Empty Parks: An Observational and Correlational Study Using Unmanned Aerial Vehicles (UAVs)

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Abstract: If a neighbourhood park fails to meet the needs of its residents usage may decrease, which potentially makes the park vulnerable to crime and social disorder. Despite the popularity of studying park visitation or park-based physical activity, there is a lack of studies on factors associated with empty parks. This study explores factors related to the underutilisation of neighbourhood parks in Salt Lake County, Utah, USA, using a novel data collection approach – unmanned aerial vehicles (UAVs). The findings from exploratory video analysis and inferential statistical modelling show that park programs and neighbourhood environments, as well as temporal aspects, are associated with the likelihood of empty parks. Additional analyses of no-child, no-senior, and no-female parks, respectively, support these findings. An understanding of park-use dynamics could promote effective plans, policies, and programs that promote park utilisation and park-based physical activity.

Keywords: Neighbourhood parks, underutilisation, direct observation, drones, unmanned aircraft systems, UAV.

1 Introduction

1.1 Background

A neighbourhood park is an important venue where people engage in physical and social activities. They offer a wide variety of psychological, social, and health benefits for users and residents (CHIESURA 2004, KONIJNENDIJK et al. 2013, LEE & MAHESWARAN 2011). Such benefits, however, can be enjoyed only if people use the parks. If a neighbourhood park fail to meet the needs of nearby residents, usage may decrease, and parks could become more vulnerable to crime and social disorder. In practice, non-use of existing parks could be an argument against improving park facilities or building new parks (GOLD 1977). In spite of the popularity of studying park visitation, there is a lack of studies on factors associated with empty parks. This lack of understanding might lead to a lack of appropriate interventions – effective park planning, design, and programming, which would result in what we see in American cities – the underutilisation of neighbourhood parks (COHEN et al. 2016).

As a new observation tool, the use of UAVs could foster a more consistent and comprehensive measurement of park use. As UAVs cover a greater area in a shorter amount of time than other methods, they are expected to save time and money required for data collection. UAV-recorded video files allow for post-data processing and validation (LENHART et al. 2008). In addition, as they capture not only the number of people but also their activities, attributes, and spatial patterns in a more accurate way, they are more informative (PARK & EWING 2017).

Thus, this study uses UAVs to collect park-user data in neighbourhood parks and explores factors related to their underutilisation. We call a neighbourhood park empty when there is

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no single person within its boundary at the time of the UAV observation. The data analysis includes two parts. First, we conduct an exploratory analysis of the UAV-captured video data as well as secondary spatial data to understand how the conditions of empty parks and surrounding neighbourhoods are different from those of more populated counterparts. Because we observed each park multiple times at different periods, we also explore how the empty parks become reoccupied at other times (e. g., morning vs. afternoon). Second, we develop statistical models that estimate the likelihood of a park being empty.

This study provides empirical evidence of park non-use with regard to park and neighbourhood design characteristics. An understanding of park-use dynamics could prompt planners, landscape architects, and municipal park officials to collaborate to formulate more effective plans, policies, and programs that promote park utilisation and park-based physical activity. The use of a novel data collection approach – unmanned aerial vehicles (UAVs) – highlights the possibility of a more consistent and cost-effective measurement of park uses.

1.2 Factors Associated with Park (Non-)use

Several studies have explored park design and neighbourhood characteristics in terms of the level of park use. For example, park size, the number of facilities, and park maintenance were found to be significant influences on overall park use (COHEN et al. 2013, SLATER et al. 2016). In addition, levels of park use vary depending on users' age, sex, and temporal differences. For older adults, park proximity and social support were highly correlated to park use (MOWEN et al. 2007). The presence of playgrounds, natural features, and good levels of maintenance were shown to be significant factors affecting children's park use (LOUKAITOU-SIDERIS & SIDERIS 2009). In addition, park use is also known to be higher on weekends than on weekdays and higher in the afternoon and evening hours than in the morning (VAN HECKE et al. 2017). Although few studies have directly attempted to understand what park and neighbourhood design characteristics could influence people to not use nearby parks, there is evidence of associations of park and neighbourhood attributes with park use or park-based physical activity that imply certain environmental barriers can deter certain group(s) of people (e. g., children, seniors, females) from using parks.

1.3 Use of Drones in Observational Research

When using a UAV to investigate attributes and activities of people in outdoor public spaces, researchers must consider practical implications and social complications of their method. For one, they must ensure that the remote pilot follows UAV operational rules governed by an aviation administration (e. g., US FEDERAL AVIATION ADMINISTRATION 2016). For most agencies, the rule requires UAVs to be registered, remain within the visual line-of-sight of the remote pilot, and not fly above people, at night, or beyond certain heights (e. g., 400 ft.; 122 m in US FAA 2016) above ground level.

Researchers must also bear in mind that the deployment of UAVs in civil applications may raise safety, ethical, and privacy issues (FINN & WRIGHT 2012; RAPP 2009). One legal review (FINN & WRIGHT 2012) found that a UAV flight within or too close to a private property might lead to trespass or nuisance claims by homeowners. On the other hand, they also found that privacy claims are limited to wherever "a UAV captures images that could have been obtained from civilian aircraft travelling in a legally authorised manner," that is, data already available to the public (FINN & WRIGHT 2012, p. 642). As the use of UAVs becomes more popular with the public, a survey using a UAV in a public space may raise fewer concerns. For both safety and reliability, researchers must ensure the provision of sufficient training to UAV pilots in advance and conduct preliminary surveys of study sites.

1.4 Study Context

Study sites are neighbourhood parks in Salt Lake County, Utah (Figure 1). Salt Lake County is the most populated county in Utah, where the state capital, Salt Lake City, is located. As of 2018, the US Census estimates, Salt Lake County has a population of 1.2 million. The total area is 807 square miles (2,090 km^2). The climate varies widely; summer is hot and dry, and winter is cold and snowy. While the Salt Lake region is noted for heavy snow and ski resorts, the average temperature in January 2019 was 28.6°F (-1.9 °C; NOAA 2019). Annual precipitation in Salt Lake County in 2018 was 17.8 inches (45.2 cm), which was much lower than the US average of 34.7 inches (88.1 cm; NOAA 2019). Salt Lake County has 17,178 acres of public parks (69.5 km^2; 3.3 % of the total county area), including 739 acres of neighbourhood parks (3.0 km^2; SLC Park & Recreation, 2015).

2 Data and Methods

2.1 Data

Data collection and analysis in this study involve three steps: 1) UAV-based video data collection of park usage and physical characteristics, 2) exploratory case study of empty parks, and 3) inferential statistical analysis of the relationships between empty parks and physical environments as compared to thriving parks. This study selected 30 neighbourhood parks in Salt Lake County, Utah, based on the diversity of their surrounding neighbourhoods' characteristics (Figure 1). Following a national study of park use (COHEN et al. 2016), this study limited the park size to between 2 and 20 acres to focus on the use of neighbourhood parks.

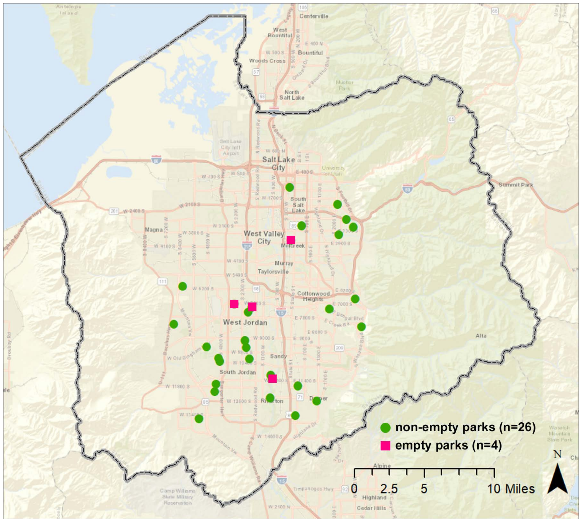

Fig. 1: Map of park sites in Salt Lake County, Utah, USA (n=30)

The observations entailed the use of a commercial UAV, DJI Phantom 4 Professional, carrying a fully stabilised 4K video camera. In the initial phase of the research, the researchers developed an observational method using UAVs and tested its reliability and validity (PARK & EWING 2017 in press). Data collection was conducted in four steps (Figure 2): 1) In a preliminary visit, an operator set a flight path and specific waypoints considering park boundary and obstacles; 2) data collection began by jotting down contextual information such as weather, park facilities, and conditions (e. g., organised event), following a field observation protocol; and 3) the UAV automatically flew through the preset waypoints and recorded the area.

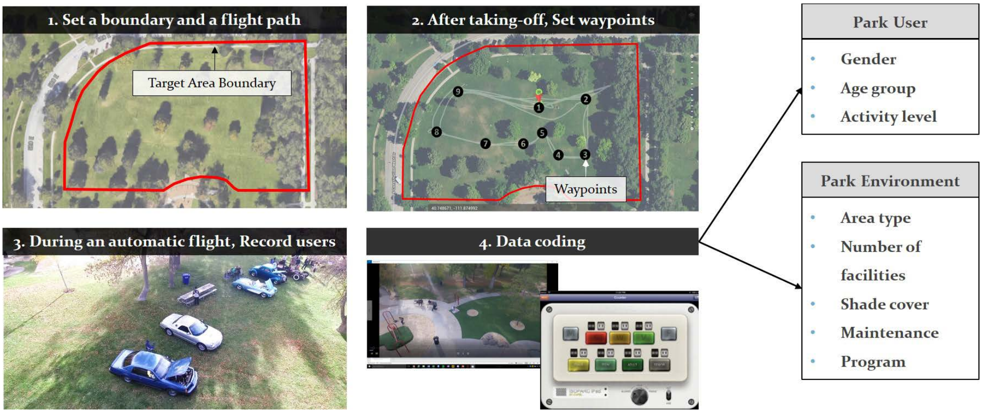

Fig. 2: Park-user data collection process using UAVs

After the on-site flights, 4) a video assessor collected park-user data by watching the recorded video files (Figure 2). The data coding procedure to count park users followed a systematic observation tool, SOPARC (System for Observing Play and Recreation in Communities; MCKENZIE et al. 2006). In SOPARC, an observer scans a target area from left to right and codes attributes and activities of each individual in the area. As a result, we geocoded each user's location on a GIS map and obtained aggregate data – counts by gender (female, male), age group (child, adult, senior), and activity level (sedentary, moderate, vigorous).

The data were collected in the fall of 2017. To understand park-use patterns across different times, each park was observed six times in total – two days of a week (one weekday and one weekend) and three times of a day (morning: 8-10 AM, early afternoon: 12 noon-2 PM, late afternoon: 4-6 PM). Each observation in a park took 10 to 15 minutes, enabling the data collection of five to six parks per two-hour observation period. Coding of the recorded video took approximately 20 minutes for each park's observation. This confirms PARK & EWING (2017) showing that UAV observation could save person-hours significantly, even after accounting for the time spent on video counts.

We conducted two inter-rater reliability tests – the extent to which two or more observers agree. First, two observers concurrently watched a video file from the UAV, and digitised park users in a GIS and coded their personal attributes independently. A total of 155 park users were digitised, and the COHEN's kappa statistics (COHEN 1960, MCHUGH 2012) were 0.92 [CI: 0.86 – 0.98] for gender, 0.87 [CI: 0.80-0.93] for age group, and 0.78 [CI: 0.69 – 0.86] for activity level. Thus, we conclude that the UAV-based observation of park users demonstrates "substantial" to "almost perfect" levels of inter-rater reliability.

Second, we examined the inter-rater reliability of the park users' locations. The differences of the geocoded location of park users between two raters were 1.04 meter on average (minimum: 0.04, maximum: 4.31, standard deviation: 0.93). Following the guideline of the FEDERAL GEOGRAPHIC DATA COMMITTEE (1998), the computed root-mean-square error (RMSE) between two observers is 1.39 meter, demonstrating a robust level of location precision for our UAV data collection protocol.

2.2 Analysis

An exploratory case study approach was undertaken to meet the objectives of evaluating the characteristics of the empty park by different users. In this case study, we first checked empty parks by different user type (i. e., child, senior, and female) after considering time differences (morning, lunch, afternoon) and weekend-weekday differences. Then, by employing UAV-based video analysis and GIS analysis using secondary data, we analysed which environmental barriers at the park and surrounding neighbourhoods might discourage park visitation. This exploratory analysis informed the variable selection in statistical modelling, the next step of the study. Each case includes video screen captures, neighbourhood-level GIS analysis, descriptive statistics, and interpretations of data. Data from UAV video analysis and secondary sources are summarized elsewhere (PARK in press).

In addition, the statistical approach of this study is a multilevel model that demonstrates the data structure. The data are hierarchical, with individual observations nested within a park (six observations per park). Six observations share the characteristics of both the park and the adjacent neighbourhoods. Thus, we modelled the likelihood of empty parks (e. g., no single person per observation period) using a multilevel logistic regression model. The models were run in R 3.6.1 Software using *glmer* function (*lme4* package, BATES et al. 2014). For variable selection, we employed a Lasso-type regularisation – a variable screening method to reduce the number of variables in a generalised linear mixed model (using *glmmLasso* package, GROLL 2017, SCHELLDORFER et al. 2014). For the penalty parameter, a lambda value with the lowest AIC (Akaike Information Criterion) score was used (GROLL 2017).

3 Results

3.1 Exploratory Case Study

Out of 180 observations – 30 parks and six observations each, 47 cases (26 %) were empty (i. e., no single person). At the park level (n = 30), more than half the parks (n = 17; 57 %) were empty (i. e., no single person) at least once out of six observations. Among them, nine parks appeared to be empty at three or more observations (with four parks being empty at five out of six observations). In terms of different user attributes, there are 133 video files having at least one person during the UAV observation. Out of 133, women didn't appear in 20 cases (15 %), while men did not show up only in eight cases (6 %). No-child cases were found in 38 observations (29 %) when any other age group of people were observed. Interestingly, no-senior cases were found in almost two-thirds of the observations (n = 82; 62 %).

For each "emptiness" case – empty parks, no-female, no-child, or no-senior, we selected one park for an exploratory case study. Table 1 shows four case sites. In Table 1, we provided two figures for each park – UAV-captured video imagery of the park and a satellite map of the park and surrounding neighbourhoods (with a location and direction of the video footage marked). We also present a few variables that might contribute to the emptiness in each case. Average values from the 30-park dataset are also provided for comparison.

Table 1: Video and GIS analysis of four case parks

Category	Park attributes	Neighbourhood attributes
Empty park: *Jordan Meadows Park*	 • Area: 4.0 acres (Avg.: 7.5 acres) • Maintenance: poor • Picnic zone: no (found on 70 % of parks) • Sports Field: no (found on 67 % of parks)	 • Entropy[1]: 0.1 (Avg.: 0.5) • Transit Stop Density[2]: 0 (Avg.: 12.4) • Median Household Income[3]: $67,389 (Avg.: $77,435)
No-female Park: *Constitu-tion Park*	 • Area: 13.7 acres (Avg.: 7.5 acres) • Organised Activities: 0 • Trail: no (found on 70 % of parks) • Creek/pond: no (found on 13 % of parks)	 • Crime Index[4]: 183 (Avg.: 119) • Entropy[1]: 0.4 (Avg.: 0.5) • Population Density (1000 peo ple/sq.mi.)[3]: 8.4 (Avg.: 9.3)

1 Entropy index, as a land-use diversity variable, measures balance between three different land uses – residential, commercial, and public. The entropy calculation is: entropy = – [residential share*ln(residential share) + commercial share*ln(commercial share) + public share*ln(public share)] / ln(3), where ln is the natural logarithm of the value and the shares are measured in terms of total parcel land areas in a ¼-mile buffer from a park. We expect mixed-use areas to generate more pedestrian activity (hence park use) than single-use residential areas.

2 Transit stop density: the number of stops divided by the area of a ¼-mile buffer (sq.mi.).

3 Data for population density (1000 people/sq.mi.), median household income, and % of non-Hispanic whites come from American Community Survey 2011-2015 five-year estimates. We gathered data at the census tract level and assigned them to the ¼-mile mile buffers based on the relative areas of the census tracts (i. e., the spatial apportioning technique).

4 Esri®'s 2016 Crime Index.

Table 1 (continued)

Category	Park attributes	Neighbourhood attributes
No-child Park: *Harmony Park*	 • Area: 9.1 acres (Avg.: 7.5 acres) • Organised Activities: 0 • Maintenance: poor • Trail: no (found on 70 % of parks)	 • Crime Index[4]: 516 (Avg.: 119) • Median Household Income[3]: $33,995 (Avg.: $77,435) • Non-Hispanic white[3]: 51.2 % (Avg.: 81.6 %)
No-senior Park: *Riverfront Park (Midas Ponds)*	 • Area: 12.3 acres (Avg.: 7.5 acres) • Organised Activities: 0 • Picnic Zone: no (found on 70 % of parks) • Sports Field: no (found on 67 % of parks)	 • Walk Score®: 22.5 (Avg.: 40.6) • % of 4-way Intersections[5]: 12.5 (Avg.: 16.6) • Crime Index[4]: 153 (Avg.: 119)

For the empty park, we chose Jordan Meadows Park because it was occupied only once – with two persons – out of six observations. The park was poorly maintained and had no picnic zone or sports field to attract visitors. Even with its moderate size (4.0 acre), the park lacked various facilities; only a tennis court, a playground, and an obsolete basketball court were found, and the rest was a lawn with some trees. The surrounding neighbourhoods were primarily residential (80 % of parcels), having low entropy level and poor transit access (no transit stop in a ¼-mile buffer), which could deter visitation from people living farther away than the adjacent properties.

Constitution Park was selected for a no-female park. There was at least one male at five observation cases – ranging from one to five – while women were observed only in two cases. Note that this park was mostly underutilised; its total user volumes range from 0 to six with a mean of 2.8. Although this park was relatively big (13.7 acres) and had several facilities,

[5] The proportion of 4-way intersections over all intersections within a ¼-mile buffer

including a tennis court and sports field, most of facilities were sports-based and no dedicated trail or ample shade were provided to accommodate sedentary-to-moderate levels of physical activity (e. g., walking, jogging). It is worth noting that the crime index was relatively high (183, compared with the overall average of 119) while there were no commercial areas near the park. Like the other cases, we found no organised events across different times of the day and days of the week.

For a no-child park, we selected Harmony Park because of its notable discrepancy between overall occupancy and the number of children visiting. The park was occupied at all six observations – ranging from five to sixteen visitors – but in only one case did we find children. The park was poorly maintained, lacked a trail, and did not have any organised event during the six observations, which is not usual given its size (9.1 acres) and multiple facilities including two baseball fields. Although Harmony Park provides a playground for children, overall maintenance of the facility and natural surveillance were poor, an assessment supported by evidence of the highest neighbourhood crime index (2nd-highest Esri Crime Index®). This may explain the absence of children as well as females (no female in two observations) and seniors (no senior in five observations) in the park. Its neighbourhoods were low-income (2nd-lowest median household income) and racially/ethnically mixed (lowest % of the non-Hispanic white population).

Lastly, for a no-senior park, we chose Riverfront Park (Midas Ponds). The park's occupancy was relatively stable – ranging from seven to fourteen visitors – but in only one out of the six cases did we find one senior visitor. Lack of facilities other than ponds and trails may explain the lack of organised events that could attract senior visitors. The park was surrounded by relatively affluent, White-dominant neighbourhoods ($96,021 median household income; 88% of non-Hispanic whites). Access to the park, however, was not convenient for seniors who might have mobility limitations as the park was surround by two wide roads and a river. The fact that overall walkability and street connectivity of the adjacent neighbourhoods were weak is another evidence that this park was not convenient for senior visitors.

3.2 Statistical Models of Empty Parks

Table 2 presents four multilevel models of empty parks. Model 1 relates an empty park (i. e., no single person) to temporal, park, and neighbourhood attributes (n = 180). Models 2 through 4 estimate the likelihood of a park being empty for a specific group of users – female, child, and senior, respectively. In the latter three models, being empty means that there are still other groups of people representative of various groups but not the specific target group (i. e., no female but male, no child but adults, and no senior but younger people). Thus, in these three models, observations with no single person were excluded, which resulted in a sample size of 133 observations.

The OR in Table 1 represents the odds ratio. An odds ratio greater than 1 indicates a positive relationship between each variable and emptiness of the park use (e. g., morning in Model 2) and an odds ratio less than 1 indicates a negative relationship (e. g., afternoon in Model 1).

Model 1 (empty park) shows that the likelihood of a park being empty decreases with afternoon time periods, higher household income, higher population density, land use mix, park size, playground, and good maintenance at $p < .05$ significance level. In Model 2 (no female), the likelihood of not having a woman in a park is only (positively) associated with morning hours at $p < .05$ significance level. Model 3 (no child) shows that parks are likely to have a

Table 2: Multi-level logistic model results

	[Model 1] Empty		[Model 2] No female		[Model 3] No child		[Model 4] No senior	
Variable	*odds ratio*	*SE*	*odds ratio*	*SE*	*odds ratio*	*SE*	*odds ratio*	*SE*
(Intercept)	169639**	0.48	0.08**	0.34	0.69	0.27	12.74**	0.22
Morning (1=yes, 0=no)	1.21	0.69	3.24**	0.54	2.09	0.52		
Afternoon (1=yes, 0=no)	0.29**	0.62			0.29**	0.60		
Weekend (1=yes, 0=no)	1.97	0.47						
Temp (℃)	0.94	0.07						
Organised activities (1=yes, 0=no)			0.24	1.09	0.18**	0.82	0.16**	0.53
Median household income ($1,000)	0.94**	0.03						
Population density (1000 per sq.mi.)	0.81**	0.10			1.00	0.04		
Land use entropy index	0.09*	1.43						
Walk Score®							0.97**	0.01
% of 4-way intersections	1.06*	0.03	1.04	0.02			1.03	0.02
Transit stop density (per sq. mi.)	1.00	0.03			1.05**	0.02		
Park size (acre)	0.67**	0.14						
Playground (1=yes, 0=no)	0.08**	1.20						
Picnic area (1=yes, 0=no)								
Tennis court (1=yes, 0=no)	1.46	0.99	1.65	0.56				
Soccer/baseball field (1=yes, 0=no)								
Basketball court (1=yes, 0=no)			0.30*	0.71				
Good maintenance (1=yes, 0=no)	0.18**	0.64			0.28**	0.61	0.37*	0.51
Random effects (standard deviation)	0.35		0.84		0.31		0.24	
Model information	*n* (observation): 180 *n* (park): 30 AIC: 146.44 lambda: 6		*n* (observation): 133 *n* (park): 30 AIC: 109.46 lambda: 6		*n* (observation): 133 *n* (park): 30 AIC: 139.92 lambda: 13		*n* (observation): 133 *n* (park): 30 AIC: 154.97 lambda: 12	

Note: *: $p<.1$; **: $p<.05$; SE: standard error child visiting in the afternoon, with any organised activity, and good maintenance. Unexpectedly, transit stop density is positively associated with the likelihood of no children in a park. Lastly, in Model 4 (no senior), seniors are likely to be present in a park when there is any organised activity, the park is well maintained, or the neighbourhood is more walkable.

4 Discussion and Conclusions

As a result of our case study and statistical modelling, we found that whether a park is empty is somewhat associated with temporal attributes, park design, program, and neighbourhood environments. A neighbourhood park might be completely empty in the morning or at lunchtime, and there may be an even higher likelihood of having no woman in a park during the morning. It is noteworthy that neighbourhood parks are important for women as they are more likely to use parks frequently for social opportunities (CURSON & KITTS 2000). In mid-size, sprawled American cities, our finding calls for interventions of the neighbourhood parks to promote women's use especially during the morning hours. Example policies may include implementating targeted programs (e. g., exercise courses) and improving built environments (e. g., safer access to parks).

Tailored facilities (e. g., well-maintained playground, trail with shade) and organised activities (e. g., sports games, family/community events) might help promote park use, to varying degrees by different user groups – from children to seniors. Our findings suggest that both children and seniors are likely to be attracted by organised events. Better park maintenance is another variable that is negatively associated with emptiness in a park across most models. These results are well-aligned with previous studies' findings that the number of organised or supervised activities, as well as well-maintained playgrounds, are related to total park user volume among children (COHEN et al. 2016, LOUKAITOU-SIDERIS & SIDERIS 2009). Urban parks are places not only for contact with nature but also for social and cultural interactions, especially for seniors. Opportunities to socialize with other people are among the key motivators of park use among seniors (LESLIE et al. 2010, ÖZGÜNER 2011, RIES et al. 2009). In particular, RIES et al. (2009) highlight the importance of a lively social environment on park-based physical activity among youth. Similarly, MOORE et al. (2010) find that forms of social participation are essential for park use by older adults.

Our case study shows that merely bigger parks or more facilities do not guarantee park use. Rather, urban planning and design need to prioritize safty, accessibility , and mixed-use neighbourhoods to promote neighbourhood park use. Neighbourhoods with higher density, more mixed uses, and better walkability would help cities and counties avoid underutilisation of their parks (VAN DYCK et al. 2013, BARAN et al. 2014, PARK in press). The nuanced findings in empty parks would provide practical implications for park planning, design, and programming. With a more thorough understanding of planning and design factors, multiple departments in a local government could collaborate to develop more effective park programs and formulate policies that promote park-based physical activities and user diversity. In particular, the role of a neighbourhood's built environment in determining park use would call for interdisciplinary collaboration among urban planners/designers, landscape architects, and park programmers.

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