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Bike-sharing: the good, the bad, and the future -an analysis of the public discussion on Twitter-

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Due to the dilemma of bike-sharing concerning its benefits and drawbacks, and its unclear future, we focused on a mixed-methods approach to analyze this public discussion through posts or "tweets" from the social media channel Twitter. We collected around 12,000 tweets in English around the world related to bike-sharing for a period of about six months. We considered two approaches, including topic clustering and sentiment analysis in tweets including: a) bike-sharing related terms and b) "future" and bike-sharing related terms. Strongly positive tweets promote bike-sharing and its benefits such as being convenient, well-performing, and sustainable. Additionally, there is a tendency to write that public, electric, and dockless are better, together with scooters. In contrast, the complaints on bike-sharing focused on inequity, rentals and safety issues, critique on authorities and laws, and poor performance especially of dockless Asian bike-sharing start-ups with low-quality bikes. Around 50% of the tweets that included the terms "future" and "bike–sharing" stated that bike-sharing is going to be part of the future of mobility as an electric dockless version together with other shared modes. The hesitant statements towards bike-sharing being part of the future referred mainly to the systems with poor bikes' quality. Politicians and stakeholders can use this information to enhance bike-sharing or consider the implementation of certain types of bike-sharing in their cities. To the best of the authors' knowledge, this study would be one of the first that analysis the public discussion on social media about a transportation system and its future using a mixed-methods approach. Future studies should aim at identifying and comparing the public opinion of different emerging transportation technologies.

Keywords: *bike-sharing, drawbacks, future, public discussion, text mining, twitter.*

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1. Introduction

Bike-sharing systems (BSS) have experienced exponential worldwide growth from one hundred programs in 2010 (Shaheen et al., 2010) to around two thousand schemes in 2019 (Meddin and DeMaio, 2019). This growth can be explained because BSS, beyond the benefits of cycling, offer the advantages of the sharing economy, and also, they have a relatively low purchasing and operating cost (Buckley et al., 2014) giving "sustainable" image to a city and supporting tourism (Ricci, 2015).

As part of the cycling benefits, BSS can help to increase public health, environmental awareness, and it can lessen the negative environmental effects of the usage of polluting transport means (Shaheen and Chan, 2015; Fishman, 2016; Shaheen et al., 2012; DeMaio, 2009). Moreover, cycling can increase the leisure time of riders while commuting (Qiu and He, 2018) and allow riders to interact with others and the surrounding environment (Brömmelstroet et al., 2017). Some systems have adapted electric bicycles which help riders to avoid perspiring, to extend traveling distance, to cycle in heterogeneous topography, and to enable cycling for riders with physical difficulties (Shaheen and Chan, 2015).

Beyond cycling benefits, BSS foster cycling access to those who might not use bikes otherwise (Shaheen and Cohen, 2019). BSS, as enlargers of the cycling population (DeMaio, 2009; Fishman, 2016), allow riders to have access to a bicycle if they do not own one of their bicycles are not available, or even if users want to cycle for a one-way trip. Users do not have to worry about bike theft or maintenance (Bachand-Marleau et al., 2012), storage, and parking in the case of docked-systems (Shaheen and Cohen, 2019). Moreover, BSS have shown to bridge the first mile-last mile connection to public transport stations (DeMaio, 2009; Shaheen and Cohen, 2019). BSS's trips have been reported to reduce mobility costs in comparison with other payment-based transport modes. For example, in Beijing, users of BSS reported a 58% reduction in travel budget (Sun, 2018).

Even with their potential benefits, some BSS have been misused, vandalized, and perceived as a public nuisance (Hamann and Güldenberg, 2018). Vandals brake bicycles, setting them on fire, or place them in unreachable places such as trees (Sun, 2018). Moreover, when private companies exit the market, they leave their bikes in the public space causing significant waste (Sun, 2018). Oversupply, low support of authorities and law, saturated markets and low-quality bicycles, disorderly parking, and safety of BSS are some historical reasons for these system failures (Hamann and Güldenberg, 2018; Sun, 2018). "Oversupply has led to graveyards of bikes, and deep concerns about quality control, maintenance, and management of these systems" (Sun, 2018). In a survey in Beijing, 35% of respondents complained about the bikes' poor quality. Therefore, Sun, (2018) states that dockless systems start-ups are worried about increasing territory and not providing a good service. In contrast, other systems suffer saturated markets, which have caused conflicts because of the lack of docking stations (Li et al., 2019).

Furthermore, bicycles are bought and stations are placed based on demand usually, then, the sharing concept is lost (Shaheen and Cohen, 2019). These systems have reported, especially in the global north, an unequal degree of infrastructure location and usage. The common user's profile is male, young, white, high income, high education, already engaged with cycling and with access to credit card and bank account (Shaheen and Cohen, 2019; Buck, 2013; Fishman et al., 2015; Murphy and Usher, 2011; Ogilvie and Goodman, 2012; Ursaki and Aultman-Hall, 2015). Traditionally less privileged people have also less access to BSS (Ursaki and Aultman-Hall, 2015). In London specifically, "women and those living in deprived areas are less likely to register to use the scheme" (Ogilvie and Goodman, 2012).

Because of the dilemma of BSS being "good or bad", i.e. the conflict between benefits and drawbacks, we aim to explore the public discussion about this dilemma and BSS being part of the future of mobility. Our goals are 1) to identify and interpret patterns and themes in the narrative about this public discussion, and 2) to describe and categorize common words, and phrases. For

this research, public discussion means the themes, ideas, opinions, facts, debates, complaints, advertising from institutions, news, researchers, riders, individuals, the general public, etc.

To get a sample of the "public" concerning this topic, we explored the public discussion from posts on social media, specifically on Twitter. This approach helps to explore the BSS dilemma across multiple cities in a cost-efficient, and anonymous way, and also, the posts came from a context from the real world, in a naturalistic way. Even though Twitter might not represent society as a whole, the results of this study can support understanding the public discussion of a sample of society. Politicians and stakeholders can use this information to enhance BSS or consider the implementation of certain types of BSS in their cities.

The remainder of this paper includes a literature review about bike-sharing, twitter, and transport-related studies using Twitter data. Then, a three-step methodology is presented including data collection, data cleaning and classification, and a mixed-methods approach for the data analysis. The results are presented in two parts: public discussion of a) the BSS dilemma and b) BSS's future. After discussing the methodology and the results, we conclude the paper with recommendations to politicians and stakeholders.

2. Literature review

2.1 Bike-sharing systems

BSS allow users to rent a bicycle offered in the public space for a short period and on an "as-needed basis" (Büttner and Petersen, 2011; Shaheen et al., 2015). According to the availability of stations, BSS are classified mainly into three categories: a) docked-based, in which bikes are picked-up and dropped-off at fixed stations, b) dockless, where bikes are picked-up and dropped-off in the public space within a service area, and c) hybrid, in which bike can either be picked-up and dropped-off at stations or in the public space (Shaheen et al., 2019).

BSS are not a new form of mobility. They started as a free service in Amsterdam in 1965 (DeMaio, 2009). After the system collapsed mainly because of vandalism and appropriation of the bicycles, the next generation, born in 1993 in Denmark, allowed a coin deposit and bike pick-up and drop-off in specific locations. Within the evolution of technology, BSS developed ICT based systems, starting in 1996 in England and 1998 in France. Users could rent bikes in stations with identification cards (DeMaio, 2009) and bikes could be tracked (Shaheen et al., 2012). After the success in Paris with 23,600 bikes in the city, BSS started being implemented around the world, arising to 120 programs in 2010 (Shaheen et al., 2010).

Finally, a fourth-generation emerged allowing a demand-responsive system, renting bikes with mobile devices, real-time integration with other transport modes, GPS tracking, and dockless systems (Shaheen et al., 2012). Nowadays, electric BSS are rapidly emerging in China and Northern Europe (Pucher and Buehler, 2017), in which e-bikes (electric bikes) reduce the physical effort of the rider (Shaheen et al., 2016).

2.2 Twitter:

Twitter (http://www.twitter.com) is a social media platform with a stronger emphasis on conversations based on microblogging (Chaniotakis et al., 2016). It does not require a reciprocate access permission -as is the case of Facebook - between the user who posts and their follower (a person who checks posts from another user). These posts are called "tweets", which can have a maximum size of 280 characters. Additionally, on Twitter, there is a retweet mechanism that allows followers to spread another person's original tweet (Kwak et al., 2010).

According to STATISTA, (2020), Twitter registered 386 million active users around the globe in April 2020. It occupied the 14th position on social networks with the most number of users. Around

a third of the users enter Twitter several times a day. The United States, Japan, Russia, and the United Kingdom are the countries with the most users. In the world, around 85% of users are younger than 50 years old and 60% are male. Twitter was the fourth most popular social media app in the United States by reach and also by monthly users in September 2019.

Tweets are publically available to software developers and users throughout the Application programming interfaces (APIs). Users can access tweets by registering in the application and they will be provided an API access key, a token, and a consumer. Tweets can be collected after searching for specific keywords or posts from specific accounts (Roesler et al., 2020). There is a limit of 100,000 requests per day and 75 requests per 15-min window in a 7-day limit for standard users (developer.twitter.com)

2.3 Twitter data and transportation systems:

Social media has been mainly used in transportation to a) share information to customers and public engagement and b) real-time or historical data collection and mining (Chaniotakis et al., 2016). Regarding data, the most common types used in transport are geotagged information of tweets and the text used in the posts.

Twitter allows public transport agencies to interact directly with users by retweeting, and also, to communicate different news as delays, events, or disasters (Casas and Delmelle, 2017). After a survey of public transport agencies in the U.S.A., Bregman, (2012) identified that Twitter is the most preferred social network used by transit authorities, followed by Facebook and YouTube. Twitter is preferred for agency news, service alerts (real-time), and press releases and statements. However, agencies reported that social media was not useful for increasing ridership, save money, and recruit and keep staff. However, transit agencies reported that social media is not a good way to reach the elderly and minorities.

Quantitative data analysis on Twitter

Real-time data has been used to estimate predictions, disruptions, and events (Chaniotakis et al., 2016). Transit agencies use real-time data from Twitter as a traffic sensor. However, it has been reported not to be reliable because people perceive congestion in different ways and the combination of the words to express "congestion" is enormous (Wojtowicz and Wallace, 2016). Another way of taking advantage of real-time tweets is to locate traffic incidents (Gu et al., 2016; Li et al., 2012; Schulz et al., 2013; Zhang et al., 2018). For example, Gu et al., (2016) developed a methodology for real-time incidents' detection and they validated them with official data.

Regarding historical geotagged data, Steiger et al., (2015) correlated tweets' locations with census data in the United Kingdon. Chaniotakis and Antoniou, (2015) identified in Athens, Greece a significant correlation between tweets' density with high-income areas and leisure or transport-related areas. Another transport-related application is the estimation of origins and destinations of trips (Yang et al., 2014). Moreover, Chaniotakis et al., (2016) correlated geolocated tweets with the conventional travel survey in Thessaloniki, Greece.

Historical text data has been used to identify points of view of transport projects, implementations, or policies. Text relevant to the policy have been categorized in a) need to travel b) transport network state or event, and c) opinion about a transport service (Gal-Tzur et al., 2014). To collect transport-relevant information and understand the public opinion of transport systems, Gal-Tzur et al., (2014) filtered messages from authorities and individuals. Around 45% of the messages in the dataset were labelled as originating from individuals. They identified that individual messages are around 45% of the times and they include mostly terms as "I" or "we" and informal terms as "lol". Also, Twitter has helped to identify numerous trips and socio-demographics in a cost-efficient manner (Grant-Muller et al., 2014). Liu et al., (2012) built a method using Twitter data to identify "the gender breakdown of different types of commuter populations"

Schweitzer, (2014) used text mining, sentiment analysis, and machine learning techniques to examine the content related to public transport and compared it with other public services on Twitter. Public agencies were shown to influence the comments with their engagement in social media. Those agencies who chatted with their users have more significantly positive sentiments in their posts. Collins et al., (2013) evaluated rider satisfaction in transit usage in Chicago, U.S.A., using sentiment analysis on Twitter. In different situations, transit riders showed a prevalence of negative sentiments rather than positive.

Most studies concerning BSS and social media have dealt with text analysis or sentiment-based analysis. For instance, Das et al., (2015) collected tweets including the term "bikeshare" in Washington DC for nine months to show a methodological approach for sentiment analysis. Rahim Taleqani et al., (2019) collected English worldwide posts on Twitter for two and a half months to understand public sentiment and topic clustering regarding dockless BSS. The posts included the hashtags "dockless", "bike sharing", and "bike share". They carried out a word clustering approach using latent Dirichlet allocation (LDA) method and discovered seven clusters of words association. They highlighted the high relationship of BSS with the word "scooter" and negative sentiment towards the shared bicycles blocking sidewalks.

Qualitative data analysis on Twitter

Qualitative methods allow analyzing text data beyond their literal description (Marwick, 2014). Because of Twitter's great amount of data and users, qualitative methods can be labor-intensive. Nevertheless, they might overcome the disadvantage of quantitative methods of not describing messages between the lines, or not identifying typos, sarcasm, or abbreviations (Gu et al., 2016; Marwick, 2014). Then, qualitative methods can reveal social norms, concerns, practices, and also complement the exploration and arguments of the quantitative methods (Marwick, 2014).

Qualitative research on Twitter has been focused on interviews, ethnography research, and textual interpretation (Marwick, 2014). Interviews can be carried about by asking users quick questions. Marwick and Boyd, (2011) carried out a snowball method in which they posted questions to their followers about their experiences, opinions and feeling about using Twitter. Then, their followers retweeted the question or questioned their followers. Ethnography research includes observing or participating in a particular online group to understand the interactions between people (Marwick, 2014). For instance, Chretien et al., (2015) used digital ethnography to investigate IT professionals and their usage of Twitter in shaping communities.

Textual analysis and discourse analysis of individual tweets are typically collected in an automated way using keywords, and then, the individual analysis of each tweet is carried out from a selected subset (Marwick, 2014). In this approach, each tweet is assigned to one or multiple "codes". "Coding is a way of indexing or categorizing the text to establish a framework of thematic ideas about it" (Gibbs, 2007). For instance, Papacharissi, (2012) coded 1,798 tweets manually for content and discourse analysis to investigate the presentations of the self. The sample was selected based according to a different conversation of trending topics.

Andreotta et al., (2019) proposed a four-steps mixed-methods approach combining the advantages of qualitative and quantitative methods to understand the public discussion on climate change. The four steps are: 1) text data are collected, 2) posts are clustered based on quantitative methods 3) extract a sample of most relevant posts or select the sample randomly, and 4) perform qualitative analysis.

To the best of the authors' knowledge, this study would be one of the first that analyzes the public discussion in social media about a transportation system and its future using a mixed-methods approach.

3. Methodology

We performed a three-step methodology to explore the language usage and to identify patterns and themes about the public discussion on the BSS dilemma and their future. The main three steps are 1) data collection, 2) data cleaning and classification, and 3) mixed-methods approach for data analysis.

3.1 Data collection

We collected tweets in English related to "bike–sharing" and related terms for all the possible combinations that represent BSS on Twitter over a determined period by using the package "twitteR" (Gentry, 2015) from the "R" programming language. The first challenge was to identify the different terms that people use to refer to BSS in social media, conventional media, and scientific articles. Si et al., (2018) searched for different terms used in scientific papers referring to BSS including "bike sharing", "bicycle sharing", "bike share", "shared bicycle", "bikesharing", "shared bike", "public bicycle", "public bike".

For this research, three different types of combinations of the term "bike-sharing" were identified in newspapers and scientific papers. They are composed of root terms (i.e. mandatory words) and complimentary terms (i.e. optional words to complement the root). Four common complements were identified concerning bike-sharing: "system", "service", "scheme", and "program". Figure 1 shows the three different types of BSS-related terms and their potential combinations. As an example, Type I includes: "public bike", "public bicycle service"; Type II terms are, for instance: "bike-share", "shared bike", "public bicycle sharing system"; and finally, Type III can present the composition of the words: "bikesharing", "bikeshare program".

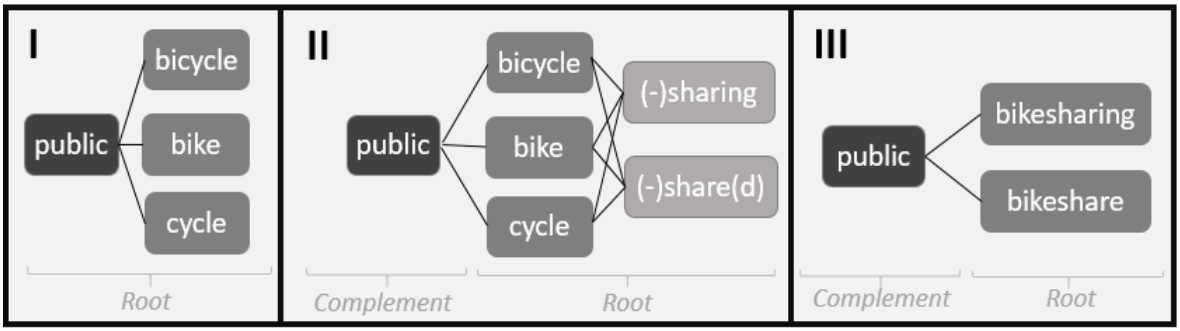

Figure 1. Terms combinations referring to BSS in the literature

3.2. Data cleaning and classification

We wanted to focus on the collection of only original ideas, based on original tweets. Original tweets represent the opinion of individual users and not the chain of an idea through retweets. Retweets are a fast way to spread opinions and they can give an idea of the post's significance. However, their frequency is correlated to the number of followers that a poster has. Therefore, neither retweets, as in Rahim Taleqani et al., (2019), nor very similar tweets are included in the study. Thus, a cleaning process is carried out to discard all the tweets that have more than 70% of identical words. A sensitivity analysis was carried out considering 90%, 80%, 70%, and 60%. Tweets with a similar idea but not original were discarded after considering 70% as a threshold. Finally, only one tweet per user and category was selected, to avoid the bias opinion of only highly active people on Twitter.

We carried out two analyses of tweets to understand the public discussion on BSS: a) Highly positive and highly negative tweets including "bike–sharing" and its related terms to understand the current situation of BSS, and b) tweets including the terms "future" and "will" to understand the discussion regarding the future of BSS.

a) Strongly positive and Strongly negative posts. To identify the dilemma of BSS being good or bad, we classified the tweets into "strongly negative" and "strongly positive". We assumed that tweets with negative words will contain the BSS disadvantages and tweets with positive words the advantages. We did not include neutral tweets assuming that they are not part of the discussion of the BSS dilemma.

Therefore, first, we classified the tweets on "positive", "neutral" or "negative" by sentiment analysis. Sentiment analysis is a text mining technique that evaluates sentiments from written language (Liu, 2012). We used a polarity lexicon-based method, which assigns a combination of words of a text to a respective sentiment, such as positive, neutral, and negative. We implemented lexicon-based methods because we aim to have a score of the frequency of either positive or negative terms, which we expect are related to benefits and drawbacks respectively. We preferred lexicon-based methods over supervised machine learning techniques because they required labeled data to train the models (Gonçalves *et al.*, 2015)

In lexicon-based methods, every word is compared to a dictionary to be classified as positive or negative. Then, a polarity score is calculated per tweet, which is defined as the algebraic sum of terms classified as positive or negative, divided by the total number of words of the tweet (Hu and Liu, 2004). If a word in a tweet is included in the dictionary, it is classified as negative, positive, or neutral. Tweets are classified as "positive" (score > 0), "neutral" (score = 0) or "negative" (score < 0). Shifter words such as negators (e.g. not), amplifiers (e.g. very), and de-amplifiers (e.g. barely) were also considered in the estimation.

In this study, we used the "vader" package in R for polarity analysis (Hutto and Gilbert, 2014). This package uses the vader dictionary with 7515 words. Vader dictionary was developed using tweets, movie reviews, among others. It includes 5 heuristics: 1) punctuation (e.g. !!!), 2) capitalization (e.g. We LOVE it), 3) shifters, 4) amplifiers, and 5) tri-gramms identification (Gonçalves et al., 2015). We chose vader dictionary because it is one of the newest dictionaries based on tweets, and also, after the comparison between several dictionaries, Gonçalves et al., (2015) showed that vader is one of the dictionaries that perform better sentiment analysis with tweets.

After assigning a polarity score to each tweet, we wanted to be on the "safe side" and have a high probability of choosing real positive or negative tweets including "bike–sharing" and its related terms. Therefore, we selected tweets between a range of 0.5 and -0.5, i.e. tweets were subset into strongly positive (e.g. > 0.5) and strongly negative (e.g. > -0.5). We considered this threshold appropriate after testing by reading part of the tweets and verifying the content.

b) Post including the term "future". We create a subset of tweets including the terms "future" and "will" in the intent of exploring the public discussion on the future of BSS.

3.3. Mixed-methods approach data analysis

After the tweets were classified into the three categories (strongly positive, strongly negative, and future-related), we carried out a mixed-methods approach for text analysis, in which, we take the advantages of quantitative and qualitative methods. Both methods should not substitute each other but complement. Quantitative methods help to describe the big dataset at a macro-level, while the

qualitative approach provides detailed information and explanation of the macro-level (Kelle, 2006).

First, we counted the most repetitive terms in each category for evaluation and comparison. The frequencies helped us to have an idea of the language used and gave us an idea of the possible themes for each category. Then, we performed topic clustering, i.e. we assigned a category, theme, or topic to every tweet. We followed one quantitative and one qualitative method for topic clustering. In this research, we used the information about the results of the quantitative approach as a starting point for the qualitative one. As the qualitative analysis can be subjective to the authors, the quantitative approach helped to corroborate the impartiality of the results.

Quantitative clustering method. Clustering is carried out quantitatively by Reinert textual clustering method (Reinert, 1983; Reinert, 1987) based on descending hierarchical classification with the open-source software IRAMUTEQ (Camargo and Justo, 2013). The selected tweets are treated as a single corpus, whereby each tweet is considered to be one paragraph. The process has mainly four steps: 1) reduction of the sparse corpus, 2) lemmatization (extracting root form words), 3) creation of units of context by classifying the words into active terms (verbs, adjectives, substantives, adverbs), and supplementary terms (prepositions, pronouns, and frequent adverbs, adjectives, etc.), 4) descending hierarchical clustering based on the frequency of the root of the words, the maximum number of clusters to be computed, and the minimum number of forms in each (Ruiz Bueno, 2017; Villeneuve, 2020). The number of clusters was set by 1) minimizing the number of tweets that do not belong to any category, 2) logical topic separation between clusters, and 3) considering a minimum distance between clusters.

Qualitative clustering method. Tweets were clustered manually (qualitatively). After reading and analyzing every tweet, each one is assigned one or more categories or "codes" based on the literal text or the meaning "between lines". For instance: the tweet "*They're the best bikesharing around because you can actually move around town fast and are affordable*" had the following codes:

- *They're the best bike-sharing around*: BSS perform well
- *you can actually move around town*: BSS good for mobility
- *fast*: BSS are convenient
- *affordable:* BSS are sustainable: Socioeconomic

We used the results of the quantitative clustering approach and terms frequency as a starting point of possible codes in our dataset. Then, those with similar codes were aggregated. If a code was identified only one time, the tweet was not included in the clustering.

4. Results

Tweets including all the possible combinations of the term "bike-sharing" were collected from 18.08.18 to 12.02.19. In total, 12,498 tweets in English were collected and cleaned with a mean of 109.6 tweets per day. A peak of around 500 tweets per day was identified on 4-7 September during the conference of the North American Bike Sharing association. Usually, there were around half of the number of tweets on the weekends than on working days. The most common terms associated with bike-sharing were "bike share", "bike sharing", "bike-sharing", and "bikesharing" (Figure 2). Together, these four terms served to collect around 70% of the total tweets. After deleting very similar tweets, the sample included 5.403 tweets.

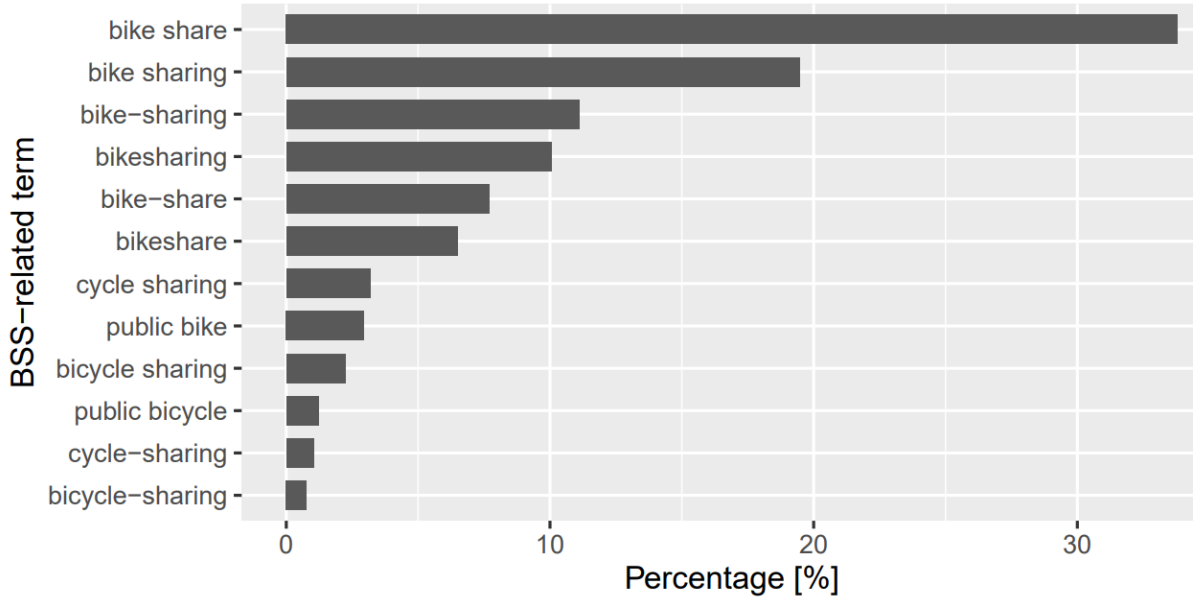

Figure 2. Relative frequencies of BSS-related terms in the collected tweets

4.1. Public discussion on BSS dilemma

The polarity evaluation showed a mean score of 0.36, where 73% of the tweets were classified as positive, 13% as neutral, and 14% as negative (Figure 3). For the analysis, strongly positive tweets were selected as those having a polarity score greater than 0.5 (n=3070) and strongly negative tweets with a score of less than -0.5 (n=682). After estimating the relative frequencies of the words' roots used in tweets in both sentiments (Figure 4), positive tweets presented a higher association with, for example, the stems terms "public", "city", "ride", "electric", "station", and "e-bike", while the negative tweets were associated with "Manchester", "mobike", "Chinese", "start-up", "million", "lot", "space" and others. In the middle line of being used in either positive or negative tweets, we found the words "dockless", "uber", "lime", "new", "launch", "city", and others.

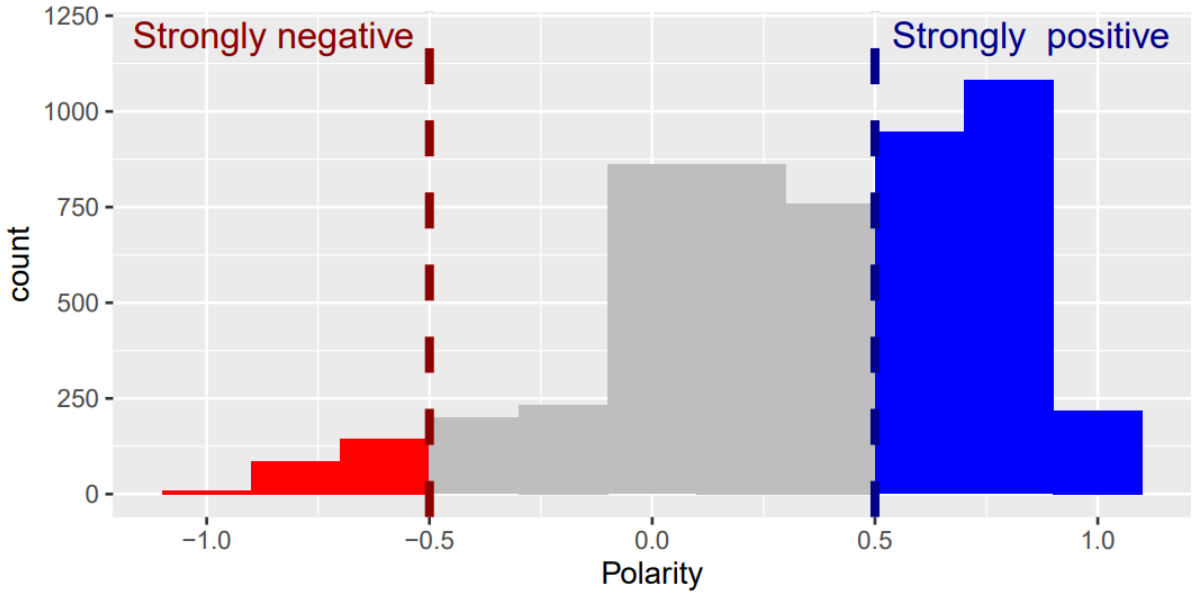

Figure 3. Polarity scores for tweets including BSS-related terms

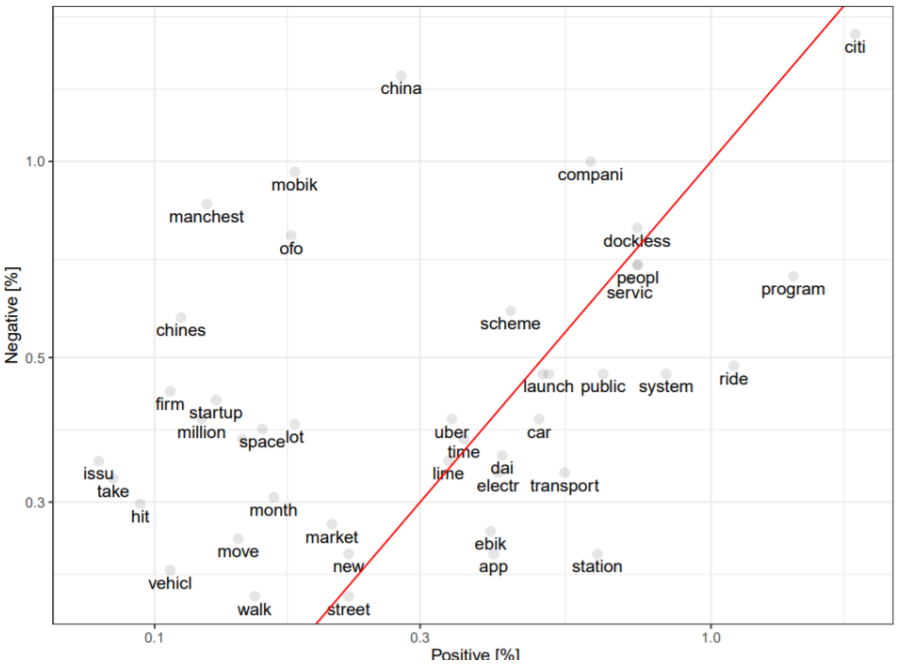

Figure 4. Words' roots relative frequencies of positive and negative tweets

Bike-sharing: The good

On the other hand, 91.04% of the strongly positive tweets were clustered into four clusters following a decreasing hierarchical clustering technique using Reinert's method (Reinert, 1983; Reinert, 1987). From the clustered tweets, the majority, 63.8%, were in the category "BSS are good" and the remaining in "BSS marketing" (Figure 5). Around half of the tweets in the category of "BSS is good" are related to BSS being good for mobility. We can corroborate this after the most associated words in this cluster are "transport", "public transport", "mobility", "solution". The remaining tweets talked about other reasons why BSS are good, e.g. when they are "dockless", "electric" and they complement with "scooter" sharing systems.

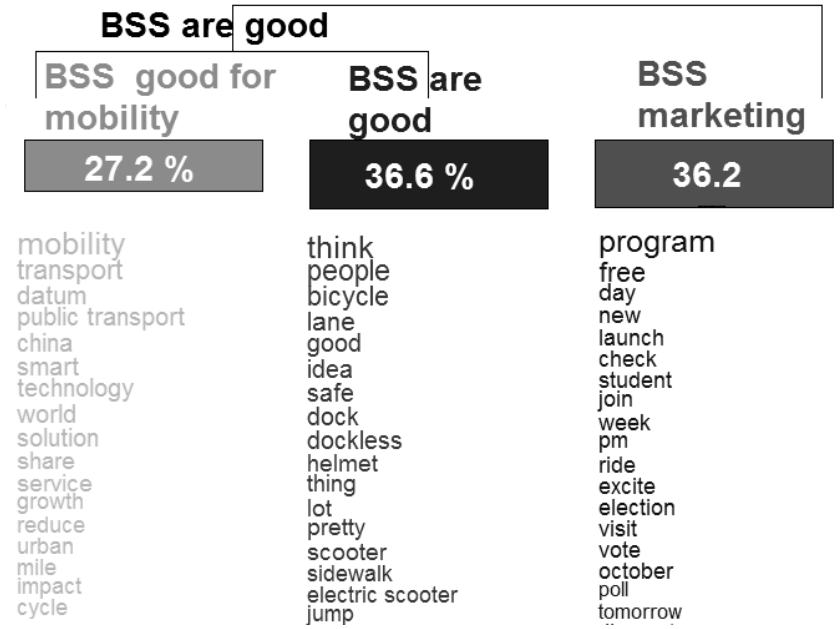

Figure 5. Quantitative topic clustering on strongly positive tweets

For the qualitative topic clustering, we subset the 150 tweets with the highest positive score. We identified mainly 7 categories (Figure 6, Table 1) in 89% of the selected tweets. Three of these categories were identified in the quantitative approach. The categories were as follows:

1. BSS are sustainable (25%). BSS are claimed to be good for the environment (6%) and the socioeconomy (19%). The environmental part is justified after stating that BSS help to reduce car usage, and replace cars and therefore, fewer emissions. The socioeconomic part is highlighted in statements that BSS are affordable and cheap, support the local economy and community empowerment, increase mobility inclusivity and equity, and also they are good for health.
2. BSS are good for mobility (17%). BSS are promoted to be good when a person does not own a bike, good for the lat-mile connection with public transport, and good to explore the city. Finally, some stated that BSS are better than car or scooter sharing.
3. BSS expansion and opening (11%). Positive tweets about a system's expansion or a system that is going to be implemented.
4. BSS marketing (11%). Posts mainly from entities promoting the usage of BSS
5. BSS perform well (10%). Tweets explaining how well a system performs. Also, this theme includes satisfied people with the service and people supporting BSS.
6. BSS are convenient (10%). This category includes the reasons why BSS are convenient: BSS are fast, fun, easy to use, riders dot not have to worry about bike thefts.
7. When better? Dockless and electric (5%). The opinion of people and entities stating that they like BSS with an electric and dockless scheme.

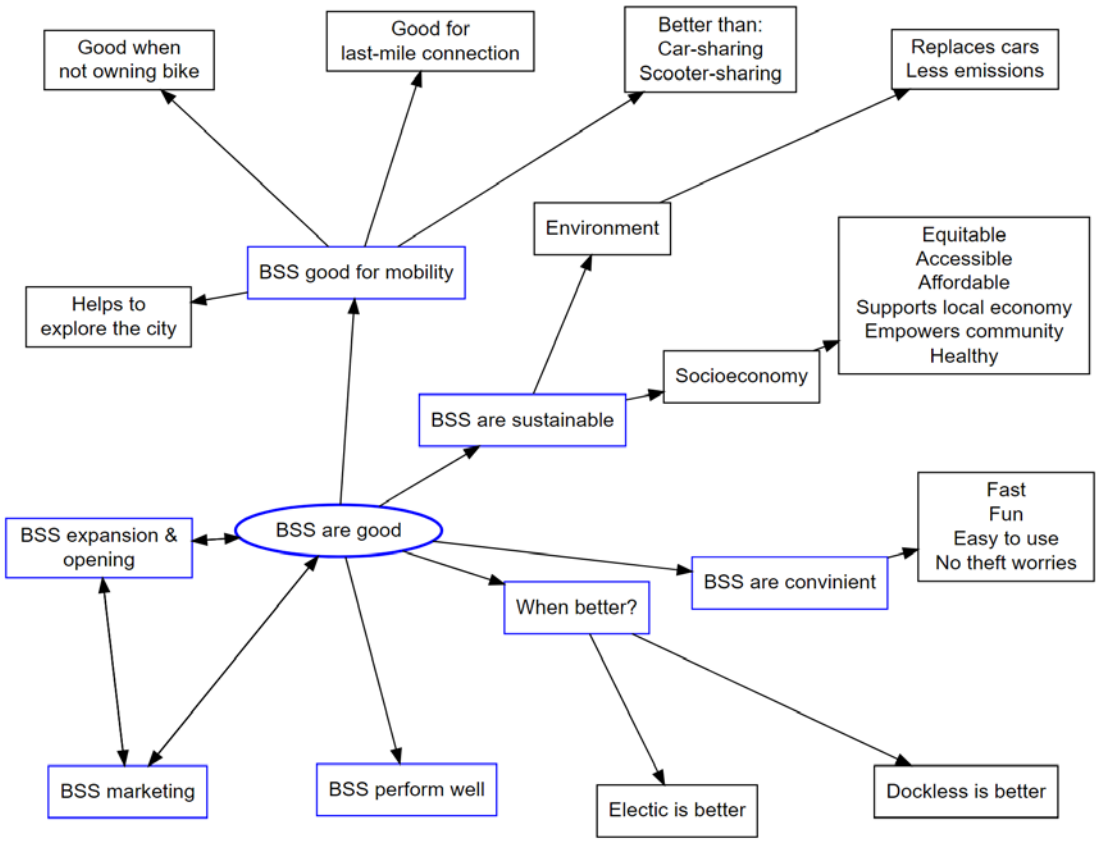

Figure 6. Qualitative topic clustering on strongly positive tweets

Table 1. Examples of strongly positive tweets per cluster

Cluster	Example	Poster & Date
BSS are sustainable	"Bike share in Africa; good for the economy , good for health , good for the environment , Good for air quality , good for job access ... what are we waiting for ?"	*@GilboCarly 14.10.2018*
BSS are good for mobility	Last year I was the only one in my apt that biked, now all four of us do. Very cool. Thanks @RideBluebikes! Bike share rocks.	*@CodyPajic 13.09.20`8*
BSS expansion & opening	Good news for cyclists in New Orleans: 485 new bike racks are coming, and bike-share rentals are now cheaper	*@CurbedNOLA 12.10.2018*
BSS marketing	"Did someone say FREE?! Yup! FREE Metro Bike Share monthly pass!!"	*@JenMaradiagaMPH 16.10.2018*
BSS perform well	"Rode a Lime bike from the ferry to @factionbrewing with @AttemptedChem and let me tell you something about bike sharing... folks, it's good. It's very good."	*@rich_roberts 01.09.2018*
BSS are convenient	"Just tried Metro Bike Share for the first time in DTLA. Great experience! I actually like the feel of the bike better than @BreezeBikeShare! Both are great; Metro bikes are lighter, smoother, faster, less clunky. Breeze has better connectivity and better docks/system locations."	*@sean_baba 08.10.2018*
Dockless is better	"There are definite benefits to going dockless, particularly in New York, where NIMBY-led fights over docking stations can hold up the placement of new bikes."	*@ReginaRyan_NYC 14.09.2018*
Electric is better	"Marlon Boarnet on Twitter: "How e-bikes are game changers, and why we should welcome them…. Light duty e-mobility has great prospects for sustainability and equity…"	*@SteveAuterman 05.12.2018*

Finally, around 2% of the tweets were classified as sarcasm, for example:

"*More free median parking, less bike share, zerp eScooter = more freedom for me and my mostly empty car! Thanks @EdReiskin @stma_muni* !" *[@Bob_Gunderson 30.08.2018]*

Bike-sharing: The bad

Four main topics were identified quantitatively from 95% of the tweets classified as strongly negative (Figure 7). Around half of the strongly negative tweets were classified as bad performances of BSS. The other topics were related to BSS oversupply especially of bikes' graveyards in China, vandalism of bikes, and cycling being not safe.

According to the qualitative topic clustering, 150 strongly negative tweets were clustered into 8 categories (Figure 8). The categories determined in the quantitative part (Figure 7) were a subset of these 8 categories. Moreover, 23 tweets did not belong to any category or they were wrongly classified due to sarcasm (~2%). An example of a wrongly classified tweet due to sarcasm is:

"*E-bikes represent a real danger" says NYC mayor. Look at the picture. Who's more dangerous: The e-cyclist who goes 30 km/h or the two-ton metal boxes that move around the city at 60 km/h?" [@LiorSteinberg, 12.03.2018]*

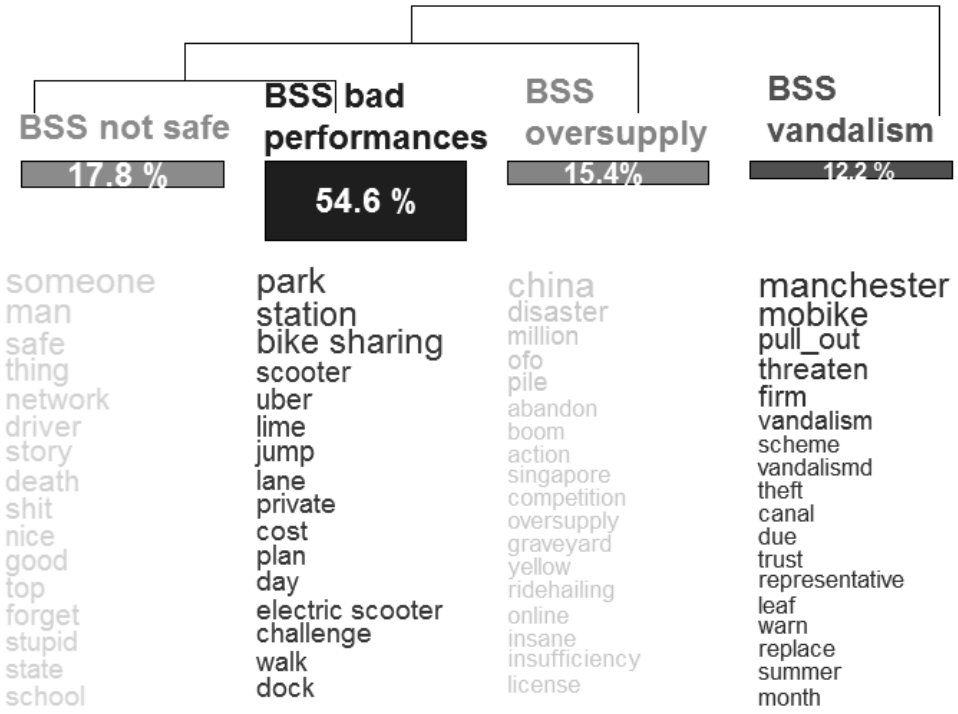

Figure 7. Quantitative topic clustering on strongly negative tweets

Around 24% of the negative tweets were related to Asian start-ups of dockless systems, and specifically to the companies "ofo" and "mobike". The predominant cluster (28.9%) was related to tweets describing BSS that have experienced poor performance or that have been pulled out from a city. The other main categories are related to vandalism issues to the bike-sharing infrastructure, mainly bicycles, and also complaints about the oversupply of some systems and the bicycle graveyards. Another cluster included the unsatisfactory deployment of the system, even approaching equity issues, issues by using or renting bicycles, and safety issues. Finally, the least frequent clusters dealt with complaints to public authorities and the lack of BSS in their cities. Table 2 shows examples of the strongly negative tweets per cluster.

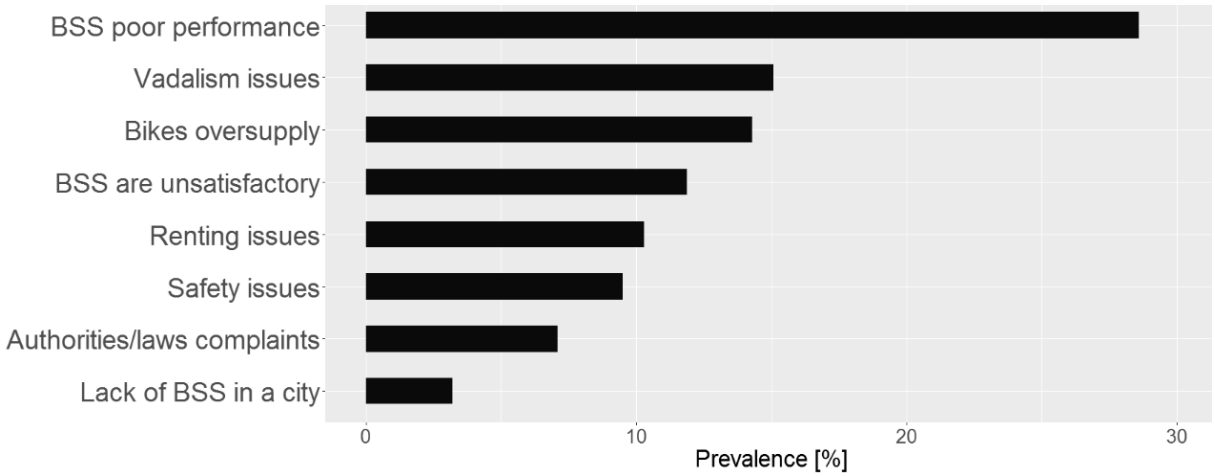

Figure 8. Qualitative topic clusters according to the strongly negative tweets

Table 2. Examples of strongly negative tweets per cluster

Cluster	Example	Poster & Date
BSS poor performance	"Bike-sharing firm Ofo's dramatic fall from grace a warning to China's tech investors"	*@rothwell_scott 27.12.2018*
Vandalism issues	"Dockless bike-sharing company pulls out of Manchester due to "theft and vandalism"	*@snebq 07.09.2018*
BSS oversupply	"Huge piles of impounded and broken bicycles lie in a rubbish dump after dozens of bike-sharing companies went bankrupt last year in Nanjing, China on January 10, 2019."	*@Joopjadieja 19.01.2019*
BSS are unsatisfactory	"The bike share touted as being "for poor people" was too expensive. Shocking."	*@ineedja_kadeeja 03.10.2018*
Renting issues	"So I lost more than 30 minutes and 5$ for nothing, no replies at all. #Useless #bikesharing #app #bikers #danger #mobike #scam"	*@braisontour 29.01.2019*
Safety issues	An 18-year-old went to the hospital last night after the brakes reportedly failed on the bike share bike he was riding. @komonews says they found a Lime bike with its brakes slashed at the scene of the crash.	*@davidlgutman 11.09.2018*
Authority/laws complaints	Lack of infrastructure, regulations killing bike-sharing services	*@TMReserve 2211.2018*
Lack of a BSS	"It never stops being mind blowing that Aberdeen has no air pollution plan. The most toxic air of a city this size in the UK, has little cycle ways, no public bike hire, our local suttle buses are the most expensive in scotland, no car pool lanes 1 person per car is just selfish."	*@soozstewart 11.02.2019*

4.2. Public discussion on the future of BSS

The word "future" or "will" and "bike-sharing" related terms were included in 426 tweets. After the quantitative topic clustering, 81% of the selected tweets were classified into 3 categories (Figure 9). Around two-thirds were categorized that the future of BSS is electric, dockless and together with scooter. The other third is related to BSS marketing offering futuristic expansions, rides, and the benefits of BSS.

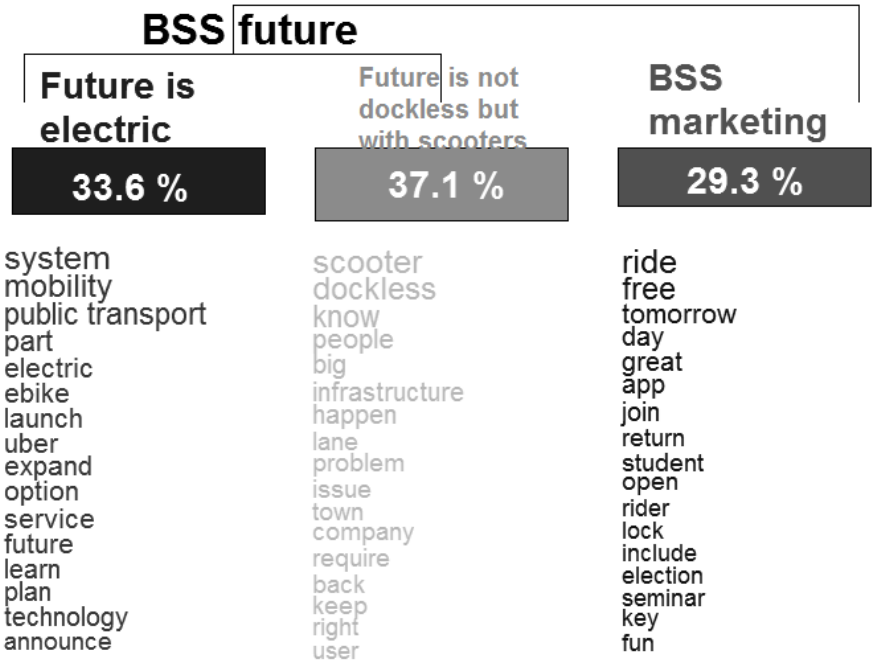

Figure 9. Quantitative topic clustering on tweets including the terms "future or "will"

For the qualitative approach, we selected the tweets including the word future (n=149) to avoid tweets associated with marketing, in which 123 tweets were clustered in 9 topics (Figure 10). Because of the language used and the availability of the tweet poster's username, while performing

the qualitative clustering, we realized that several tweets selected belonged to scientists, activists, politicians, municipalities, BSS companies, and media. Table 3 shows examples of the different topics of tweets including "future" and BSS-related terms.

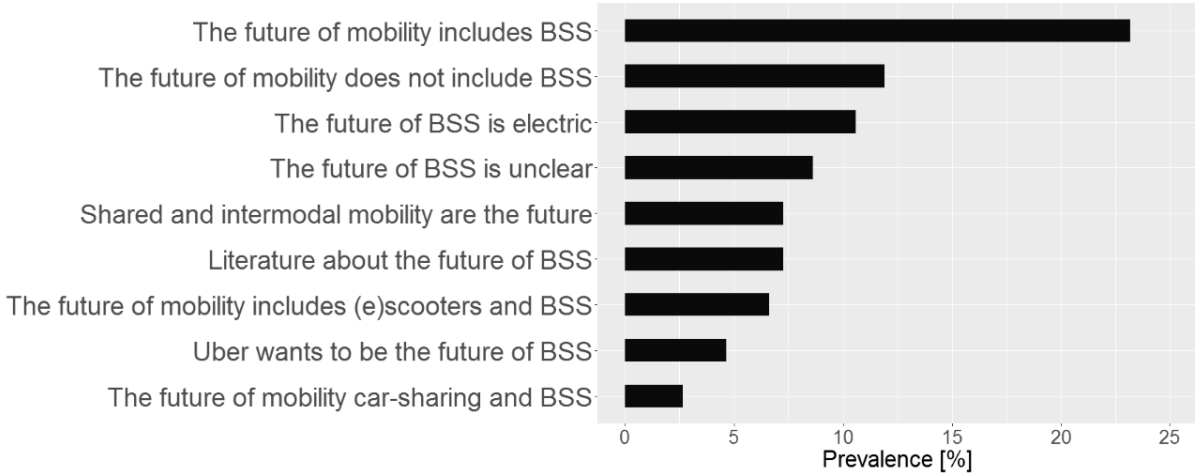

Figure 10. Topic clustering considering the BSS-related tweets classified as negative (n=142)

Around 50% of the tweets stated that BSS are included in the future of mobility. Highlights are towards the future of BSS being electric and the future of mobility including other shared modes e.g. scooters and cars. On the other hand, 11.9% of the tweets stated that BSS is probably going to collapse. It is worth mentioning, that around 50% of these statements specifically refer to Asian dockless BSS start-ups.

Table 3. Examples of tweets referring to the future of BSS

Cluster	Example	Poster & Date
The future of mobility includes BSS	"The future of #bikeshare programs is bright, To counter congestion and pollution worldwide, bike share will surely go in high gear. #Cycle2work #future #green #Mobility #made #easy"	*@mobycy 17.10.2018*
The future of mobility does not include BSS	"Google "bicycle graveyards China" to see a glimpse of the future of bikeshare and scootershare strategies. Should the profit makers bear responsibility?"	*@JosephHsuMD 08.09.2018*
The future of BSS is electric	"As mayor of one giant hill, electric bike sharing is the future."	*@JeromeMayaud 07.01.0218*
BSS future is unclear	The @CDPHPCycle bike-share program has provided 15,000 rides this year, with three months left in the season. But future is uncertain...	*@gazettesteve 08.09.2018*
Shared and intermodal mobility are the future	"The future of #transportation is #multimodal. The shift is rapidly happening from vehicle ownership to #ridesharing, #bikesharing, #scootersharing, and #AutonomousVehicles. Urban cities are seeing lower demand for #parkinglots…"	*@Lucky_Sandhu, 19.11.2018*
Literature about the future of BSS	"From my colleague Nicole, her Monocle article on the future of bikesharing."	*@LongBranchMike 30.08.2018*
The future of mobility includes (e)scooters and BSS	"Have you rode on an E-bike or scooter in your town yet? These could be the future of #urbancommuting! Will E-Bike Sharing Platforms Revolutionize Urban Commuting?"	*@MMAMidAtlantic 04.02.2019.*
Uber wants to be involved the future of BSS	"Uber wants to drive the future of bike-sharing. #Sustainability #SharingEconomy #Auto"	*@TheFutureLab 30.08.2018*
The future of mobility car-sharing and BSS	"1$ to start., car sharing, just like bike share is the future of transit in large cities. — at Ballard Farmers Market"	*@joseph_procella 27.11.2018*

5. Discussion

Tweets including BSS-related terms were 3.7 times more often classified as positive than negative. These results are comparable to Rahim Taleqani et al., (2019), who collected 2.8 times more positive than negative tweets regarding dockless BSS. The number of tweets collected over a relatively long period of time helped us to understand that the public discussion of BSS-related terms tends to be more positive than negative.

Strongly positive tweets presented a higher frequency of the word "e-bike" and "city", which showed the high acceptance of BSS using electric bikes. There was a debate between terms "new" and "dockless", in which some talk positively about them and others negatively. Therefore, we assumed that the debate or dilemma is towards new BSS entering a city and dockless systems. On the other hand, there was a tendency among negative tweets to include the words "Manchester", due to the vandalism problem in this city of bicycles with the company "mobike". This negative tendency also included terms such as "ofo" or "China", which show higher negativity towards dockless Asian BSS start-ups with low-quality bikes. Furthermore, "space" and "million" gave us an idea of complaint about the oversupply and their space consumption. Also, we could see that "start-up" was associated with negative and "public" to positive. This result gives us the idea that public systems are preferred than private start-ups.

Strongly positive tweets promoted BSS and their benefits such as convenience, good performance, and sustainability. Additionally, there is a tendency to write that electric and dockless are better, together with scooters. On the other hand, most of the strongly negative tweets were related to poor performance, vandalism, and oversupply, in which most of the complaints were related to dockless Asian BSS start-ups with low-quality bikes. We also discovered complaints related to safety and cycling, which were identified as a barrier with regard to taking out a BSS membership in Melbourne and Brisbane (Fishman et al., 2015).

Strongly negative tweets were posted more frequently from private individuals rather than institutions or media. In contrast to strongly negative tweets and based on topic clustering around a third of the strongly positive tweets were related to marketing and promoting BSS by media and companies which provide the service rather than private individual sharing experiences or opinions. Some posters commented on the inequitable usage and distribution of the allocation of the infrastructure of BSS, and also they complained about the high usage costs. This means that not only in scientific studies (Lucas, 2019; Ogilvie and Goodman, 2012) but also, BSS users and citizens are perceiving BSS as inequitable (see Table 2), even though BSS are promoted to be equitable, affordable and accessible.

Regarding the future of BSS, such tweets were posted by users who were mainly scientists, practitioners, and media more than common people, commenting on their thoughts. However, these posts gave us the impression that BSS are part of the future of mobility, especially as an electric version, and developed together with other shared modes such as scooters. On the other hand, it is doubtful that Asian dockless systems are seen as being part of the future of mobility, mainly due to oversupply and low acceptance among the public, which was shown in their posts commenting theft and vandalism.

The quantitative clustering approach helped us for automatic analysis of a big number of tweets, while the qualitative approach provided more help in understanding the problem better, having fine-tuned categories, and diagnosing sarcasm and wrongly classified tweets. The categories from the qualitative approach were mainly the most frequent topics. Therefore, the quantitative

approach helped as a starting point for the qualitative analysis. Also, if a macro approach is required the quantitative approach is a good approximation about the public discussion.

Qualitative methods are blamed to be subjective, and not generalizable. Thanks to the quantitative approach and the frequency of the terms, the subjectivity in this research is reduced, however, this approach was labor-intensive. On the contrary, quantitative methods are less laborious but their results are at a macro level and dependent on the dictionary implemented and include sarcasm which could not be detected. Nevertheless, in the qualitative clustering approach, we identified the same categories as in the quantitative approach and also, around 2% of sarcasm. In conclusion, the qualitative approach helped to understand the quantitative results.
Furthermore, let's not forget the frequency of the term, which collaborated not only with the language usage but also helped to identify where are the conflicts in the public discussion. This approach helped us as a starting point of the debate of dockless systems and also start-ups vs public.

This study presented some limitations. Lexicon-based approaches alone do not have the ability to infer the polarity of a tweet at a sentence level (Gonçalves et al., 2015). However, the dictionary used was created and validated using tweets (Gonçalves et al., 2015; Hutto and Gilbert, 2014). According to the sentiment analysis, photos, videos, and URLs were excluded. Furthermore, strongly negative posts might be "trolling", i.e. posts in which their "real intention(s) is/are to cause disruption and/or to trigger or exacerbate conflict" for their amusement (Hardaker, 2010). In order to avoid the inclusion of trolling, further research can select the users of the tweets who have an account for more than 2 months and have more than a minimum number of followers.

The public discussion on BSS does not reflect the ideas, comments, or complaints of people who do not use Twitter, and neither of Twitter users who did not post in English. However, Twitter allowed us to collect opinions, thoughts, or ideas from the news, activists, pessimists, people from different cities and nationalities, etc. Strongly positive and strongly negative tweets might not reflect an individual opinion. However, this study aimed to understand different components of the public discussion, and therefore, news, marketing, ideas, comments, and opinions were included in the analysis. Further research can explore the individual opinion with segregating methods, for instance, those presented in Gal-Tzur et al., (2014).

Moreover, we did not search for commercial names of BSS, in which we might have missed the collection of potential tweets related to BSS. We wanted to get the general public discussion on BSS and by searching for specific names, the information could have been biased to a specific system. Even though, we did not search for commercial names, mainly Asian dockless companies where included in the posts and also the BSS company "Lime" due to their high implementation in English-speaking countries.

In summary, we were able to identify the general public discussion as expressed on Twitter and a tendency of an emerging transportation system within a relatively short period of time while using few resources. However, we want to highlight that this approach would not replace approaches that involve interviewing, observing, or surveying people. However, further research might be oriented on interviews related to understanding deeper the main topic cluster and debates such as dockless systems, and equity issues.

5. Conclusions

There were 3.7 times more original tweets including the term "bike–sharing" classified as positive than negative. The benefits and drawbacks of BSS could be identified by counting the most

frequent terms and qualitative and quantitative topic clustering methods. Strongly positive tweets promote BSS and their benefits such as BSS being convenient, well-performing, and sustainable. Additionally, there is a tendency to write that public, electric, and dockless are better, together with scooters. Strongly negative tweets focused on poor performance, vandalism, theft, and oversupply of BSS, especially with regard to dockless Asian BSS start-ups with low-quality bikes. Around 50% of the tweets including "future" and BSS-related terms stated that BSS are going to be part of the future of mobility in an electric version together with other shared modes. Around half of the statements that were hesitant towards BSS as being part of the future, refer to the dockless BSS start-ups.

We want to conclude by highlighting some policy recommendations and how we could make bike-sharing better for cities based on the public discussion. BSS are highly probable to be part of the future of mobility because of the benefits discussed above. These systems are higher accepted when they are public, inclusive, affordable (or even free), keep communication with clients, and their design and allocation are based on public participation and people's needs (equity). The most accepted designs are when the systems are hybrid systems (dockless + docked), electric, and integrated with public transport in terms of infrastructure and price. On the contrary, start-ups are less accepted by the public, especially if they do not have communication with users and have placed an excessive amount of low-quality bicycles in a dockless format that blocks other transport modes.

Finally, we recommend politicians and stakeholders sponsor these active modes using terms from posted benefits of BSS. They can use these terms in their marketing efforts if the arguments match their systems: convenient, healthy, fast, fun, cheap, easy to use, inclusive, environmentally friendly, no theft worries, help to explore the city, connected to public transport.

Further research might include the comparison of tweets regarding BSS to other shared modes such as car-sharing, scooter or ride-sharing. Also, interviews can be carried out with different people that posted about the future of BSS to gain a deeper understanding of their opinion. Finally, public discussion related to equity and shared systems can be further studied.

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