

   Lake
   Pond
   Water fountain
   Stream
   Other

6. Estimate the percentage of the POS occupied by the water feature(s)?

   Up to 25%
   26% & up to 50%
   51% - 75%
   More than 75%

7. (a) Are there other aesthetic features in the POS?

   (b) Which of the following features are present? (Tick all relevant)

   Statues
   Gazebos/Rotunda
   Sculptures
   Ducks/Swans
   Bridge
   Rocks
   Other

8. Are there trees in this POS?

9. Estimate the approximate number of trees present

   1 – 50 trees
   50 – 100 trees
   More than 100 trees

10. Where are the trees placed? (tick all relevant)

Perimeter all sides
Perimeter some sides
Along walking paths
Random placement throughout
Other

11. Are there gardens in this POS?

12. (a) Are there walking paths or cycleway within or around the POS? (tick all relevant)

    Walking path/s
    Designated dual-use path/s
    None

    (b) Shade along paths (Tick one)

    Very good (canopies of many trees touch) (5)
    Good (canopies of some trees touch) (4)
    Medium (canopies don't touch but trees close together) (3)
    Poor (canopies of trees don't touch and trees spread apart) (2)
    Very poor (little or no shade) (1)

13. Describe the placement of paths within the POS (Tick all relevant)

    Perimeter, all sides
    Perimeter, some sides
    Diagonal
    Radial
    Path around water/visual feature
    Other

14. Is there evidence that the grass is watered?

15. Are dogs allowed? (tick all relevant)

    Yes, on leash at all times
    Yes, on leash at certain times
    Yes, no leash specific
    Not allowed
    Not specified

16. Is access for dogs:

    Allowed for all areas
    Restricted from some areas
    Not specific

17. Is graffiti present?

18. Is vandalism evident?

19. Is there litter throughout the POS?

Amenities

20. Is children's playground equipment present?

21. What items of play equipment are present? (tick all relevant)

    Swing/s
    Slide/s
    Climbing equipment
    Hanging bars/rings
    Seesaws/rockers
    Bridges/tunnels
    Activity panels (eg Noughts & crosses)
    Cubby house/s
    Other

22. What is the playground surface? (Tick all relevant)

    Sand
    Grass
    Rubber
    Gravel or pebbles
    Woodchips
    Other

23. Is playground shaded?

    Partial cover/shade
    Total cover/shade
    No cover/shade

24. Are barbeque present?

25. Are picnic tables present?

26. (a) Are there parking facilities serving the POS?

    (b) Estimate the number of bays

    0 – 20
    21 – 50
    More than 50

27. Are there public access toilets?

28. Is there a kiosk/cafe present?

    7 days per week
    Weekdays only
    Weekends only
    No

29. Is there access to public transport within one block of POS?

30. Is there seating present?

31. Are there clubrooms/meeting rooms present?

32. Are rubbish bins present?

33. Are dog litter bags provided?

34. In how many locations in POS are dog litter bags present?

35. Are there taps or other water sources accessible for dogs?

36. Are drinking fountains present?

Safety

37. Is there lighting within the POS (i.e. not just street lighting)

38. Where is the lighting located? (tick all relevant)

    Around courts, buildings and equipment
    Along paths
    Perimeter all sides
    Perimeter some sides
    Random throughout POS

39. From the centre of the POS, how visible are surrounding roads? (Tick one)

    Road/s clearly visible from the centre of the POS
    Road/s is partly visible from the centre of the POS
    Road/s cannot be seen from the centre of the POS

40. (a) From the centre of the POS, how visible are the surrounding houses? Clear visibility means you can clearly see windows, backyards, or front yards of houses overlooking the park? (Tick one)

    House/s clearly visible from the centre of the POS
    House/s is partly visible from the centre of the POS
    House/s cannot be seen from the centre of the POS

    (b) How many of these houses overlook the park?

    More than 10
    Between 5 and 10
    Between 1 and 5

    (c) Is there any area of the POS where you are unable to clearly see surrounding houses?

41. Are all rounds surrounding the POS minor roads or cul-de-sacs?

42. (a) Does the major road/s have a zebra crossing to assist access to the POS?

    (b) Does the major road/s have a pedestrian crossing with signals to assist access to the POS?

43. To what extend do you agree or disagree with each of the following statements regarding

this POS? (circle one number for each item)

1 = Strongly Agree (**SA**)
2 = Agree (**A**)

3 = Neither Agree nor Disagree (**Neither**)
4 = Disagree (**D**)
5 = Strongly Disagree (**SD**)

	SA	**A**	**Neither**	**D**	**SD**
POS is interesting for walking					
POS is suitable for casual ball sports					
POS is suitable for cycling					

Remote sensing technique of feature extraction

Activities

1. For what type of activities is the space designed? (tick all relevant)
   - Walking (only if path)
   - Cycling
   - Children's playground
   - Grass Open Space

Environmental quality

2. Is the POS adjacent to bushland?
3. Is the POS on the beach/river foreshore?
4. Are there water features in within the POS?
5. Type of water feature (tick all relevant)
   - Lake
   - Pond
   - Water fountain
   - Stream
   - Other
6. Total **water area** of water feature
7. Estimate the percentage of the POS occupied by the water feature(s)?

   Water percent (total water area/POS area)

   - Up to 25%
   - 26% & up to 50%
   - 51% - 75%
   - More than 75%
8. Are there trees in this POS?
9. Estimate the approximate number of trees present

   - 1 – 50 trees (1)
   - 50 – 100 trees (2)
   - More than 100 trees (3)

   Percentage of tree coverage in POS (tree coverage/POS area)

10. Where are the trees placed? (tick all relevant)

    - No trees present (0)
    - Perimeter all sides (4)
    - Perimeter some sides (3)
    - Along walking paths (2)
    - Random placement throughout (1)

11. Are there gardens in this POS?
12. Are there **walking paths** within or around the POS? (tick all relevant)

    Shade along the paths?
    - No shade (0)
    - Very good (canopies of many trees touch) (5)
    - Good (canopies of some trees touch) (4)
    - Medium (canopies don't touch but trees close together) (3)
    - Poor (canopies of trees don't touch and trees spread apart) (2)
    - Very poor (little or no shade) (1)

13. Is there evidence that the grass is watered?

Amenities

14. Is children's playground equipment present?
15. Is playground shaded?

Partial cover/shade
Total cover/shade
No cover/shade

16. Is there access to public transport within one block of POS?

Safety

17. **Number of roads** within a 20m buffer of the POS

18. **Number of houses** within a 20m buffer of the POS

19. Are houses/roads present on all sides of the park?

    How many sides or the park are roads present?
    How many sides of the park are houses present?

20. How many **houses** are within a (e.g. 50m) buffer of the children's playground?

Appendix B Classification of Public Open Space

Classification	Size (hectares)	Catchment Population/ Service Area	Location	Timing of Use	Facilities – Core and Optional
Residual	< 0.2	Surrounded by other public open spaces that better service the catchment area.	Citywide	Not applicable.	No new development or investment. No infrastructure. No signage or other reserve identification. Maintained at minimum level until resolution of long-term future achieved.
Local	0.2 – 0.3	Encouraged for local children's play, for identity and sense of place, and as resting places for the elderly or disabled people in appropriate circumstances.	Should be located to be easily accessed by foot by the catchment population.	Daytime to early evening through to sunset. Predominantly utilized during daylight hours.	On-street parking. Service vehicle access. Local play equipment. Informal play areas. Relaxation areas. Areas for dog walking under control. Natural shade cover. Irrigated lawn. Minimum 1 bin. Minimum 1 seat. Minimum 1 drinking fountain. Footpaths. Signage.
Small Neighbourhood	0.3 – 0.5	Serving about 600 dwellings with a maximum 400 metre walk from most dwellings.	Should be located where nearby buildings overlook the park and provides sufficient road frontage to accommodate visitor parking.	Daytime to early evening through to sunset. Predominantly utilized during daylight hours.	On-street and off-street parking. Service vehicle access. Local play equipment. Informal play areas. Relaxation areas. Areas for dog walking under control. Natural shade cover. Irrigated lawn. Bin. Seating facilities. Minimum 1 drinking fountain. Footpaths. Signage.
Medium Neighbourhood	0.5 – 1.5	Serving about 700 dwellings and be a maximum 400m	Should be located where nearby buildings overlook	Daytime to early evening through to	On-street and off-street parking. Service vehicle access. Local play equipment. Informal play areas.

		walk from most dwellings.	the park and provides sufficient road frontage to accommodate visitor parking.	sunset. Predominantly utilized during daylight hours.	Relaxation areas. Areas for dog walking under control. Natural shade cover. Irrigated lawn. Bin. Seating facilities. Minimum 1 drinking fountain. Footpaths. Signage.
Large Neighbourhood	1.5 – 2.5	Serving about 800 dwellings with street on all sides, but in some instances it may have a portion of its perimeter, with directly abutting development that has only footpath frontage.	Should be located where nearby buildings overlook the park and provides sufficient road frontage to accommodate visitor parking.	Daytime to early evening through to sunset. Predominantly utilized during daylight hours.	On-street and off-street parking. Service vehicle access. Local play equipment. Informal play areas. Relaxation areas. Areas for dog walking under control. Natural shade cover. Irrigated lawn. Bin. Seating facilities. Minimum 1 drinking fountain. Footpaths. Signage.
Community	2.5 – 5.0	Serving the residents of approximately an 800 metre catchment unless serviced by other POS that provides the same purpose.	Located within the catchment and be easily accessible to residents, preferably by foot, bicycle or public transport.	Day to late evening. Social gatherings common with some structured community events.	On-street parking with formalised verge parking where necessary to meet traffic safety requirements. Sharing of parking in adjacent public facilities is encouraged. Service vehicle access. Community play equipment similar to that found in a major playground. Informal play areas. Relaxation areas. Areas for dog walking under control. Natural shade cover. Formal shelter structures. Irrigated lawn. Bins. Seating facilities. Drinking fountains with minimum 1 universal

					access fountain. Universal picnic areas with barbecues and washing facilities. Small universal access public toilet facilities Small-scale hardstand multi-use court such as basketball/tennis. Lighting for limited evening use — safety and security only (e.g. barbecues). Footpaths connected to surrounding network. Bus stop location desirable. Signage. Bicycle racks. Power supply access.
District	5.0 – 20.0	Servicing residents and visitors approximately a 1.5km – 2.5km radius.	Location is usually determined by resource availability and opportunities to utilise and/or protect the public open space. Preferably schools are located in conjunction with district open space enabling joint use and maintenance of public open space such as playing fields.	Day to late evening. community	On- and off-street including associated public vehicle entry/s. Service vehicle access. Play equipment similar to that found in a district and regional playground. The number and type of playgrounds will depend on the layout of the public open space and location of other play facilities in close proximity. Formal sport and recreation activities (primary). Multi-purpose clubroom facility/s with outdoor open social areas, community areas, storage areas, informal spectator viewing facilities (where appropriate). Sportsfield lighting. Informal active recreation facilities (multi-use courts etc.). Informal play areas. Relaxation areas. Areas for dog walking under control. Possible canine facilities or exercise stations. Natural shade cover. Formal shelter structures.

					Irrigated lawn. Waste facilities —commercial and standard bins. Sports benches and seats. Drinking fountains with minimum 2 universal access. Picnic areas with barbecues, shade structures, tables and washing facility/s. Universal access public toilet facilities. Safety and security lighting and possible ancillary features where required. Path networks (informal trails, dual use paths etc.). Bus stop location desirable Signage — directional and interpretive. Bicycle racks. Natural area associated facilities. Drainage, electrical, sewer and communication infrastructure.
Regional	30.0 – 80.0 +	Serves all City residents and wider metropolitan region. Principle catchment area is approximately 2.5km radius.	Location is usually determined by resource availability and opportunities to utilise and/or protect the public open space.	Daytime to late evening. Activities possible in buildings extending into early hours of the morning.	On-site and formal verge parking or on-street parking with restrictions as required. Internal roadways for service, building and car park access. Entrance statements and features. Service access and compounds with lockable storage facilities. Regional play equipment. The number and type of playgrounds will depend on the layout of the POS and location of other play facilities in close proximity. Formal sport and recreation activities (primary). Multi-purpose clubroom facilities with outdoor open social areas, community areas, storage areas, informal spectator viewing facilities etc.

					Sports field lighting. Informal active facilities (full court, multi-use court facilities etc.). Informal play areas. Relaxation areas. Areas for dog walking under control. Possible canine facilities and exercise stations. Natural shade cover. Formal shelter structures and or pavilions or varying sizes to cater for group functions and social activities. Irrigated lawn. Waste facilities and compound for clubs/groups. Numerous bins. Numerous sports benches and seats. Several standard and universal access drinking fountains. Several picnic areas with barbecues, picnic tables and washing facilities. Universal access public toilet facilities as required and distributed throughout the reserve servicing relevant nodes. Safety and security lighting and possible ancillary features where required. Path networks (trails, circuits, dual use and designated Bikewest network paths). Bus stop location desirable. Signage — directional, interpretive and informational (e.g. conservation points). Bicycle racks. Natural area associated facilities. Possible multi-purpose recreational facility. Possible event infrastructure, such as amphitheatres and spectator seating as required. Drainage, electrical, sewer and

					communication infrastructure. Unique and strong landscape identity.
Foreshore Reserve	Variable	No specific catchment, need dispersal across City for accessibility.	Dependent on natural resource availability and opportunity to create or improve new or existing habitats. Natural conservation areas may either be an individual site or form a component of other public open spaces that fall under other classifications (e.g. bushland areas in a regional open space or wetland/lake in a community open space).	Generally daytime only. Supervised evening use associated with relevant activities such as nocturnal observation wildlife walks etc.	Street parking preferred. Limited on-site parking at perimeter (non-bituminised surface). Consolidated limestone tracks or sand trails. Wildlife observation stations and boardwalks with benches where required. Drinking fountains at trail heads where required. Park identification and regulatory signage. Interpretive and directional signage along trails where required. Adjacent to facilities on other POS. Fire tracks and breaks. Vehicle control fencing and perimeter fencing for pedestrian control where required.

Appendix C Traveling Time and Auditing Time

Address/Location	Travelling time	Auditing Time
Day 1		
Princess Road, Crawley		
↓	30 minutes	
Laurie Strutt Reserve		20 minutes
↓	1 minutes (4 minutes walk)	
Star Swamp Bushland Reserve		90 minutes
↓	1 minutes (5 minutes walk)	
Apex Park		10 minutes
↓	9 minutes	
Okely Lorraine Reserve & Monyash Reserve		150 minutes
↓	7 minutes	
Lake Careniup		60 minutes
↓	6 minutes	
Zaccaria Park		20 minutes
↓	2 minutes	
Lake Gwelup Reserve		60 minutes
Day 2		
Princess Road, Crawley		
↓	20 minutes	
Caratti Park		15 minutes
↓	2 minutes	
Stirling Civic Garden		60 minutes
↓	6 minutes	
Milett Park		15 minutes
↓	3 minutes (9 minutes walk)	
Munro Reserve		10 minutes
↓	3 minutes (10 minutes walk)	
John K Lyons Oval		15 minutes
↓	1 minutes (5 minutes walk)	
Bennett Park		20 minutes
↓	1 minutes (6 minutes walk)	
Steward Park		20 minutes
↓	1 minutes (4 minutes walk)	
Disbrey Park		20 minutes
↓	2 minutes walk (5 minutes walk)	
Butlers Reserve		20 minutes
↓	4 minutes	
Joe Rice Playground		20 minutes
↓	3 minutes	
Brenda Morton Reserve		25 minutes
↓	2 minutes	
Peace Drove		20 minutes
Day 3		
Princess Road, Crawley		
↓	30 minutes	
Balcatta Reserve & Richard Guelfi Reserve		100 minutes
↓	4 minutes	
Jones Paskin Reserve		30 minutes
↓	4 minutes	
Vrankovich Reservation		25 minutes
↓	3 minutes (10 minutes walk)	
Antonio Scarfo Reserve		25 minutes
↓	2 minutes (10 minutes walk)	
Sheldrake Reserve		25 minutes
↓	3 minutes	
Spoonbill Lake		30 minutes
↓	3 minutes	
Cherrytree Gardens		20 minutes
↓	6 minutes	
Landchester Reserve		25 minutes
Day 4		
Princess Road, Crawley		
↓	24 minutes	
Peace Grove		20 minutes
↓	5 minutes	
Empire Avenue		25 minutes
↓	2 minutes	
AS Luketina Reserve		25 minutes
↓	5 minutes	
Hale/Pearson Reserve		20 minutes
↓	2 minutes (7 minutes walk)	
Sweeting Reserve		20 minutes
↓	1 minutes (3 minutes walk)	
Woodlands Reserve		20 minutes
↓	2 minutes	
Jackadder Lake & Tamarisk Reserve		60 minutes
Day 5		
Princess Road, Crawley		
↓	17 minutes	
Glendalough Open Space		70 minutes
↓	4 minutes	
Herdsman Lake		120 minutes
Day 6		
Princess Road, Crawley		
↓	30 minutes	
Millington Reserve		90 minutes

Appendix D Literature Review

Geospatial Automation of Ground Based Subjective Surveys: A Case Study of the Public Open Space Tool (POST)

Literature Review

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10881064

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Abstract

Public open space with high quality environment attracts more people and provides many benefits. Hence, maintaining the quality of public open space is important in order to provide better environment for the local neighbourhood. There are different ways to measure the quality of public open space such as, a needs-based approach, SPACES instrument, Geographical Information System (GIS) and Google Earth. These instruments, however, have their own limitations. In this connection, this paper will attempt to illustrate a new remote-assessment approach that makes use of feature extraction technique to provide a quick and inexpensive measurement of the quality of public open space.

Introduction

The Australian Bureau of Statistics (ABS) forecasts that Australia's population will rise to 35.9 million by 2050 (Bell *et al.* 2010). After reaching a population of 1.55 million in 2005, the population of Perth (the capital of Western Australia) is expected to reach 2.39 million by 2031 (Grose 2009). Perth also has the fastest rate of suburban growth among the Australian cities (Grose 2009). As a result of urbanisation, the world's population has become increasingly concentrated on cities (Kong & Nakagoshi 2006). Consequently, the growing and increasingly urbanised populations are expected to increase the demand for more land to be released for development (Fischer & Heilig 1997). Furthermore, population increases triggered the rapid growth of urban centre and city planners faced difficult challenges in their efforts to expand infrastructure. New housing, commercial and industrial redevelopment schemes not only destroyed valued green spaces but will also diminish the quality of social life and sense of community (Burgess *et al.* 1988). Various researches claimed that increasing population will negatively influence the quality of life. As Byrne and Sipe (2010) indicated, with higher population comes the risk of losing precious public open space for urban infill, placing residents in noisy locations, concentrating social disadvantage, and potentially undermining social cohesion.

Since 1990, sustainable development has become one of the leading paradigms that emphasise the need for preserving the natural biological systems that underpin the global economy (Potter *et al.* 2008). Hence, it is important to consider environmental protection as part of the development process in order to provide future generation with an undiminished natural resource.

Improving urban green space represents an important and cost-effective opportunity for people to transform their local neighbourhoods and improve their quality of life (CABE Space 2010). Consequently, it is important for city planners to consider the need to provide better infrastructure and, more housing and to sustain and protect habitats and ecosystems. Recent research has also indicated that public open space is important to the health and wellbeing of urban residents and that it provides a range of ecosystems services benefits that are crucial if cities are to prosper over the long term (Byrne *et al* 2010). Thus, it is important to enhance the quality of public open space in order to provide a better environment for the local neighbourhood. Towards this end, this paper will be divided into three sections. First, it will identify the definition of public open space and the features of open space. Second, it will identify the factors of public open space that influence human behaviour. Lastly, the paper will examine the tools used for measuring the quality of public open space and the built environment.

Defining Public Open Space

The importance of open space is widely recognised as land use planning systems are now considering environmental, social, economic, and culture development (Maruani & Amit-Cohen 2007). The term 'open space' was first used in London by committee on public trails in 1833 (Turner 1992). In 18th and 19th Centuries, public open space was first established to meet public demand for amenities and recreational areas and to reduce social stress which was threatening the existing social order and political systems (Maruani & Amit-Cohen 2007). The traditional view of parks is usually zoned for recreation purpose with playground equipment and barbeque. While this is still true to some extent, there are now further explanations of public open space. Open spaces are identified as a 'natural' environment composed of abiotic (soil, water, minerals) and biotic (plants, animals, microorganisms) elements (Maruani & Amit-Cohen 2007, p. 2). In Australia, public open space is understood as open space which serves external recreational needs of the local community (Grose 2009). It includes playing fields for sports (e.g. Australian Rules football and cricket) and grassed areas as open parks, but does not includes setbacks and buffers required by legislation around environmentally sensitive areas such as the coast and wetlands, nor does it include large areas set aside regionally for preservative of bushland (Grose 2009). However, urban green space is defined differently in other countries. It was defined as outdoor places with significant

amounts of vegetation, and exists mainly as semi-natural areas (Grose 2009; Kong & Nakagashi 2006).

In Liveable Neighbourhood (Edition 2), the Western Australia Planning Commission (WAPC) defined public open space as 'land used or intended for use for recreational purposes by the public and includes parks, public gardens, foreshore reserves, playgrounds and sport fields' (WAPC 2000, p. 86). Taylor *et al.* (2011) defined public open space as 'space that people can access legally, including vacant lots, playgrounds, and public gardens' (Taylor *et al.* 2011, p.106). Timperio *et al.* (2007, p. 336) defined it as 'state government managed reserves, other managed reserve, parks with water reservoirs, reserves or parks, open space not officially recognized as a reserve or parks (including foreshores), scouting associations, and sporting or recreation spaces (including golf courses)'.

Despite the various definitions associated with public open space, there are nevertheless some commonalities in the various definitions. Overall, public open spaces have been defined as parks, public gardens, foreshore reserves, playgrounds, reserves and sport fields that offer important opportunities for sport and recreation. This is consistent with the definition established by The City of Stirling in its Public Open Space Strategy. The City defined public open space as 'open developed and undeveloped areas, such as parks, reserves, wetlands, bushlands, coastal reserves and special purpose open spaces' (City of Stirling 2008, p. 3), aimed at creating a network of resource efficient quality public open space across the City that will satisfy current and future recreation needs in an equitable and sustainable manner. The City developed a new classification system to identify the different types of public open space within its area. In 2005, the council adopted a classification of seven different categories: local open space, community open space, district open space, regional open space, natural conservation areas, special purpose open space and residual land (City of Stirling 2008).

Importance of Public Open Space

The public planning of open spaces over the years reveals two contradictory approaches – (1) typical of planners and geographers; and (2) typical of ecologists and conservationists (Maruani & Amit-Cohen 2007). The first focuses more on meeting human demands for recreation, amenities and environmental quality while the second focuses on conservation open space for protecting existing landscape and natural values (Maruani & Amit-Cohen

2007). In Australia, public open space is the third single most well-known venue for physical activity after street and home (Giles-Corti *et al.* 2005). In this regard, it is important to make sure that there is enough parks and public open space. WAPC mandates that 10% of the land in new housing developments must be allocated to public open space (WAPC 2000, p. 63). Increasing empirical evidence, in fact, indicates that the presence of public open space in urban contexts contributes to the quality of life in many ways (Chiesura 2004). Public open space also plays multiple roles in making cities more sustainable and pleasant places by providing ecological benefits, social benefits and economic benefits (Byrne and Sipe 2010).

(1) Public health benefits

Public open spaces are now widely identified as major contributors both to the quality of the environment, and to human health and well-being in inner city and suburban areas (Morries 2003). In Australia, nearly half of all Australians do not meet the daily recommendation of 30 minutes of physical activity (Armstrong *et al.* 2000). Recent research indicate that low levels of physical activity increase the risk of obesity and related diseases including diabetes, cardiovascular disease and cancer (Kaczynski & Herderson 2007). Hence, there is a positive relationship between health and public open space (CABE Space 2010).

Public open space has been linked with environments that are both more walkable and more playable, with aesthetics and street connectivity influencing patterns of use (CABE Space 2010). Therefore, improving physical activity levels and the use of public open space have been consistently identified as the top public health priority to reduce premature mortality and prevent chronic disease such as diabetes, obesity and hypertension (Great Communities Organisation 2007; Kaczynski & Herderson 2007). Moreover, active use of public open spaces or parks may reduce stress, feeling of anger, frustration and aggression (Groenewegen *et al.* 2006; Cheisura 2004). In fact, exposure to natural environment can improve people's health and well-being by providing restoration from stress and mental fatigue. In turn, this can enhance the feelings of social safety and reduce actual rates of aggressive behaviour and criminal activity (Groenewegen *et al.* 2006). Consequently, public open space plays an important role in encouraging physical activity which leads to improvement of mental health, physical health and wellbeing.

(2) Ecological benefits

The environmental benefits of public open space can be provided through the attenuation of 'heat island' effects, filtering air, reducing noise, sequestering carbon and attenuating storm-water (Byrne & Sipe 2010; Great Communities Organisation 2007; Sherer 2003). For example, in an area of complete tree cover (such as contiguous forest stands within parks), trees can remove pollutants, specifically as much as 15% of ozone, 14% of sulfur dioxide, 13% of particulate matter and 8% of the nitrogen oxide (Great Communities Organisation 2007; Sherer 2003). Trees also act as natural air conditioners to keep cities cooler, mitigating the effects of concrete and glass that can increase the heat under the summer sun (Sherer 2003). Moreover, trees and the soil under them can act as natural filter for water pollution (Sherer 2003). Trees are also more effective and less expensive to use in managing the flow of stormwater runoff than concrete sewers and drainage ditches (Sherer 2003). Moreover, public open space in appropriate areas can minimise the impact of people on vegetation and wildlife by protecting habitats and breeding grounds (Department of Planning and Urban Development 1991). For instance, the development of habitat areas and wildlife in Herdsman Lake, Stirling, has brought international recognition while providing much needed recreation resources for the community (Department of Planning and Urban Development 1991). Additionally, public open space may provide potential net revenue as local authorities could compensate for the carbon sequestering capacities of their space (Byrne *et al.* 2010).

(3) Social benefits

Aesthetically, public open space provides a context for social interaction and serves as tangible reminders of childhood and memories of community life. They also offer 'gateways' or opportunities for people to escape from the stresses of urban life (Burgess *et al.* 1988). Public open space also makes the inner-city neighbourhoods more liveable. For example, the barbeque facilities, picnic table, and playgrounds that exist in public open space make people enjoy gathering in, and using, public open space and in doing so, has an important role in promoting and fostering human contact and interaction (City of Banyule 2007). Access to public open space has been strongly linked to reductions in crime and in particular, to reductions in juvenile delinquency (Sherer 2003). In 1990, Florida Police documented a 28% decrease in juvenile arrests after the city of Fort Myers,

built a new youth recreation centre and started a new recreational and academic program (Great Communities Organisation 2007).

(4) Economic benefits

Recently, researchers found that public open space also provides significant economic benefits. They enhance property values, increase municipal revenue, bring in homebuyers and workers and attract retirees (APP 2002). In fact, many people are willing to pay a larger amount for property located close to parks or open spaces than for a home that does not offer this amenity (Sherer 2003; APP 2002; Byrne & Sipe 2010). For example, after the Centennial Olympic Park was built in Atlanta, adjacent condominium prices rose from $114 to $250 a square foot (APP 2002). Public open spaces often become one of a city's signature attractions and a prime marketing tool to attract tourists, conventions and businesses. Kings Park in Perth is one example. With an Education Centre that runs nature study programmes, more than 11000 children visit Kings Park annually (Department of Conservation and Environment 1981). Commonwealth Scientific and Industrial Research Organisation, government departments and tertiary institutions also used it regularly for research. Kings Park also has many important recreation value, facilities and features that attract more than 5 million people a year (Department of Conservation and Environment 1981). Furthermore, organised events held in public open space or parks often bring substantial positive economic impacts to their communities, filling hotel rooms and restaurants and bringing customers to local stores (Sherer 2003).

Attributes of Public Open Space

There are numerous observable factors that may influence the use of public open space. These factors include the quality and quantity of space; characteristics of potential users (such as age, gender, socioeconomic status and ethnicity); psychological factors (e.g. self-efficacy, perceived barriers) influencing personal preferences; the match between park attributes and needs of local users; park maintenance; access to competing local facilities; and perceived safety (Giles-Corti *et al.* 2005; Badland *et al.* 2010). For example, litter, the sign of vandalism and lack of management can give the feeling that the sites are potentially unsafe, which in turn, reduces the number of people using it (Barbosa *et al.* 2007). Giles-Corti *et al.* (2005) argued that distance from home to public open space will influence the frequency of use and type of usage. It is also likely that due to more working hours, it is important to provide easily accessible public open space as people do

not have time to visit remote regional parks for contact with nature (Grose 2009). Moreover, public open space and parks are more likely to stimulate activity if they were aesthetically pleasing with tree-lined paths rather than empty open space (Kaczynski & Herderson 2007).

Badland *et al.* (2010) argued that safer public open space have more street visibility and greater surveillance from surrounding houses, lighting and controlled pedestrian crossings. Crawford *et al.* (2008) examined the relations between neighbourhood socio-economic status and features of public open space. Their study identified that public open space in neighbourhoods with high socio-economic status possessed more amenities (e.g. drink fountains, picnic table), walking and cycling paths, trees that provide shade, water feature (pond, creek), lighting, and signage regarding dog access. Meanwhile, neighbourhoods with lower socio-economic status had a greater level of incivilities, for example litter, broken glass, evidence of alcohol use, graffiti or tagging.

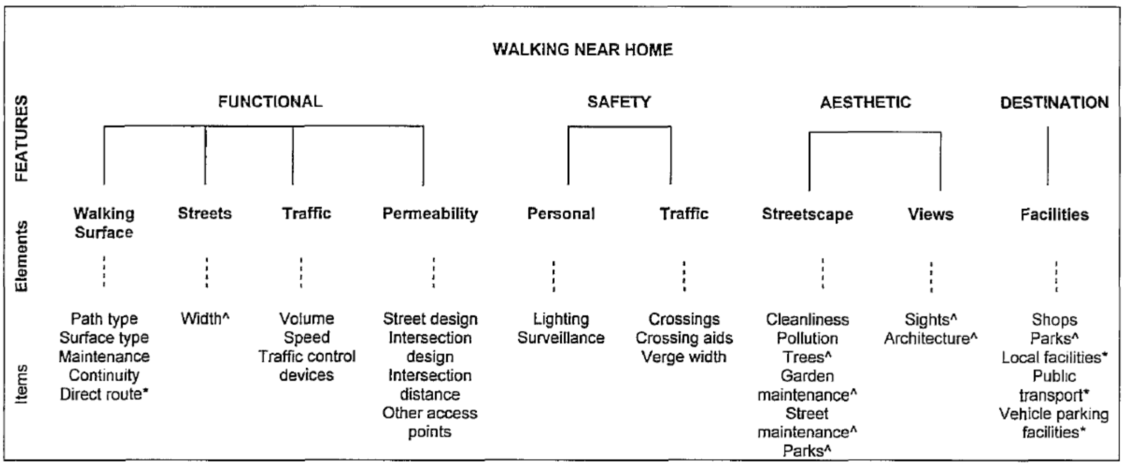
Golicnik & Thompson (2010) argued the importance of understanding weather in relation to the individual's use of public open space. Their study claimed that weather condition (temperature, wind, dryness and sunshine) influenced the amount of people using the public open space. People tend to stay indoors or restrict outdoor activities during higher temperature (summer). Hence, it is important to consider all the attributes, such as material selection, use of vegetation, shade provisions and urban geometry when designing a public open space.

Measuring the Quality of Public Open Space

Traditionally the quality of public open space has been assessed through a needs-based approach. This approach considers the socio-economic and bio-physical characteristics in the surrounding area of the public open space (Byrne and Sipe 2010). This approach assumes that people will minimise travel costs (e.g. time, fuel cost and energy) by using the closest available resource (Byrne and Sipe 2010). The approach is based on detailed community surveys, focus group research, participant observation, ethnographic data, analysis of census data, and detailed assessments of existing parks (Byrne and Sipe 2010). However, this approach is considerably time consuming and resource intensive.

The School of Population Health, University of Western Australia developed an audit instrument called Systematic Pedestrian and Cycling Environmental Scan (SPACES).

These frameworks are based on the features (the overall factors that summarise the physical environment); elements that influence each of those features (those factors that form the components of features); and items that influence the elements (factors that have the potential to be changed to improved an element (Pikora *et al.* 2002; Pikora *et al.* 2006). Figure 2 shows the factors included in the frameworks.



^Items included only in walking for recreation analysis
*Items included only in walking for transport analysis

Figure 1 Overview of the physical environmental factors included in the frameworks (Pikora et al. 2006).

The functional features included the physical attributes and quality of the path and street and reflect the basic structural aspects of the local environment (Pikora *et al.* 2006). Conversely, the safety feature consists of two elements – personal safety and traffic safety. The third factor is aesthetic features which showed the physical environment that is enjoyable for walking. This feature includes two elements – streetscape and views. Lastly, the destination features imply the availability of community and commercial facilities in the neighbourhood that provide reasons for people to walk such as schools, parks and public transport. The SPACES instrument was generally easy to use and was a reliable and practical instrument for collecting data. However, the usefulness of SPACES was limited by the need to visit each public open space to observe and rate the physical environment. Furthermore, it was an expensive measurement task for large-scale studies. Clifton *et al.* (2007) argued that SPACES instrument was designed mostly for use in Australia because some of the features measured were poorly matched to American environment. For example, there is no differentiation between residential and commercial driveways, no questions about the degree of enclosure or the setback of buildings on the street. Therefore, the question about number of road lanes was changed to include all

driving lanes (turning lanes) in order to allow a better assessment of conditions at street crossings (Clifton *et al.* 2007).

The Centre for Built Environment and Health designed an auditing mechanism called Public Open Space Tool (POST) to assess the quality of public open space. The content validity was developed by a panel of six experts – two community architect and planners, one public health academic, two government experts on planning and one government expert on sport and recreation (Giles-Corti *et al.* 2005; Taylor *et al.* 2011; Badland *et al.* 2010). The POST collects data from 80 questions in four areas – activities, environmental quality/aesthetics, amenities and safety. The activity section is about the type of usage and the specific activities for which space was designed. The data for environmental quality/aesthetics based on the number of trees, walking path; quality of shade along the paths; park contours; the presence of graffiti and etc. The amenities section shows the presence of children's playground equipment, barbecues, picnic tables, parking facilities and public toilet. The safety factor included the presence of lightning, visibility of surrounding houses or roads, type of surrounding roads and presence of crossings. The POST features grouped by attributes are listed in Table 1.

POST			
Activity	**Environmental quality/ aesthetics**	**Amenities**	**Safety**
* Type of usage	* Trees	* Children's play equipment	* Lightning
* Type of activities	* Shadows	* Barbeque	* Visibility of surrounding houses/roads
	* Park contours	* Picnic table	* Presence of crossings
	* Graffiti	* Parking facilities	
		* Public transport	
		* Rubbish bin	
		* Drinking fountains	

Table 1 Public Open Space Tool

The POST instrument is an improvement of SPACES and addresses the limitations of SPACES. In SPACES instrument, the items measuring the number and height of the trees were based on subjective overall impressions – this will demonstrate poor reliability (Pikora *et al.* 2002). Hence, POST assess the canopy size as a means of characterising street trees (Pikora *et al.* 2002). However, visiting a large numbers of parks is time consuming and subject to the interpretation of data collectors. Moreover, POST and

SPACES do not include questions about the residents of socially advantaged and disadvantaged areas.

Alternatively, researchers proposed that a Geographic Information System (GIS) analysis could better assess the diverse needs of potential park users by evaluating the socio-demographic composition of park catchment (Byrne and Sipe 2010). GIS is a computed based tool for mapping and analysing features and events on earth (Long & Srihar 2004). GIS have been defined as 'automated systems for capture, storage, retrieval, analysis and display of spatial data' (Nicholls 2001). Moreover, GIS technology integrates common database operations such as query and statistical analysis, with maps (Long & Srihar 2004). It is a very powerful tool for acquiring and studying geographic data quickly and accurately based on different sets of hypothetical parameters (Nicholls 2001; Long & Srihar 2004). There are four conceptions of equity that should be considered when developing a need based GIS assessment techniques – equitable distribution, compensatory equity where resources are redistributed to those most in need to ameliorate inequalities; demand distribution where the most vocal residents get the most resources; and market based distribution (Byrne and Sipe 2010). Using GIS, researcher could examine the spatial distribution of different types of open space and the socio-demographic composition of residential areas, the relationships between open space type, socio-demographic characteristics while the potential quality of life issues could be explored by using the Australian Bureau of Statistics' socio-economic indexes for the areas (SEIFA) based on the census data for the cities (Byrne *et al.* 2010).

Taylor *et al.* (2011) describes a new remote-assessment approach by using Google Earth to provide fast and inexpensive measurement of the quality of public open space. They used an area in the southwest of Sydney as the study site due to the high density of children and different types of public open space in the area (Taylor *et al.* 2011). By using Google Earth, the time and resources required to conduct audits of public open space could be reduced greatly. However, not every question in POST could be covered by using Google Earth. Hence, in the study of Taylor *et al.* (2011), 14 items and one section of another item could not be assessed reliably because of low image resolution. Some examples of the question that had been removed are related to dog litter bags and watering of grass. Hence, remote sensing using Google Earth is not only limited by the low image resolution, it may also be up to three years out of date.

This paper introduces feature extraction techniques to address the limitations of the methods above in measuring the quality of open space. In digital image processing – feature extraction – visual features such as shape, size, pattern, tone (or hue), texture, shadows, site, association, colour, height (elevation) and depth are used to characterise images and describe the content of image (Japan Association of Remote Sensing 1999; Lillesand *et al.* 2004aa; Ivasic-Kos *et al.* 2010). Feature extraction is the process of generating features of interest to be used in the selection and classification tasks. The 'relevant' information about an object could be extracted through experiments and used as features to classify the object. The term 'feature' here refers to recognisable objects or structures in the image (e.g. vegetation types, urban materials, transportation features, land use/ land cover) with similar characteristics (whether they are spectral, spatial or otherwise) (Shah 2007; Spatial Energy n.d.; Sowmya & Trinder 2000; ERDAS Inc n.d.). Therefore, feature extraction aims to accurately retrieve these features and enhance the distinguishable of surface materials based on their spectral characteristics (Shah 2007; ERDAS Inc n.d.). Typically, feature extraction techniques are to map from larger and complex problem space into a smaller and simple feature space (Manolescu n.d.). General, feature extraction provides an elegant and efficient alternative (Manolescu n.d.).

The features of image in the image database are extracted and obtained feature space (or vector) is stored in the feature database. Hence, the feature space will compare the query image with the image in the feature database and retrieve the similar images with the smallest feature distance. Figure 2 described this process (Chora´s 2007).

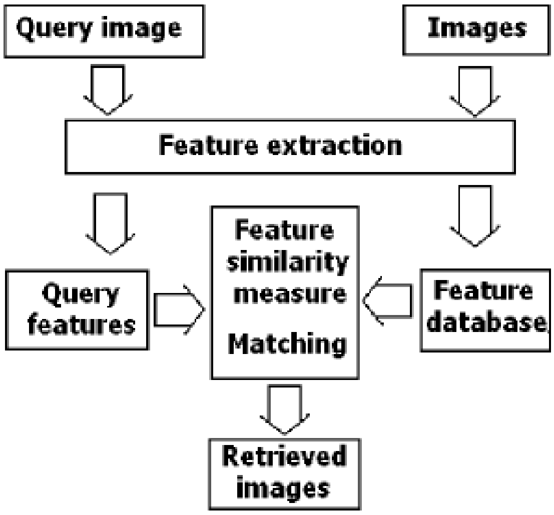


Figure 2 Process of feature extraction (Chora´s 2007).

There are two classes associated with feature extraction – information classes and spectral classes. Information classes refer to categories of interest, for example buildings, vegetation, water bodies, different tree species or forest types, etc (Overwatch Textron System 2008a). The spectral classes are groups of similar pixels with respect to the brightness values in the spectral channels of the data (Overwatch Textron System 2008a). The process of feature extraction thus matches the spectral classes in the image data to the information classes of interest (Overwatch Textron System 2008a). There are several feature extraction techniques in remote sensing including Normalises Difference Vegetation Index (NDVI), Principal Component Analysis (PCA), Minimum Noise Fraction (MNF), The Independent Component Analysis (ICA), Supervised Classification, and unsupervised Classification (Shah 2007; ERDAS Inc n.d.; Benediktsson *et al.* 2003).

NDVI is one of the most widely known feature extraction techniques used to examine vegetation health. It is an important vegetation index that responds to changes in the amount of green biomass as the seasonal and inter-annual changes in vegetation growth and activity can be monitored and the rationing reduces many forms of multiplicative noise (Jensen 2005b). PCA transforms the original remotely sensed dataset into a substantially smaller and easier to interpret set of uncorrelated variables that represent most of the information present in the original dataset. It is very useful for reducing the dimensionality of hyper-spectral dataset (Jensen 2005b). MNF was widely employed in remote sensing for data compression and noise reduction of hyper-spectral data. It is used to determine the true or inherent dimensionality of the hyper-spectral data, to identify and

segregate noise in the data, and to reduce the computation requirements of further hyper-spectral processing by collapsing the useful information into smaller set of MNF images (Jensen 2005b; Jensen 2005e). ICA presents a linear transformation to obtain the independent components and each component will contain information corresponding to specific feature (Shah 2007; ERDAS Inc n.d.).

Supervised classification is training closely controlled by the analyst. The identity and location of some of the land-cover types are known *a priori* through a combination of field-work, interpretation of aerial photography, map analysis and personal experience (ERDAS Inc n.d.; Jensen 2005c). In contrast to supervised classification, unsupervised classification is more computer-automated. The computer is required to group pixels with similar spectral characteristics into unique clusters according to some statistically determined criteria (Jensen 2005c). However, the techniques discussed above have the common disadvantage; they are all per-pixel classifiers. Moreover, the quality of the classification is based on the analyst's understanding of the concepts behind the classifiers available and knowledge about the land cover types under analysis (Lillesand *et al.* 2004b). As such, expert knowledge-based classification is needed to overcome the limitation.

Feature extraction technique will be used in this study as it can overcome the problem of time-intensity and high cost of using POST. Moreover, feature extraction was more accurate, easier and more straightforward to use. It also saved considerable labour costs (Visual Learning Systems 2004b). Figure 3 shows the cost-benefit analysis of feature extraction project compare to hand digitising methods (Overwatch Textron Systems 2008b).

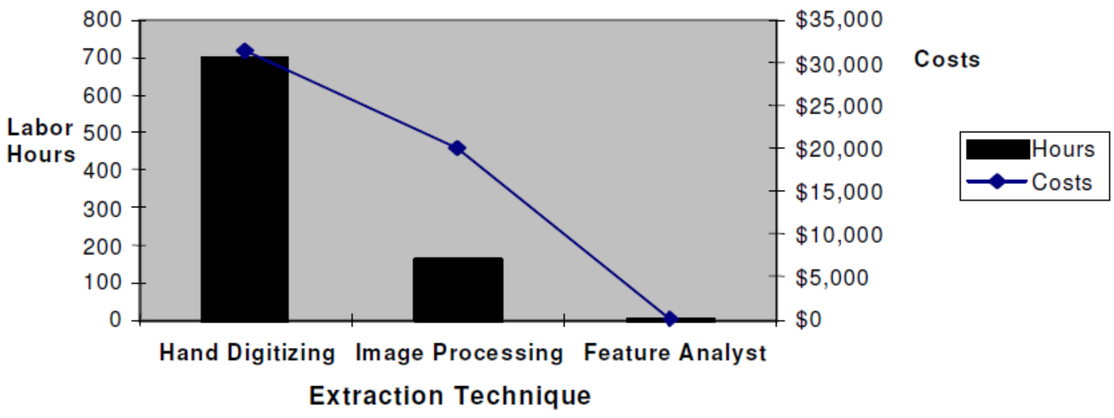


Figure 3 Cost-benefit analysis for feature extraction techniques for the 1999 multi-modality image fusion project (Overwatch Textron Systems 2008b).

Moreover, it can also address the limitation of low resolution from Google Earth. By using high resolution imagery, open space is not the same any more in whole image but objects such as trees, lakes are easily identifiable (Hiremath & Kodge n.d.). In addition, the cost of high resolution imagery decreases the need to update geospatial data – this can provide timely decision and increase the accuracy of the result (Visual Learning systems 2004b).

Conclusion

Based on the foregoing, it is clear from the academic literature that public open space provides an important and cost-effective opportunity for people to transform their local neighbourhood and improve their quality of life. The quality of public open space is essential in providing a better environment for the local neighbourhood. To date, there had been several methods used to measure the quality of public open space, both manually and remotely – but these instruments have their own limitations. Given advancement in technology and the availability of more detailed mapping software packages, there is an opportunity to improve on current methods of assessing the quality of public open space.

In acknowledgement of this emerging opportunity, this research aims to:

"Examine the feasibility of automating the Public Open Space Tool (POST) using high resolution satellite imagery and feature extraction technology to increase the efficiency of data collection for a large number of parks in the Perth Metropolitan Area".

Specifically, this paper has two objectives. The first objective is to develop a set of routines using geospatial technologies to extract features from public open spaces as an alternative to subjective POST audit. The second objective is to compare the accuracy of feature extraction techniques with on-ground application for the POST.

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Appendix A *Research Project Proposal*

Geospatial Automation of Ground Based Subjective Surveys: A Case Study of the Public Open Space Tool (POST)

Proposal

Introduction & Background

The Australian Bureau of Statistics (ABS) forecasts that Australia's population will rise to 35.9 million by 2050 (Bell *et al.* 2010). As the population grows and as more and more people choose to live in urban environments, city planners facing difficult challenges in their efforts to expand infrastructures. The increasing population will sorely influence the quality of life; for example, by losing precious public open space to urban infill, by placing residents in noisy locations, by concentrating social disadvantage, and by potentially undermining social cohesion (Byrne and Sipe 2010). Hence, city planner have to consider the importance of public open space which is important to health and wellbeing of urban residents and provides a range of ecosystem services benefits that are crucial if our cities are prosper over the long term (Byrne *et al.* 2010). Public open space can be defined as all open space of public value which offer important opportunities for sport and recreation and also act as a visual amenity, such as parks, community gardens and playgrounds (Taylor *et al.* 2011; Sunarja *et al.* n.d.; Byrne *et al.* 2010). Aesthetically, people enjoy gathering in and using public open space as it plays an important role in promoting and fostering human contact and interaction (City of Banyule 2007). Hence, urban design must ensure that public open space are easy to get to, are safe and have high levels of environmental quality (Sunarja *et al*. n.d.).

To assess the quality of public open space the Centre for Built Environment and health designed an auditing mechanism called the Public Open Space Tool (POST) (Appendix A). The tools was designed for auditing public open spaces such as parks and ovals, with particular emphasis on the physical attributes that may either encourage or discourage their use for physical activity (School of Public Health n.d.). What has become apparent is that visiting a large number of parks is time consuming and subject to the interpretation of data collectors. Over the past decade, researcher used 'needs based' approach to

examine the quality of open space by consider the socio-demographic and bio-physical characteristics of areas for which parks are needed, or where park facilities are (Byrne and Sipe 2010). It is necessarily based on detailed community surveys, participant observation, focus group research, ethnographic data and analysis of census data (Byrne and Sipe 2010). As this approach is considerably more time consuming and resource intensive than a standards approach, researchers suggested that a geographic information system (GIS) analysis could better assess the diverse needs of potential park users by evaluating the socio-demographic composition of park catchment (Byrne and Sipe 2010). Using GIS, researcher could examine the spatial distribution of different types of open space and the socio-demographic composition of residential areas (Byrne *et al.* 2010). Taylor *et al.* (2011) identified that populating the POST tool using the interpretation of Images in Google Earth can significantly reduce the amount of time and money spent collecting data. However, further efficiency could be gained through recently developed feature extraction techniques allowing for the assessment of a large number of parks at one time.

Aims

The overall aim of this research is to examine the feasibility of automating the Public Open Space Tool (POST) using high resolution satellite imagery and feature extraction technology to increase the efficiency of data collection for a large number of parks in the Perth Metropolitan area.

Objectives

1. Develop a set of automated routines using geospatial technologies to extract feature from public open spaces as an alternative to subjective POST audits.
2. Compare the accuracy of feature extraction techniques with on ground application for the POST.

Methodology

1. *Study site*

The study area is located at the City of Stirling, approximately 8 kilometres north of the Perth CBD, Western Australia (City of Stirling 2010). The City of Stirling is committed to the good management of the City's parks and reserves. The largest reserves in the City, Regional Open Space (ROS), are of particular crucial as they have various functions for informal active recreation, passive recreation, organised sports, environmental conservation and substantial green relief to the urban form of the City (City of Stirling

2008). Therefore, the Public Open Space Strategy has been developed by the City of Stirling as the framework that works to manage the recreation and open space assets and provide for current and future community needs (City of Stirling 2008).

2. *Data – Aerial image and Census data*

Using LIDAR from the Department of Water and high resolution 4-band aerial imagery from Landgate while socio-demographic data taken from the Australian Bureau Statistics.

3. *Feature Extraction*

Feature extraction enables GIS analysts to rapidly and accurately collect vector feature data from high-resolution satellite and aerial imagery. Advanced spectral analysis enables the identification of subtle differences in landcover using a range of indices and functions. These discriminators enable the skilled operator to generate classes of landcover or vegetation that reflect the complexity of the spectral characteristics in an image source (Geoimage 2010).

4. *Analysis*

Examine the difference between results of feature extraction and on ground assessments of the POST. Kappa statistic will be used for the statistical measure of agreement between two observers.

Budget

Items	Cost	Source
Aerial photo	$2000	Provided by Dr. Bryan Boruff
Remote Sensing software	$800	Provided by Dr. Bryan Boruff
ESRI GIS software; ArcGIS	$200	
Travel for Park Audit	$200	
Printing	$50	
Total	***Approximately $450***	

Timeline of research and report development

	Month	Jan-Feb	Mac	Apr		May			Jun			Jul		Aug			Sep			Oct		
	Date		28/3	4/4	18/4	2/5		16/5	6/6		20/6	4/7	18/7	1/8	15/8	29/8	12/9		26/9	10/10	24/10	
Literature Review	Background reading						**Milestone 1 – Literature review for supervisor to comment**			**Milestone 2 – Final Literature Review**								**Milestone 3 – Draft of research article**				**Milestone 4 – Finish of project: Final report to be submit**
	Base reading of POST																					
	Analysis of study site																					
	Analysis of content																					
	Finalize literature review																					
Data collection	Aerial image																					
	Analysis of Census data																					
GIS analysis	Spatial distribution																					
	Determine the spatial pattern of demographic change																					
	Feature extraction																					
Analysis of information	POST survey/analysis																					
	Combine all the information																					
	Addresses each of the objective																					
Development of action plan	Collaborative discussion and recommended actions																					
Draft report																						
Final report and presentation																						

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Appendix A *Public Open Space Tool*

QUALITY OF PUBLIC OPEN SPACE TOOL (P.O.S.T.)

1) Reference Number ☐☐☐☐☐☐☐☐

2) Address ________________________

____

3) Area (hectares) ☐☐☐.☐☐☐☐

4) Postcode ☐☐☐☐

5) Geocode X ☐☐☐.☐☐☐☐☐☐

Y ☐☐☐.☐☐☐☐☐☐

6) Year of Establishment of POS: ____________

Activities

7) Type of usage *(tick all relevant)*
- Active-formal ☐1
- Active-informal ☐1
- Passive only ☐1 *(go to Q9)*

8) For what type of activities is the space designed? *(tick all relevant)*
- Tennis (grass/hard courts) ☐1
- Soccer ☐1
- Football ☐1
- Netball (grass/hard courts) ☐1
- Cricket ☐1
- Baseball ☐1
- Walking (only if paths) ☐1
- Cycling ☐1
- Fitness Circuit ☐1
- Basketball/Netball Hoops ☐1
- Hockey ☐1
- Athletics ☐1
- Rugby ☐1
- Children's playground ☐1
- Other ____________ ☐1

Environmental Quality

9) Is the POS on the beach/river foreshore?

Yes ☐ 1 No ☐ 2

10) Are there water features within the POS?

Yes ☐ 1 No ☐ 2 *(Go to Q13)*

11) Type of water feature *(tick all relevant)*
- Lake ☐1
- Pond ☐1
- Water Fountain ☐1
- Stream ☐1
- Other ____________ ☐☐

12) Estimate the percentage of the POS occupied by the water feature(s) *(tick one)*
- Up to 25% ☐1
- 26% & up to 50% ☐2
- 51% -75% ☐3
- More than 75% ☐4

13) (a) Are there other aesthetic features in the POS?

Yes ☐ 1 No ☐ 2 *(Go to Q14)*

(b) Which of the following features are present? *(tick all relevant)*
- Statues ☐1
- Gazebos/Rotunda ☐1
- Sculptures ☐1
- Ducks/Swans ☐1
- Bridge ☐1
- Rocks ☐1
- Other ____________ ☐1

14) Are there trees in this POS?

Yes ☐ 1 No ☐ 2 *(Go to Q18)*

15) Estimate the approximate number of trees present *(tick one)*
- 1 – 50 trees ☐1
- 50 – 100 trees ☐2
- More than 100 trees ☐3

16) Where are the trees placed? *(tick all relevant)*
- Perimeter all sides ☐1
- Perimeter some sides ☐1
- Along walking paths ☐1
- Random placement throughout ☐1
- Other ____________ ☐1

17) Are there gardens in this POS?

Yes ☐ 1 No ☐ 2

18) (a) Are there walking paths or cycleways within or around the POS? *(tick all relevant)*
- Walking path/s ☐1
- Designated dual-use path/s ☐1
- None ☐1 *(Go to Q20)*

(b) Shade along paths *(tick one)*
- Very good (canopies of many trees touch) ☐1
- Good (canopies of some trees touch) ☐2
- Medium (canopies don't touch but trees close together) ☐3
- Poor (canopies of trees don't touch and trees spread apart) ☐4
- Very poor (little or no shade) ☐5

19) Describe the placement of paths within the POS *(tick all relevant)*
- Perimeter, all sides ☐1
- Perimeter, some sides ☐1
- Diagonal ☐1
- Radial ☐1
- Path around water/visual feature ☐1
- Other ____________ ☐1

20) Is there evidence that the grass is watered?
Yes ☐1 No ☐2

21) Are dogs allowed? *(tick all relevant)*
Yes, on leash at all times ☐1
Yes, on leash at certain times ☐1
Yes, no leash specified ☐1
Not allowed ☐1 *(go to Q23)*
Not specified ☐1 *(go to Q23)*

22) Is access for dogs: *(tick one)*
Restricted from some areas ☐1
Allowed all areas ☐2
Not specified ☐3

23) Is graffiti present?
Yes ☐1 No ☐2

24) Is vandalism evident?
Yes ☐1 No ☐2

25) Is there litter throughout the POS?
Yes ☐1 No ☐2

Amenities *(tick one only for each question)*

26) Is children's play equipment present?
Yes ☐1 No ☐2 *(go to Q30)*

27) What items of play equipment are present? *(please tick all relevant)*
Swing/s ☐1
Slide/s ☐1
Climbing Equipment ☐1
Hanging Bars/Rings ☐1
SeeSaws/Rockers ☐1
Bridges/Tunnels ☐1
Activity Panels (eg noughts & crosses) ☐1
Cubby House/s ☐1
Other (specify) ____________ ☐1
____________ ☐☐

28) What is the playground surface? *(tick all relevant)*
Sand ☐1
Grass ☐1
Rubber ☐1
Gravel or pebbles ☐1
Woodchips ☐1
Other (specify) ____________ ☐1
____________ ☐☐

29) Is playground shaded? *(tick one only)*

	Area 1	Area 2
Partial cover/shade	☐1	☐1
Total cover/shade	☐2	☐2
No cover/shade	☐3	☐3

30) Are barbecues present?
Yes ☐1 No ☐2

31) Are picnic tables present?
Yes ☐1 No ☐2

32) (a) Are there parking facilities serving the POS?
Yes ☐1 No ☐2 *(Go to Q33)*

(b) Estimate the number of bays *(tick one only)*
0 - 20 ☐1
21-50 ☐2
More than 50 ☐3

33) Are there public access toilets?
Yes ☐1 No ☐2

34) Is there a kiosk/café present? *(tick one only)*
7 days per week ☐1
Weekdays only ☐2
Weekends only ☐3
No ☐4

35) Is there access to public transport within one block of POS?
Yes ☐1 No ☐2

36) Is there seating present?
Yes ☐1 No ☐2

37) Are there clubrooms/meeting rooms present?
Yes ☐1 No ☐2

38) Are rubbish bins present?
Yes ☐1 No ☐2

39) Are dog litter bags provided?
Yes ☐1 No ☐2 *(Go to 41)*

40) In how many locations in POS are dog litter bags present?
____

41) Are there taps or other water sources accessible for dogs?
Yes ☐1 No ☐2

42) Are drinking fountains present?
Yes ☐1 No ☐2

Safety

43) Is there lighting within the POS? (i.e., not just street lighting)
Yes ☐1 No ☐2 *(Go to Q45)*

44) Where is the lighting located? *(Tick all relevant)*
Around courts, buildings, and equipment ☐1
Along paths ☐1
Perimeter all sides ☐1
Perimeter some sides ☐1
Random throughout POS ☐1

45) From the centre of the POS, how visible are surrounding roads? *(tick one)*

Road/s clearly visible from the centre of the POS ☐1
Road/s is partly visible from centre of the POS ☐2
Road/s cannot be seen from the centre of the POS ☐3

46) (a) From the centre of the POS, how visible are the surrounding houses? Clear visibility means you can clearly see windows, back yards, or front yards of houses overlooking the park? *(tick one)*

Road/s clearly visible from the centre of the POS ☐1
Road/s is partly visible from centre of the POS ☐2
Road/s cannot be seen from the centre of the POS ☐3 (go to Q47)

(b) How many of these houses overlook the park? *(tick one)*

More than 10 ☐1
Between 5 and 10 ☐2
Between 1 and 5 ☐3

(c) Is there any area of the POS where you are unable to clearly see surrounding houses?

Yes ☐1 No ☐2

47) Are all roads surrounding the POS minor roads or cul-de-sacs?

Yes ☐1 *(Go to Q49)* No ☐2

48) a) Does the major road/s have a zebra crossing to assist access to the POS?

Yes ☐1 No ☐2

b) Does the major road/s have a pedestrian crossing with signals to assist access to the POS?

Yes ☐1 No ☐2

49) To what extent do you agree or disagree with each of the following statements regarding this POS? *(circle one number for each item)*

1 = Strongly Agree (**SA**)
2 = Agree (**A**)
3 = Neither Agree nor Disagree (**Neither**)
4 = Disagree (**D**)
5 = Strongly Disagree (**SD**)

	S.A.	**A**	**Neither**	**D**	**S.D**
•P.O.S. is interesting for walking	1	2	3	4	5
•P.O.S is suitable for casual ball sports	1	2	3	4	5
•P.O.S. is suitable for cycling	1	2	3	4	5

I HAVE CHECKED EACH QUESTION ☐

Appendix E Sample pages of format journal article

Exercise and Substance Use Among American Youth, 1991–2009

Yvonne M. Terry-McElrath, MSA, Patrick M. O'Malley, PhD, Lloyd D. Johnston, PhD

Background: The National Institute on Drug Abuse has called for increased research into the use of physical activity in substance abuse prevention, specifically research into physical activity type and context.

Purpose: This paper examines the relationships between (1) secondary school student substance use and (2) exercise in general and school athletic team participation, and examines such relationships over time.

Methods: Nationally representative cross-sectional samples of 8th-, 10th-, and 12th-grade students were surveyed each year from 1991 to 2009. Substance use measures included past 2-week binge drinking and past 30-day alcohol, cigarette, smokeless tobacco, marijuana, and steroid use. Analyses were conducted during 2009–2010.

Results: Across grades, higher levels of exercise were associated with lower levels of alcohol, cigarette, and marijuana use. Higher levels of athletic team participation were associated with higher levels of smokeless tobacco use and lower levels of cigarette and marijuana use across grades and to higher levels of high school alcohol and steroid use. Exercise helped suppress the undesired relationship between team participation and alcohol use; exercise and athletic team participation worked synergistically in lowering cigarette and marijuana use. Observed relationships were generally stable across time.

Conclusions: There appear to be substantive differences between exercise and team sport participation in relation to adolescent substance use. These findings from cross-sectional data suggest that interventions to improve levels of general physical activity should be evaluated to determine if they help delay or reduce substance use among youth in general as well as among student athletes.
(Am J Prev Med 2011;40(5):530–540)

Introduction

The costs of tobacco, illicit drug, and alcohol abuse are staggering[1–4]; improved prevention methods are needed. Support for exercise in preventing substance use is well grounded in theory and neurobiology.[5–14] However, the National Institute on Drug Abuse has identified important knowledge gaps in the relationship between physical activity and substance use including "type, amount, context (including access), and persistence of physical activity."[15] The current study focuses on relationships between physical activity type and adolescent substance use.

Adolescence is a key developmental stage for prevention; most substance initiation occurs at ages <18 years.[16,17] Early onset associates with heavier, problematic substance use[18]; delaying onset results in substantially less lifetime use and dependence.[19,20] Effective strategies to increase physical activity among adolescents do exist.[21,22] Thus, utilizing physical activity in substance use prevention among adolescents is promising if relationships between adolescent physical activity and substance use can be further explored.[15]

Youth substance use and poor exercise are interrelated.[23,24] However, studies indicate no single relationship between adolescent exercise and substance use. Alcohol has associated positively to exercise in some studies,[25–29] negatively in others,[30,31] and has been unassociated in others.[32,33] For cigarettes, exercise primarily associates with lower levels of use[25,34,35]; however, some studies have shown no or inconsistent findings.[36,37] Relationships between exercise and illegal drug use are generally negative,[25,30,38,39] but positive with smokeless tobacco.[25,35,39]

Such inconsistencies may associate with how exercise is defined. Team or competitive sport participation asso-

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prevalence rates are still high enough to detect relationships (e.g., an average of more than 20% of eighth-graders reported past 30-day alcohol use from 1991 to 2008).[17] Further, the data show that more middle school youth participate in athletic teams than high school youth; thus, low participation rates cannot account for observed differences. The population participating in athletic teams throughout the high school years may exhibit qualitatively different motivations and personality characteristics that are associated with higher levels of alcohol use. Research confirms substantial attrition in almost all team sports as students move from middle school to completion of high school.[61] Part of such attrition may be attributable to a higher level of competition; by the senior year, student sport participation is limited to the most skilled and likely most competitive,[61] a characteristic associated with increased alcohol consumption.[62]

Limitations

These findings should be considered within their limitations. Available physical activity and substance use measures were single-item self-report measures. The single-item general exercise measure did not incorporate exercise intensity or duration, and the single-item team sports participation item did not account for participation in team sports outside of school environments or differences in type of team sport. Some school districts do not offer school-based team sports; youth who were involved in non-school-based athletic teams may have been excluded. Further, research has indicated significant differences in substance use rates by type of team sport.[40,63,64] The data are cross-sectional and thus cannot be used to draw causal conclusions. However, as noted previously, 30-day substance use was chosen as the time frame to minimize endogeneity. Such limitations notwithstanding, the present study's use of a representative national sample and consistent measures over time contribute substantially to understanding the relationships between adolescent physical activity and substance use.

Conclusion

The current study supports the possible preventive effects of physical exercise on adolescent substance use and indicates important differences exist between general exercise and team sports participation. Frequent exercise appears to be associated strongly with lowered levels of adolescent alcohol, tobacco, and marijuana use for the general student population and school athletic team participants.

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