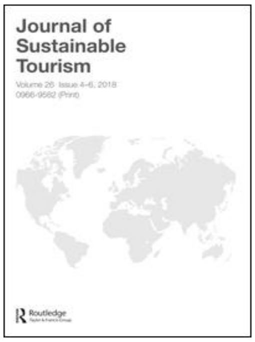

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Visitor bikeshare usage: tracking visitor spatiotemporal behavior using big data

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ABSTRACT

Bikeshare programs are a popular, convenient, and sustainable mode of transportation that provide a range of benefits to urban communities such as reduction in carbon emissions, decreased travel times, financial savings, and heightened physical activity. Although, tourists are especially inclined to use bikeshare to explore a destination as the programs are a convenient, cheap, flexible, and an active alternative to vehicles and mass transit little research or attention has focused on visitor usage. As such the current study investigated the spatial-temporal usage patterns of bikeshare by visitors to an urban community using GPS based big data ($N = 353{,}733$). The results revealed differential usage patterns between visitors and local residents based on user provided ZIP Codes using a 50 mile geometric circular buffer around the urban destination. The visitors and residents significantly varied on numerous trip behaviors including route selection, time of rental, checkout/check-in locations, distance, speed, duration, and physical activity intensity. The user patterns uncovered suggest visitors primarily use bikeshare for leisure based urban exploration, compared to residents' primary use of bikeshare to be public transportation related. Implications for bikeshare, urban planning, and tourism management are provided aimed at delivering a more sustainable and richer visitor experience.

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Bikeshare; cycling; tourist tracking; GPS; big data; bikeshare tourism

1. Introduction

As communities seek to improve active and sustainable transportation, investment in bicycle infrastructure and the adoption of cycling friendly policies and programs has grown (Pucher et al., 2010). Bikeshare programs are one such solution that has shown merit in improving sustainable urban mobility while providing a variety of ostensible benefits to the local community such as convenience, encouragement of cycling, financial savings, and the reduction of carbon emissions (Fishman et al., 2013; Shaheen et al., 2010). These systems offer a cheap and convenient means of transportation for short trips and work well in connection with public transportation systems in reducing travel times (Jäppinen et al., 2013). As such, bikeshare programs have drastically risen in popularity over the last decade becoming a multi-billion dollar global industry as over 2,000 public use bicycle programs consisting of more than 17 million bikes are currently in operation worldwide in mostly densely populated urban areas with the majority of the programs operating in China (DeMaio et al., 2020; Wadhwani & Saha, 2019).

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Bikeshare has grown from humble beginnings to technological innovation through four distinct phases or "generations" of evolution (Fishman, 2016). The first generation of bikeshare consisted of free untracked bicycles circulated throughout Amsterdam in the 1960s, and then the second generation adopted a more regimented approach as the bicycles were provided via secure dedicated stations that required a simple coin deposit to use. Modern bikeshare systems have evolved considerably with the third generation using smart access systems that require checkout and check-in at physical kiosks and the bikes are often equipped with GPS and other modern cycling technology (e.g., dynamo lights, modern brakes, electric assist) allowing the bikes to be tracked and make ridership easier. The latest fourth generation systems are comprised of free floating or "dockless" bikes that do not require stations or kiosks and are accessed by GPS based smartphone applications.

Although, bikeshare programs were originally designed to cater to local residents they provide a multipurpose sustainable mode of transportation for tourists as well (Dickinson & Lumsdon, 2010; Kaplan et al., 2015). Tourists are indeed a group that is especially inclined to benefit from bikeshare programs as they provide an efficient and convenient mode of transport to explore a destination in a physically active manner thus creating demand for the systems (Kaplan et al., 2015; Zhang et al., 2015). Many urban communities do indeed offer organized bike tours or leisure focused bike rental services that are focused on providing tourists with a means to explore a destination in an active manner. However, bikeshare provides a more flexible option for visitors since no limits are placed on route selection, and independent cycling service providers are not required and/or timetable restricted presenting an ideal mode of transportation for visitors to explore an urban destination. As described by Midgley (2009) bikeshare systems offer visitors several advantages over leisure based bike rental companies as the bikes can be rented and returned at different locations, access is fast and easy, the systems apply existing technology (i.e., phones), and are typically designed as part of the public transportation system, and the business models are more diverse.

Cycling related travel, where cycling is the main purpose of the trip has emerged as a distinct segment of the tourism industry and gained significant scholarly interest in recent years (e.g., Buning & Gibson, 2015; Han et al., 2017; Lamont, 2009). This growth coincides with the urban renaissance of cycling in many cities alongside the drive to become bicycle friendly through the development of cycling infrastructure (Pucher et al., 2010; 2011). However, cycling by tourists as a mode of transportation has received relatively scant attention despite being an important and valued user group of urban cycling infrastructure (Deenihan & Caulfield, 2015). Thus, insight into how destinations can build and leverage cycling infrastructure that manages and enhances the movement and experiences of tourists and creates opportunities to improve physical activity and local impact in the destination is needed (e.g., Deenihan & Caulfield, 2014; Panter et al., 2016; Weed et al., 2014). Such research will provide destinations with objective evidence to aid in the development of tourism strategy and city planning as well as improve bikeshare operations. To date, no apparent research has empirically investigated bikeshare usage behaviors by visitors. However, the addition of GPS data to new third generation bikeshare systems combined with the use of big data methodology provides innovative opportunities to explore usage patterns including those of visitors (Fishman, 2016; Romanillos et al., 2016). Thus, the purpose of this project was to investigate the spatiotemporal usage patterns of third generation bikeshare by visitors to an urban community using big data.

2. Literature review

2.1. Bikeshare usage

As bikeshare programs have seen tremendous growth in the last decade so has scholarly interest into usage patterns, user preferences/demographics, safety, distribution, and their related benefits (Fishman et al., 2013). Indeed, bikeshare use has been linked to meeting recommended leisure and transport related physical activity standards and to wider economic benefits to the urban economy from improved transport efficiency and sustainability (Bullock et al., 2017; Liao et al., 2017). Evidence also suggests bikeshare systems positively impact physical activity as bikeshare trips often replace sedentary forms of travel while reducing trip duration (Fishman et al., 2015). Convenience is typically the most common reason behind the use of bikeshare systems followed by low cost, reductions in travel time, and health benefits (e.g., Bullock et al., 2017; Fishman, 2016). Conversely, research by Fishman et al. (2014) found the convenience of driving, lack of docking stations, safety concerns and convenience of public transport to be barriers to bikeshare usage. Bikeshare programs are most commonly used in warmer months during the morning and evening on weekdays and midday on weekends (Fishman, 2016). Evidence from bikeshare systems across Australia, United States, and the UK suggest duration of bikeshare trips typically range from 16 to 22 minutes (Fishman et al., 2014). Research has also investigated the demographic background of bikeshare users and largely found it to differ from the general population (Fishman et al., 2013). Bikeshare users are typically male, have high employment rates, education levels, low average age, caucasian, and live in the urban area (e.g., Fishman et al., 2013; LDA Consulting, 2012; Ogilvie & Goodman, 2012). Interestingly, several studies have found users of bikeshare systems are more likely to own a personal bike and ride bikes outside of bikeshare systems than non-users (Fishman et al., 2012; Fuller et al., 2011; Shaheen et al., 2011).

2.2. Visitors and bikeshare

Although research into bikeshare systems is plentiful, specific investigation into the use of such system by visitors is quite limited to research purely based on visitor perceptions despite programs being targeted towards visitors and marketed as a tourism product. A study by Kaplan et al. (2015) using the theory of planned behavior explored the intentions of potential holiday visitors to Copenhagen to use a new bikeshare system. The authors found bikeshare to be highly sought after for multiple purposes, with visitors primarily wanting to use the bikes to discover the city and visit local parks with friends and family members. Intentions to use the system were driven by favorable perceptions of cycling, ease of cycling, and interest in bike technology. A study by Serna, et al. (2017) through online social media sentiment analysis of resident and visitors on bikeshare argues that coordinated planning is needed amongst between bike infrastructure (i.e., paths) and bikeshare components (e.g., amount of stations, price, bike quality) in order to provide positive user experiences. Still, the authors were unable to distinguish visitors from residents within the analyzed data. Recently, Zhou et al. (2020) based on a survey administered to Chinese tourists, environmental awareness, perceived rule adherence by others and ease of access to bikes were found to be the key factors that lead to tourist satisfaction of bikeshare.

Although research on tourists and bikeshare usage is limited to the aforementioned work, some inferences can be derived from research on casual bikeshare users compared to annual members. Casual members are likely visitors as they purchase access to a bikeshare system that only allows access for one time 24 hour access compared to members that purchase annual memberships allowing for unlimited annual use. Research by Faghih-Imani and Eluru (2015) investigated bikeshare usage in Chicago and found differences amongst annual members and day use members based on destination station choice. The authors found that in general stations near bicycle paths and those with high bike capacity were the most commonly chosen by both groups. The destination choice of annual members suggested the system was often used for daily commuting to work and complemented the public transit system. However, daily users were found to more commonly select stations that suggested leisure use (i.e., parks) and used bikeshare to replace public transit similar to the tourists studied by Kaplan et al. (2015). A study by Buck et al. (2013) on Washington, D. C. bikeshare program users found comparable results in that the majority of short term users used the bikes for recreational tourism reasons and for longer durations than members. The majority of casual users in Brisbane, Australia also reported that their main trip purpose was for leisure or sightseeing purposes (Roy Morgan Research, 2013). Lathia et al. (2012) investigated the changes of the London bikeshare system before and after the introduction of casual users. The authors discovered the demand on many stations around the city drastically changed once causal users were allowed, for instance the stations closer to central London switched from being destinations to origins. Surprisingly though, peak demand remained at morning and evening commuting times. While a lack of research exists on visitor bikeshare use, tourism focused research on tracking visitor behavior is abundant.

2.3. Tracking tourists

According to, Lew and McKercher (2006) and McKercher and Lau (2008) tourist itineraries intra-destination can form a variety of spatiotemporal patterns. These patterns range from no movement from the accommodation and utilitarian point to point trips to unrestricted destination wide movement that is complex and exploratory in nature As such, research into the intradestination movement behaviors and patterns of tourists enables communities to improve transportation planning, the product and image development of the destination, and the management of localized tourism impacts (Lew & McKercher, 2006). The spatial temporal intradestination movements of tourists typically are depicted in uneven patterns (McKercher & Lew, 2004). Prior research has also focused on the routes used by self-drive and cycling tourists often focused on developing and accessing tourism themed routes around rural tourism attractions (e.g., Olsen, 2003; Ritchie, 1998; Shih, 2006). Through the use of GPS data visitors can be encouraged and supported to explore previously unknown areas of an urban community and at off peak times while creating a resource for city planners to aid in building and locating new attractions (Shoval, 2008).

In recent years, research into tracking the movement of tourists in a destination has gained popularity as the requisite technology has become increasingly accessible, inexpensive, and easy to use (Shoval & Ahas, 2016). In conducting tourist tracking related research a range of data sources have been used by researchers such as Bluetooth, passive mobile positioning, geotagged photos, social media messages, and more (e.g., Versichele et al., 2014; Vu et al., 2015; Zhao et al., 2018). Still, GPS receivers are by far the most commonly used technology as two thirds of the studies in a recent review of tourist tracking research were based on GPS data (Shoval & Ahas, 2016). The authors explain GPS tourist research is typically focused around a relatively small area such as a natural park (Hallo et al., 2012) or a historic attraction (Huang & Wu, 2012), principally because physical GPS devices often have to be distributed to study participants. However, due to the creation of GPS enabled smartphones and related smartphone apps tourist tracking data collection has become quite easier to implement and inexpensive while also reducing the inconvenience to the study participants (Yun & Park, 2015). Still, the use of smartphones is limited as a data collection method as it only includes those who have a smartphone, who have tracking capabilities on their smart phones enabled, and also consent to being tracked.

GPS based tourism research has revealed numerous insights into the patterns of intradestination movement of tourists. For instance, McKercher et al. (2012) conducted a study using GPS data loggers on visitors to Hong Kong and discovered differential patterns of behavior based on first-time and repeat visitors. The authors found that first time visitors visited a wider range of locations over one long trip from their accommodation largely centered on iconic locations, while repeat visitors made multiple short trips to fewer locations. In another GPS based study, Grinberger et al. (2014) researched first time visitors to Hong Kong and found behaviors based on allocations of space and time noting that most participants reduced the amount of spaces visited for more time at each stop. GPS based research has also shown merit in providing communities with tools and initiatives to improve sustainable destination management (Edwards & Griffin, 2013). Indeed, Edwards and Griffin (2013) found through GPS data paired with interviews and questionnaires that tourists walked up to 35 km a day, but lack of knowledge of public transportation and attractions was reported as a serious constraint to navigating the urban destination as they explored the "fine grain" details of the city. Furthermore, research by Hardy et al. (2020) using GPS based tourist tracking argues that transportation is a key element to dispersing tourism benefits throughout a destination. So, clearly research is needed to understand how visitors navigate urban destinations and use sustainable public transit elements such as bikeshare to explore and experience a destination.

2.3.1. Tracking cycling tourists

Regarding the use of tourist tracking methods in the context of cycling only a few related works have been published. From user generated GPS data, Wolf et al. (2015) solicited GPS files, supplementary to questionnaires and public participation geographic information systems (PPGIS), from mountain bikers in the Northern Sydney area. The authors found that capturing the actual GPS tracks provided in-depth spatiotemporal data. Still, Wolf et al. (2015) reported that GPS tracking was much more difficult compared to PPGIS data collection as potential study participants were less willing to collect GPS data due to the advanced technical knowledge and longer time commitment required. Another study using GPS data related to cycling, Bil et al. (2012) detail a method to create a GIS database of cycling tourism infrastructure in the Czech Republic. The study used physical GPS devices operated by volunteer mappers to track cycle trails, locate hazardous sites, and types of surfaces thus arguing for continued use of GIS databases to aid in planning and developing cycle trail networks. However, the data collection required each participant to be trained individually and the use of costly GPS devices.

Still, much is unknown about how visitors behave within a destination and the related use of cycling related infrastructure in experiencing an urban community. Much has been published on the use and benefits of bikeshare programs generally and on tracking and understanding tourist preferences and behaviors, but these disconnected lines of inquiry have not been explored collectively. As such scholars have yet to provide behavioral evidence to aid destinations in developing and managing bikeshare programs to fit the needs of tourists and leverage the systems for tourism based outcomes such as improving visitor experiences, localized economic impact, and marketing communities as active and sustainable destinations. Thus, this study aimed to provide empirical evidence of the actual behaviors of visitors as they explored an urban community via bikeshare.

2.4. Study context

To explore the usage of bikeshare systems by visitors, the *Pacers Bikeshare* program located in Indianapolis, IN was examined. Pacers Bikeshare was founded in 2014 and is positioned around the Indianapolis Cultural Trail (ICT), an 8 mile long bike and pedestrian path that connects six urban cultural districts, tourism landmarks including a convention center, art installations, cultural landmarks, parks, and an 18 mile rail trail (Indianapolis Cultural Trail, 2019). Indianapolis hosts a variety of large sporting and business events attracting more than 28 million visitors annually and is routinely ranked as the top convention city in the United States (Visit Indy, 2016). The ICT has been widely regarded as a model for bike friendly urban development nationwide and is considered to be one of the most valuable tourism products in Indianapolis (Schoettle, 2017). The trail has been hailed as a great success and asset for the city and evidence suggests numerous benefits from the trail for the community such as increased property values and the creation of new trailside businesses and related jobs (Majors & Burow, 2015).

The Pacers bikeshare is a third-generation bikeshare system consisting of 29 stations (referred to as kiosks herein). The program is unique compared to other bikeshare systems in that in addition to station-to-station trip data the bikes are fitted with GPS loggers. Each bike computer collects GPS locations every six seconds while the bikes are in motion. The study was conducted in collaboration with the Indianapolis Cultural Trail Inc. to aid in managing the program to meet visitor demand, improve ridership amongst visitors, and ultimately increase the tourism impact of the program on the local community. As such, the following research question guided the study,

RQ: How do visitors use bikeshare programs within an urban destination in-comparison to local residents?

3. Method

A wealth of prior research on bikeshare exists largely in the field of public transportation and likewise tourist tracking research is ubiquitous tourism outlets. Thus, bike mounted GPS data were used to study visitor behavior via bikeshare usage as it provides a superior method to research spatiotemporal behavior providing a high level of precision and accuracy over other types of big data used in tourism research (e.g., Li et al., 2018; Shoval, 2008). The unique dataset studied combined GPS routing data and station to station point data allowing for investigation into both routes and destination choice which allows for connections to broader contexts in planning such as cycling infrastructure (Romanillos et al., 2016). As such, the research team in collaboration with the ICT staff organized and analyzed a big data set of GPS files using both GIS and statistical methods. Visitor status was derived by using the billing ZIP Code associated with each trip. The ZIP Code of the bikeshare users was provided by the user directly as required by the system upon renting a bike. Hence, trips with a ZIP Code located outside a 50-mile radius of Indianapolis were denoted as non-resident visitors based on Indiana's state definition of tourism (Indiana Office of Tourism Development, 2015). The 50-mile radius buffer was created using a simple geometric circular buffer in Maptitude GIS.

3.1. Data description

Raw GPS data from the inception of the Pacers Bikeshare program in September 2014 to July 2018 in a collection of comma separated value (CSV) files was provided by the ICT. The Pacers Bikeshare system allows five different access options: (1) annual membership, (2) 24 hr casual membership purchased at a kiosk, (3) 24 hr casual membership purchased in advance via the ICT website, (4) monthly membership which was only instated in late 2017, and (5) other various promotional memberships. The system was setup primarily for short rides as trips over 30 minutes incur additional fees at $2 for 30-60 minutes and $4.00 for each additional 30 minutes.

The complete dataset included more than 23.4 million GPS points resulting in 447,805 total trips. A trip is defined herein as the collection of GPS points from when a bike is checked out at a kiosk to when it is checked back into a kiosk. Each trip in the data was represented by a unique identifier, trip ID. See Table 1 for frequency of trips based on visitor status and year. In addition to the latitude and longitude values for the GPS points the data also contained variables for membership type (i.e., annual, casual, membership), bike id, user id, membership type,

Table 1. Frequency of trips for visitors and residents.

	2014	2015	2016	2017	2018	Total
Resident	20,153 (83.5)	87,470 (79.0)	71,010 (81.0)	71,638 (81.6)	35,260 (81.2)	285,531
Visitor	39,80 (16.5)	23,288 (21.0)	16,649 (19.0)	16,126 (18.4)	8,159 (18.8)	68,202
Annual Total	24,133	110,758	87,659	87,764	43,419	353,733

Note. Number in parenthesis represent % of total trips by year, data reported is dated from September 2014 to July 2018.

Table 2. Derived variables.

Derived variable	Description
Trip duration	Difference between return time and rental time
Long trip	Is trip duration greater than 30 minutes?
Weekend trip	Trip during weekend?
Trip month	Month of trip
Trip hour	Hour (between 00-23) when the trip started
Time of day	Time of day when the trip occurred Between 00-05:59: Night Between 06-11:59: Morning Between 12-17:59: Afternoon Between 18-23:59: Evening
Speed (MPH)	Average speed in miles/hr calculated from distance and trip duration
PA Intensity	Intensity of physical activity based on the physical exertion criteria listed in the Ainsworth et al. (2011) compendium.
Visitor	User's ZIP Code located outside a 50-mile radius of Indianapolis.
Route	Either round trip (bike checked out and returned to the same station) or one-way (bike checked out and returned to a different station)
Rental Kiosk Cat	Category of rental kiosk: Central Business District (CBD), CBD_attractions, CBD_mixed, Convention Center, Culturual neighborhood, Hospital, Library, Park, University
Return Kiosk Cat	Same as rental kiosk cat

Note. $^{***}p < .001$.

ZIP Code, rental and return kiosk, rental and return date and time, total distance of the trip, date and time.

3.2. Data analysis

3.2.1. Procedures

Prior to data analysis several procedures were undertaken in order to organize, clean, and explicate the data. First, the raw CSV data was loaded into a PostgreSQL database and was consolidated into a single table using PostGIS spatial database extension. Trip lines were then created by aggregating point data based on unique trip identifiers. The GPS recording time was used to temporally sort the GPS points which made up the individual trips. This trip data contained several outliers due to inaccuracies of the GPS data similar to other studies tracking cycling routes and GPS based research in urban areas (Harvey & Krizek, 2007; Shoval & Isaacson, 2007). Several of the individual trips were deemed implausible and inaccurate (i.e., passing through buildings, off track) a common issue with the use of GPS in urban areas (Illand et al., 2018). Thus, outlier trips based on consecutive distance and time between adjacent GPS points and speed (mph) were removed based on two standard deviations of the variables. Trips with durations longer than 180 minutes and less than 2 minutes were also removed as they were likely the result of a mechanical error such as a bike not properly docking (Fishman et al., 2014). Other erroneous trips with a missing ZIP Code and incorrect ZIP Code were also removed.

From the total distance and duration of each trip, speed (mph) was calculated by distance traveled and time taken to cover that distance. Importantly, distance herein was not the Euclidean distance between start and end kiosk locations, but the actual distance covered during the trip. Next, several derived variables (Table 2) were calculated from original trip attributes including: trip duration, long trip, weekend trip, trip month, trip hour, time of day, and speed. Rental/return kiosk locations were manually (visually) assigned categories based on location (Figure 1). Lastly, physical activity intensity (variable PA Intensity) was derived from speed and categorized into light (0-5 mph), moderate (5-9.5 mph), vigorous (9.5-14 mph), and very vigorous (>14 mph) categories based on the Ainsworth et al. (2011) compendium.

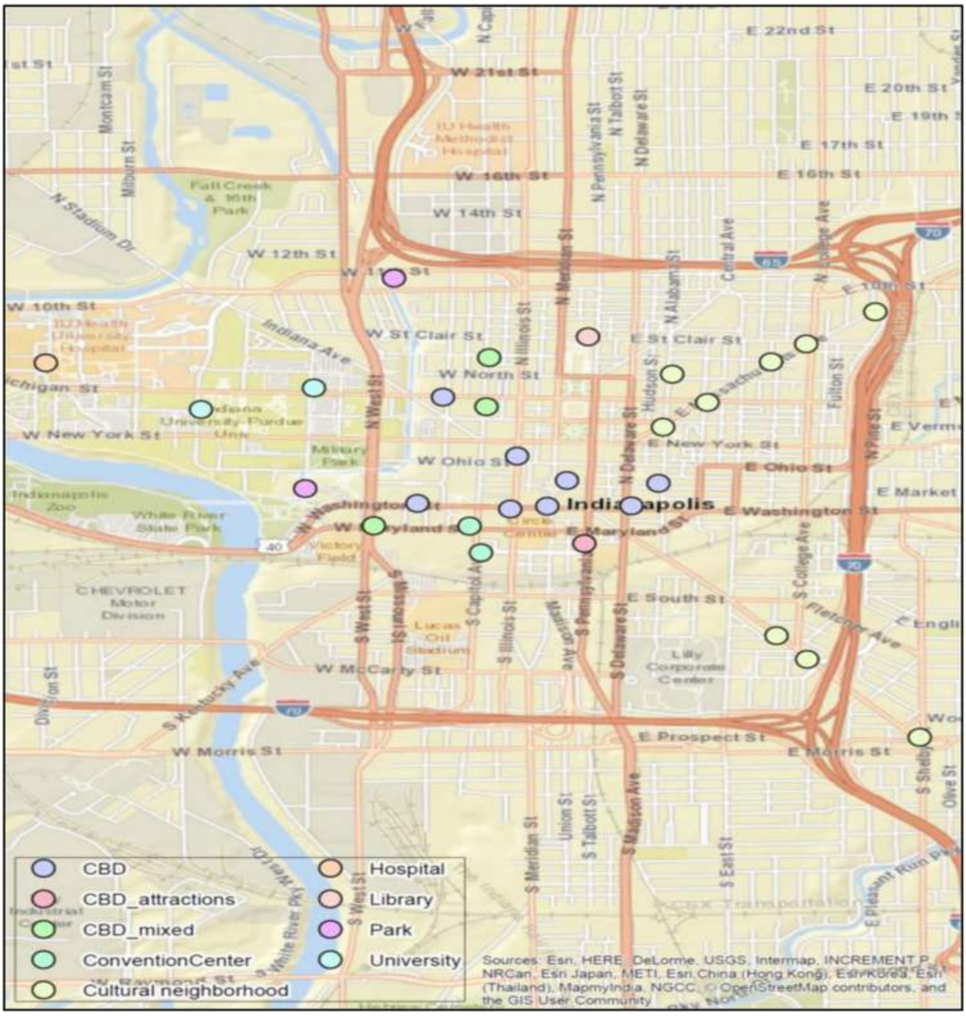

Figure 1. Categorized kiosk map.

3.2.2. Group comparison testing

To answer the research question, to investigate the differences between resident and visitor usage of bikeshare in an urban destination several analyses were performed using IBM© SPSS© Statistics 25.0. First, frequencies and cross tabulations with Pearson Chi-Square testing was run to test for differences between residents and visitors based on the following variables: trip month, weekend trip, long trip, time of day, PA intensity, checkout kiosk, and return kiosk. Next, independent samples t-tests were performed to test for differences between residents and visitors based on trip distance, trip duration, speed, and usage fees. Further, tables and charts were created using the R software package (R Core Team, 2019) and QGIS (QGIS Development Team, 2015). In creating distinct heat maps of resident and visitor trip patterns (Figures 2 and 3) layer blending mode and feature blending mode were used to provide qualitatively interpretable trip images (QGIS Development Team, 2015). This rendering method was used as the origin-destination of some cases was identical and users might have taken vastly different routes during each trips. Trip visualization was convoluted as the origin-destination trips used the same street segments and hence were overlaid with all other trips. Hence, to highlight the overall differences in the riding behaviors between visitors and residents the *multiply* feature blending mode was used in which the final color of the pixel (on the image) is the multiplicative value of

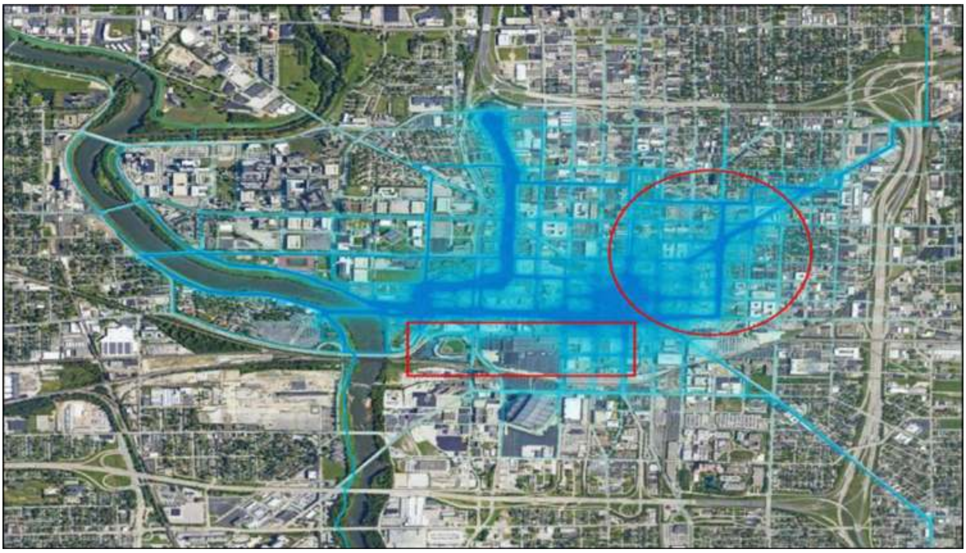

Figure 2. Resident trips.
Note. The annotated areas highlight noticeable differences in riding between visitors and residents. Overlapping trips (i.e., routes that were more frequented by users) appear darker than pixels with fewer overlapping trip routes.

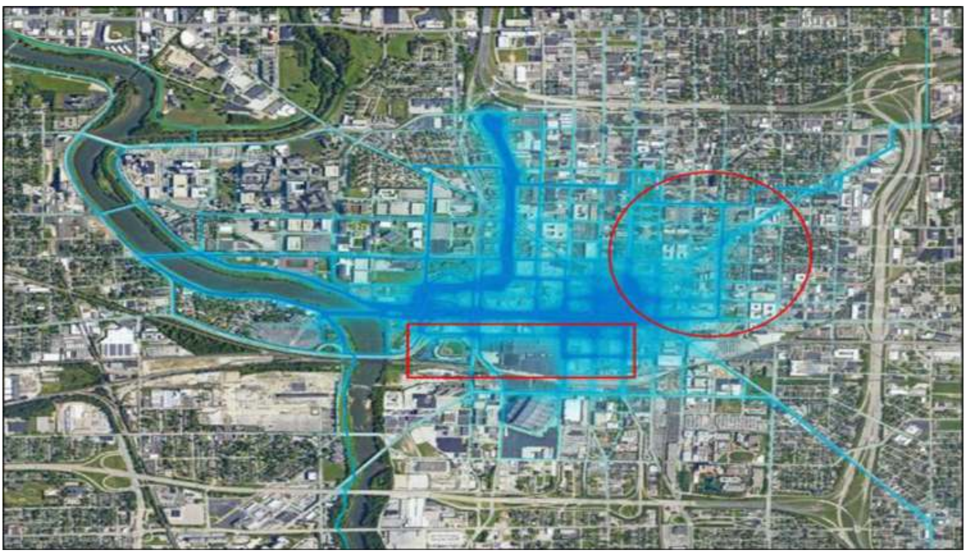

Figure 3. Visitor trips.

all overlaying features. Thus, a pixel with many overlapping trips (i.e., routes that were more frequented by users) appear darker than pixels with fewer overlapping trips.

3.3. Sample description

As a result of cleaning the raw data, the final sample size available for analysis was $N = 353{,}733$ (78% of original trips). Of the entire sample, 19.3% of the recorded trips were by 17,545 unique visitors taking an average of 3.89 trips per user predominately on 24 hr kiosk purchased passes (88.4%). Regarding resident users, 27,536 unique resident users were recorded taking an average of 10.37 trips on primarily annual passes (65.4%). Despite, the relatively low frequency of visitor trips compared to resident trips, visitors made up 38% of total system users based for the

Table 3. Trips proportions (%) based on resident and visitor usage.

Variable	Resident ($n = 285{,}531$)	Visitor ($n = 68, 202$)	χ^2
Month			3,584.39***
January	2.3	0.6	
February	3.6	2.1	
March	5.6	4.2	
April	8.9	8.5	
May	11.6	12.9	
June	13.3	15.0	
July	14.0	18.6	
August	10.9	12.7	
September	12.8	12.9	
October	9.3	8.3	
November	4.9	3.3	
December	2.8	1.0	
Time of Day			2,682.96***
Morning	24.9	15.8	
Afternoon	48.1	55.5	
Evening	25.1	27.1	
Night	1.9	1.7	
Day of Week			13,048.11***
Weekday	71.9	49.2	
Weekend	28.1	50.8	
Physical Activity Intensity			8,255.79***
Light	12.7	23.8	
Moderate	69.8	68.9	
Vigorous	15.7	6.5	
Very Vigorous	1.8	0.8	
Long Trip			10,425.53***
Less than 30 minutes	89.6	74.9	
More than 30 minutes	10.4	25.1	
Route			3,073.61***
One Way	90.3	82.9	
Round Trip	9.7	17.1	

Note. Pearson Chi-Square reported, ***$p < .001$.

duration of the study. For the study period, usage fees for trips over 30 minutes amounted to USD$68,036.42 for visitors and USD$105,528.66 for resident users.

4. Results

The results provide a distinctive portrayal of the varying patterns of behavior amongst resident and visitor use of the bikeshare program studied. Several temporal patterns emerged between these two groups. Pearson Chi-Square testing revealed significant differences ($p < .001$) between visitors and residents based on the month the trip was taken [χ^2 (11, $N = 353{,}733$) = 3,584.39], the time of day [χ^2 (3, $N = 353{,}733$) = 2,682.96], the day of the week [χ^2 (1), $N = 353{,}733$) =13,048.11], physical activity intensity [χ^2 (3, $N = 353{,}733$) = 8,255.79], trips over 30 minutes [χ^2 (1, $N = 353{,}733$) = 10,425.53], and for check out and for return kiosk [χ^2 (64, $N = 353{,}733$) = 46,437.76]. See Table 3 for the full results. As expected both resident and visitor usage peaked during the summer months (i.e., June, July, and August). However, visitors were far less likely to use the program during the colder months (i.e., October, November, December, and January) and more likely to use the program during the summer compared to residents. Afternoon and evening times were the two most popular times amongst both visitors and residents to use the bikeshare program. Residents used the system in the morning more frequently (24.9%) compared to visitors (15.8%), while the visitors took more trips during the afternoon (55.5%) and evening (27.1%) than the residents studied (48.1%, 25.1% respectively). Trips were primarily taken by

Table 4. T-test for distance, trip duration, average speed, and usage fee.

	Resident ($n = 285{,}531$)		Visitor ($n = 68{,}202$)		
	M	*SD*	*M*	*SD*	*t*-test (353,731)
Distance (Miles)	1.89	1.96	2.92	2.69	114.07***
Trip Duration (Mins)	16.54	19.88	28.03	26.48	126.78***
Average Speed (MPH)	8.00	2.53	7.00	2.63	−92.24***
Usage Fee (USD)	0.37	1.70	1.00	2.73	75.96***

Note. ***$p < .001$.

Table 4. T-test for distance, trip duration, average speed, and usage fee.

	Resident ($n = 285{,}531$)		Visitor ($n = 68{,}202$)		
	M	*SD*	*M*	*SD*	*t*-test (353,731)
Distance (Miles)	1.89	1.96	2.92	2.69	114.07***
Trip Duration (Mins)	16.54	19.88	28.03	26.48	126.78***
Average Speed (MPH)	8.00	2.53	7.00	2.63	−92.24***
Usage Fee (USD)	0.37	1.70	1.00	2.73	75.96***

residents during the week (71.9%) as compared to visitors who took trips almost evenly between weekdays (49.2%) and the weekend (50.8%).

Comparing visitor trips with resident trips based on physical activity intensity, both groups' trips predominately fell into the moderate category. However, residents more often took trips that classified as vigorous (15.7%) and very vigorous (1.8%) physical activity, whereas visitors took relatively more light (23.8%) physical activity trips. The vast majority of trips were less than 30 minutes in duration for both groups, but visitors took relatively more trips that exceeded 30 minutes (25%) compared to residents (10.4%). Importantly, trips over 30 minutes incurred additional usage fees. Regarding route selection, both groups primarily chose one-way trips, nonetheless visitors recorded more round trips (17.1%) than residents (9.7%).

Results from the independent samples *t*-test revealed significant differences ($p < .001$) between the resident and visitor bikeshare users based on distance, trip duration, average speed, and usage fee (Table 4). Visitor trips were on average more than a mile longer than resident trips ($M = 2.92$; $M = 1.89$). Congruently, visitor trips were more than 10 minutes longer than resident trips on average ($M = 28.03$; $M = 16.54$). Resident trips were found to be significantly faster than visitor trips recording mean speeds of 8.00 mph and 7.00 mph respectively. Lastly, the usage fees incurred by visitors was significantly higher than residents as visitor trips recorded a mean fee of USD$1.00, whereas resident trips recorded a mean fee of USD$0.37 reflective of the differences in trip duration and trips over 30 minutes which incur additional fees. .

Regarding trip patterns, resident and visitor users significantly differed based on Pearson Chi-Square testing (χ^2 (64, $N = 353{,}733$) = 46,437.76, $p < .001$) as numerous variances in the routes chosen were discovered (Table 5 and Figures 2 and 3). The most popular checkout and return kiosks for both groups were the CBD locations. The majority of resident usage both at checkout (66.8%) and return (67.1%) was derived from kiosks in the CBD and the cultural neighborhoods, whereas visitor usage was spread across a wider variety of kiosks. As a result, several patterns emerged when comparing the two groups' behaviors. Visitors more heavily used the kiosks located in parks for both checkout and return compared to residents. For example, 17.7% of all visitor trips began at a park based kiosk compared to only 10.1% of resident trips.

The convention center kiosks were also popular with visitors as twice as many trips originated or finished from this location compared to residents. Exploring the individual trips patterns, the most popular trip by residents originated from a cultural neighborhood and terminated in the CBD (12.7%) and the second most popular trip originated in the CBD and terminated in a cultural neighborhood (12.3%). However, the most popular visitor trip originated and terminated in

Table 5. Checkout kiosk and return kiosk proportions (%) for resident trips (n = 285,531) and visitor trips (n = 68,202).

	Return Kiosk									
Checkout Kiosk	CBD	CBD Attraction	CBD Mixed	Convention Center	Cultural Neighborhood	Hospital	Library	Park	University	Total
CBD	11.7 (13.3)	0.8 (0.6)	3.2 (2.2)	1.2 (1.9)	12.3 (7.2)	0.2 (0.3)	1.0 (0.7)	2.5 (4.4)	1.5 (1.5)	34.3 (32.1)
CBD Attractions	0.8 (0.6)	0.3 (0.3)	0.5 (0.2)	0.2 (0.2)	1.5 (0.8)	0.0 (0.0)	0.1 (0.1)	0.1 (0.2)	0.1 (0.1)	3.5 (2.4)
CBD Mixed	3.5 (2.4)	0.5 (0.2)	0.9 (1.8)	0.4 (0.7)	2.1 (1.6)	0.0 (0.0)	0.2 (0.1)	0.5 (0.9)	0.4 (0.4)	8.5 (8.2)
Convention Center	1.0 (2.2)	0.2 (0.2)	0.4 (0.8)	0.4 (2.1)	1.0 (1.2)	0.0 (0.0)	0.1 (0.1)	0.3 (1.0)	0.2 (0.3)	3.7 (7.8)
Cultural Neighborhood	12.7 (8.2)	1.6 (0.9)	1.9 (1.3)	1.1 (1.5)	11.7 (9.5)	0.1 (0.0)	0.7 (0.4)	1.8 (1.9)	0.9 (0.5)	32.5 (24.3)
Hospital	0.2 (0.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.0 (0.1)	0.0 (0.0)	0.0 (0.2)	0.0 (0.1)	0.4 (0.8)
Library	0.9 (0.6)	0.1 (0.1)	0.2 (0.1)	0.1 (0.1)	0.8 (0.5)	0.0 (0.0)	0.1 (0.1)	0.2 (0.3)	0.1 (0.1)	2.6 (2.0)
Park	2.7 (4.9)	0.1 (0.2)	0.5 (0.9)	0.2 (0.2)	1.8 (2.3)	0.0 (0.2)	0.2 (0.4)	3.8 (7.2)	0.7 (0.8)	10.1 (17.7)
University	1.4 (1.5)	0.1 (0.1)	0.3 (0.4)	0.1 (0.2)	0.9 (0.6)	0.0 (0.1)	0.1 (0.1)	0.7 (0.7)	0.8 (0.9)	4.5 (4.5)
Total	34.9 (33.9)	3.8 (2.5)	8.0 (7.8)	3.8 (7.6)	32.2 (23.8)	0.4 (0.8)	2.4 (2.4)	9.9 (16.8)	4.6 (4.6)	100.0 (100.0)

Note. % of resident trips reported, visitor % in parenthesis, χ^2 (64, $N = 353{,}733$) = 46,437.76, $p < .001$.

the CBD (13.3%), and the second most popular originated and terminated in a cultural neighborhood. Furthermore, as depicted in Figures 2 and 3 residents took considerably more trips along Massachusetts Avenue, a mixed residential and entertainment neighborhood, (the diagonal thoroughfare, demarcated by a circle). However, visitors took considerably more trips along Georgia Street (the rectangular annotation) which connects the convention center to the left and the Bankers Life Fieldhouse sports arena to the right.

5. Discussion

Although prior work has explored the perceptions of visitors related to bikeshare (i.e., Kaplan et al., 2015; Serna et al., 2017; Zhou et al., 2020), the current study is the first scholarly inquiry to investigate the actual behaviors of visitors using bikeshare to explore and urban destination. As such, the purpose of the project was to investigate the spatiotemporal usage patterns of third generation bikeshare by visitors to an urban community using big data. The differential pattern of behavior of visitors in comparison with local residents uncovered herein establishes that visitors are indeed a unique, important, and lucrative user group of bikeshare programs. Thus, destination managers, urban planners, and local government will be empowered with objective empirical evidence to inform the development of tourism strategy and city planning as well as aid in bikeshare operation. The results revealed that visitors used bikeshare more frequently during warmer months, in the afternoon/evening, and on the weekend than residents. In general though, the program was predominately used during the warmer months by all users similar to other research on bikeshare generally (Fishman, 2016). Visitors took longer trips in distance and duration at a slower pace than residents while incurring higher usages fees compared to residents. Visitors also more often took round trips, as they returned to the same kiosk as they originally checked out the bike. The visitors were found to more often explore the CBD and the surrounding areas by starting and ending in the same area. For instance trips, commonly began and ended in the CBD. However, the visitors likely used the bikeshare system for leisure related purposes like exploring the city, visiting landmarks, parks, local businesses, and/or general recreational riding. These assumptions are further reflected in the pattern of checkout and return kiosk locations uncovered as the visitor trips were frequent near tourist sites and originated and terminated in the same areas.

The kiosk to kiosk results demonstrate that residents rode back and forth between the CBD and the surrounding cultural neighborhoods quite frequently and more so than visitors. The pattern of behavior of residents depicted in the study findings seems to be reflective of bike trips for utilitarian transportation purposes such as commuting to work or running errands. This finding likely explains the trip purposes uncovered in other work on bikeshare usage generally without differentiation of visitors and residents. For example, a study of bikeshare users in Brisbane, Australia revealed casual users predominately (65%) reported leisure or sightseeing as their primary trip purpose whereas members predominately used the system for work related trips (Roy Morgan Research, 2013).

Bikeshare was originally thought of as a sustainable mobility solution for the first and last mile problem so urban residents can connect to existing public transportation systems (e.g., Griffin & Sener, 20160; Liu et al., 2012). However, the study results depict that visitors use these programs irrespective of public transport as their trip patterns demonstrate urban exploration rather than urban transportation suggesting bikeshare is being used as an alternative to public transportation not as a supplement. Kaplan et al. (2015) argues a similar finding that tourist bikeshare use likely differs from the utilitarian use of local users. Further, as demonstrated by McKercher et al. (2012) and Grinberger et al., (2014), first time visitors' movement intradestination is often exploratory as they often visit a variety of iconic tourist sites. Bikeshare is ideally suited for visitors to explore a city though, as it is cheap, easy to use, and a physically active alternative to driving or public transportation and the behaviors revealed here reflect this purpose (Zhang et al., 2015). However, as evidenced by Edwards and Griffin (2013) visitors often face difficulty in using public transit in exploring a city. Thus, visitors need to be educated on how to ideally experience a destination using transit systems such as bikeshare.

The longer trip durations, further distances, and slower speeds recorded by visitors can likely be explained by the ideals behind the slow tourism movement (Dickinson & Lumsdon, 2010). An exemplar of slow tourism, travel by bike allows visitors to slow down and interact with their surroundings by allowing for a deeper and more authentic travel experience through engagement with people and the place as compared to car travel (Dickinson et al., 2011). Cycle tourists generally have been found to take a slower and more relaxed pace while often visiting peripheral areas or as depicted in the study results surrounding cultural neighborhoods in addition to the urban core (Ritchie, 1998). The context of the study, Indianapolis, Indiana has certainly benefitted from the bikeshare system and construction of the ICT as research from Majors and Burow (2015) found businesses along the trail have experienced increased revenue leading to job creation and an increase in property values creating $560k to $1.9 million in annual economic impact. In general, cycling tourism provides considerable visitor spending to a community as a meta-analysis conducted by Weed et al. (2014) found cycling tourists spend £15.48 (USD $19.45) to £48.97 (USD $61.52) per day in a host community.

In comparing the residents and visitors, the visitor users incurred significantly higher and more frequent overuse fees for trips over 30 minutes. Over the roughly 4 years of data analyzed for the study a substantial amount of revenue to the program was generated from these fees which amounted to USD$68,036.42 attributed to visitor trips or one dollar per trip. This number might seem inconsequential to some, but larger bikeshare programs operate at a much larger scale than the program studied which only has 251 bikes. In comparison, the New York Citi Bike system, the largest in United States, has more than 10,000 bikes in operation whereas millions of bikeshare bikes are in operation in numerous cities throughout China (Denyer, 2017). Thus, visitor usage presents a considerable source of revenue for bikeshare programs.

Another salient point of difference in how visitors and residents used the program in regards to intensity of physical activity, as residents recorded significantly more high intensity trips compared to visitors. Bikeshare programs are thought to be a possible solution to increase physical activity in the urban area which they operate (Liao et al., 2017; Shaw et al., 2017). Indeed, empirical evidence suggests that a bikeshare program can have an overall positive health impact while reducing travel time by replacing trips made by public transport, walking, and automobile (Woodcock et al., 2014). Nonetheless, the implementation of bikeshare programs have been shown to positively increase overall active travel time (Fishman et al., 2015). As visitors studied here averaged nearly 30 minutes per trip the results suggest bikeshare may provide a potential contribution to meeting daily physical activity guidelines (see U.S. Department of Health and Human Services, 2018). The visitors studied are likely traveling slower and more casually as a result of getting lost, stopping at various tourist sites, and generally exploring the city whereas residents are taking trips directed at a specific destination. Indeed, Weed et al. (2014) and Downward and Lumsdon (2001) argue that casual recreational cycle tourists are more likely to engage in tourist behaviors like visiting coffee shops and restaurants and thus likely to spend more making this group a valuable market segment.

5.1. Conclusion

The present study provides an opening look into visitor use of bikeshare in an urban destination through analysis of the behavioral patterns of users over the course of 5 years of ridership data. Bikeshare provides a sustainable mode of transportation for visitors to connect public transportation to an intended tourism destination and most notably allows for the slow exploration of a destination. As such, the study results provide numerous implications for both tourism management, bikeshare, and transportation planning.

5.1.1. Management implications

Firstly, the principal implication of the study arises from the magnitude of bikeshare use by visitors discovered as the systems were originally designed for residents. Bikeshare use by visitors was found to account for almost a fifth of all trips taken and more than a third of users over the roughly four years of data studied, firmly establishing visitors as a major user group. As a result destinations should consider bikeshare programs to be a direct marketable tourism product and a boost to the overall destination image that also improves urban mobility, enjoyment of the city, and localized impact for all (e.g., multiuse paths paired with local businesses and tourism infrastructure).

Second, for destinations, bikeshare can likely provide visitors with a richer and more sustainable transportation option that has the potential to create a more relaxed authentic experience allowing for better access to peripheral areas and tourist sites (Dickinson et al., 2011). Indeed, the results here extend the findings of Hardy et al. (2020) regarding the use of transportation to disperse tourism benefits as bikeshare is shown to provide visitors a means to explore an urban destination more widely. Thus, the needs of visitors should be integrated into the planning and implementation of cycling infrastructure and bikeshare programs to improve local impact and tourism experiences. As explained by Shoval (2008), GPS data of tourist movements provides communities with a resource to build and plan future infrastructure and attractions while also encouraging visitors to explore peripheral areas as further evidenced here. The program studied provides a model of bike/pedestrian infrastructure design as the ICT strategically passes by numerous local businesses and tourism attractions offering visitors a clear route to explore the city coupled with the bikeshare program that encourages curious active visitation. Third, visitors should be strategically encouraged to use bikeshare systems to improve visitor experiences and related localized impact. Partnerships with hotels and events to offer bikeshare access would certainly help in this regard, as posited by Serna et al. (2017) that coordinated planning is needed for tourism related bikeshare success. Strategic partnerships between hotels, local businesses, bikeshare operators, and multiuse paths can be leveraged to design cycling routes to offer visitors an ideal experience through a bespoke tour of a destination encouraging interaction between tourists and hosts. Indeed, bike touring routes could be designed in urban destinations similar to the driving routes studied by Hardy (2003), in which attractions, interpretation, stakeholder participation/collaboration, and marketing are key to providing high quality visitor experience.

Evidence from Deenhihan and Caulfield (2015) argues visitors value different levels of cycling infrastructure and are willing to increase cycling time and pay for cycling lanes and more so for separated bike paths. In constructing cycling infrastructure to cater to visitor needs the results suggest cycling time and distance are less important than selecting the quick, efficient, and utilitarian routes used by residents. Thus, based on the results urban cycling routes and bike paths that travel by landmarks, parks, event venues and other tourism sites analogous to the study context would be ideally suited for visitors similar to self-drive tourism routes (e.g., Olsen, 2003).

Lastly, bikeshare operators should view visitors as a unique and lucrative user group that necessitate a specialized management approach to ensure the system is dually suited for the utility purposes of residents and leisure purposes of visitors. This could be achieved by improving ease of access, providing maps/directions, suggested routes/stops/photo locations, and flexible rental options such as a weekend pass or longer rental times. A related implication for operators to encourage visitor use is related to rebalancing, a known major issue as users often take one-way trips that create kiosks that are either full or empty requiring laborious redistribution by bikeshare staff (e.g., Chardon et al., 2016). The results demonstrate that visitors are almost twice as likely to take round-trips thus decreasing the need to rebalance bikes and creating cost savings. A rather unique context of the study is the placement of the bikeshare system around an urban bike/pedestrian path, which likely further encouraged visitors to use the program, similar connections to bike infrastructure should be considered and promoted to visitors.

5.1.2. Limitations and future research

Prior research on tourist tracking using GPS has been limited by small sample sizes and the need to physically distribute GPS devices, which may cause demand bias, whereas prior bikeshare research has largely overlooked visitor use and/or demand. However, research on GPS enabled bikeshare programs usage coupled with big data methods as described herein provides unprecedented access to understand the actual behaviors of visitors, while overcoming the methodological shortfalls of other strategies. Although the study overcame previous gaps in the literature it was limited by several issues that necessitate acknowledgement and present opportunities for future research. The current research provides substantial explanatory power through the use of big data, but was limited by the available and derived variables without direct input from users.

Much of the research on bikeshare use by non-members uses a similar approach to the present study as intercepting bikeshare users can be quite difficult and often no contact data is provided for daily or casual users (e.g., Fishman 2016; Fishman et al. 2013). Thus, much is still unknown about visitor bikeshare use such as preferences, variance based on type of visitation (e.g., day trip, overnight, leisure), experiences, motivation, expenditure, socio-economic background, decision making and more. The use of surveys and interviews delivered via intercept, email, or smartphone applications will certainly supplement and provide further explanation to the study results. Although, quantitative analysis of GPS based data has considerable value in understanding tourist behavior and can provide powerful insights into spatial-temporal patterns (Li et al., 2018; Shoval & Ahas, 2016), complimentary qualitative inquiry is also needed to understand why choices are being made and how bikeshare is perceived and leveraged by visitors in experiencing a destination. The use of new methods including photo elicitation, mobile video, and ethnography will be useful in elucidating linkages between mobility, attachment, embodiment, and sensory engagement with the destination space and overall tourism environment (i.e., Hinch & Holt, 2017; Larsen, 2014; Spinney, 2011). Certainly, future research pairing GIS, big data, bikeshare, and smartphones will provide not only provide spatiotemporal findings, but also factors that affect the dispersion of tourists and the related impact throughout a destination (e.g., Hardy et al., 2020).

The use of GPS enabled bikeshare data in tourism research combines the strengths of different tracking technologies without some of the limitations, as no physical devices need to be distributed, data collection is passive, data accuracy is relatively high, geographic scale can cover entire urban areas, and data can be collected continuously (see Shoval & Ahas, 2016 for a debate on these issues). However, many traditional bikeshare systems are not fitted with GPS technology thus preventing similar inquiry in other cities, volunteered geographic information, activity tracking apps such as Strava, and other user based data collection methods maybe helpful in managing this issue in the future (Romanillos et al., 2016; Wolf et al., 2015). The latest version of bikeshare technology known as floating or “dockless” programs do not require users to check out and check-in bikes at a physical kiosk, which creates other issues as the bikes often end up dumped randomly throughout cities even in waterways (Carey, 2018). Dockless programs have risen dramatically in popularity in recent years largely due to the lack of kiosks which makes implementation cheaper and easier, instead these systems rely on real time GPS tracking to manage inventory (Pal & Zhang, 2017).

Similar dockless programs using electric scooters are also being deployed throughout North America and other countries prompting regulation and varying public acceptance and recent research argues that the spatial and temporal usage patterns of scooters vary greatly from bikeshare use (Mckenzie, 2019). Still, research on both bikeshare and scooter-share programs is scarce regarding visitor use. Future research should investigate the behavior and demand of these programs by visitors especially as the bikes and scooters are equipped with GPS creating opportunities to use big data and uncover the range of benefits to both users, policy makers, and scholars (Romanillos et al., 2016). Such research will certainly require a strong connection between the transportation sharing industry providers (e.g., Lime, Bird, Mobike) and researchers (Li et al., 2018).

Certainly, the results discovered herein are applicable to other urban destinations operating bikeshare programs. Although previous research has investigated cycling tourism associated with trail networks such as rail trails largely in rural areas (e.g., Lumsdon et al., 2004; Meschik, 2012) and cycling events (e.g., Buning et al., 2016; Mackellar & Jamieson, 2015), future work should consider the linkage between tourism, bikeshare, and urban trail networks as they relate to economic, social, and environmental impacts including connections to public health for urban communities. Research into bikeshare use around major tourism oriented events such as conferences and large sporting events is similarly warranted (Corcoran et al., 2014). Regardless of the specific direction, research around the intersection of travel, bikeshare, and big data has much to provide for both scholars, bikeshare operators, urban planners and the tourism industry.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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