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How to Save Bike-Sharing: An Evidence-Based Survival Toolkit for Policy-Makers and Mobility Providers

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Abstract: A new mobility ethos is needed for cities looking to overcome the problems that have been accumulated for decades by a transport paradigm that prioritises automobiles over people. Bike-sharing, a measure promoting voluntary travel behaviour change, could be part of a refined toolbox that will help in forging this new ethos. Despite a rapid emergence during the last handful of years, as evidenced by 1956 operational local schemes and approximately 15,254,400 self-service public use bicycles across the world, bike-sharing has been attracting negative attention lately. Tens of schemes have closed down, deemed as financial or operational failures, stigmatising bike-sharing's brand and putting the future of the concept itself in jeopardy. However, discounting bike-sharing as flawed may not be fair or accurate. This paper identifies a formula of success for bike-sharing operations based on a state-of-the-art case study analysis, which is supported by primary data evidence from two survey-based studies in Sweden and Greece. This paper suggests that residents in cities hosting or looking to host bike-sharing schemes are usually very supportive of them but not always likely to use them. More importantly, this paper delivers some key policy and business lessons that form a survival guide for effectively introducing and running public bicycle schemes. These lessons include, among others, the need for: tailoring the system design and expansion strategy according to the host city needs, city-operator and commercial partner synergies, more bike-friendly infrastructure and legislation, pro-active cultural engagement, anti-abuse measures, enhanced fleet management and realistic profit expectations.

Keywords: bike-sharing; public bicycles; shared use mobility; cycling; sustainable transport

1. Introduction

An excessively car-centric transportation system has been the cornerstone of urban development for decades now; a cornerstone associated with adverse effects on social, economic and environmental sustainability. These effects that characterise the century-long reign of the conventional, fossil-fuelled, human-led, privately-owned car include increased traffic congestion, climate change, local air and noise pollution, road injuries and casualties, obesity and chronic diseases, decline in physical activity and a loss of social engagement [1–3]. All of them will continue to increase without appropriate interventions [4–6]. A new mobility ethos is needed, therefore, for cities looking to effectively address these challenges, which, among other actions, will require policy-makers and mobility providers to promote voluntary travel behaviour change via powerful active and shared transport initiatives [7]. This will push forward the transition to a paradigm change [8] that will help cities plagued by conventional unsustainable thinking to transform into smart cities [9,10]. Bike-sharing, the greenest form among shared use mobility interventions, can potentially be a key to this transition. Bike-sharing is defined as *a system referring to the provision of affordable short-term access to locally branded bicycles on an*

'as-needed' basis that could extend the reach of public transit services to final destinations and be a door-opener for increased bicycle usage [11].

Bike-sharing, typically framed as an ideal and innovative first- and last-mile travel solution for congested metropolitan environments [12,13], and less often tested for the context of smaller and medium cities [14], is now more relevant than ever before [15]. The recent game-changing introduction of stationless and free-floating schemes where bicycles are unleashed from docking stations, allowing users an extra layer of mobility freedom [16], expanded the traditional dock-based bike-sharing provision and transformed the concept into one with a door-to-door travel potential. Bike-sharing has, from that point onwards, emerged rapidly across the globe, with 1956 operational schemes and approximately 15,254,400 self-service public bicycles and pedelecs in use [17], as an easily implementable modal shift mechanism that is iconic for the host city's commitment to sustainable transport operations [18,19].

However, at the same time bike-sharing, especially with a growing number of reckless and under-designed implementations of dockless systems, is attracting negative attention, with numerous schemes shutting down as huge financial or operational failures. This has forced usually smaller bike-sharing companies to go bankrupt and even put some iconic ones in danger. The withdrawal of Mobike from Manchester and Ofo from London in the UK, reflecting the retreat of the two strongest and most recognisable international bike-sharing operators, and the closure of Bluegogo, China's third-biggest bike-sharing company with 20 M users and £226 M in deposits at its zenith, underline a burning need. Research needs to revisit what makes bike-sharing services efficient at an operational level and how local schemes can transform into valuable smart city ingredients that flourish in the long term.

This paper aims to re-invent the formula of long-term success for bike-sharing operations by developing policy and business lessons that will help policy-makers and transport providers in establishing and managing these schemes more effectively, and, to a degree, other micromobility systems. This paper provides support to the argument that the concept of bike-sharing is not a failing one that will be dismissed as a whole in the near future, but a resourceful one that is being harshly "tested" at present by substandard decision-making, planning and management, on many occasions.

Hereafter, the paper provides a literature review, a description of the chosen methodology, a concise analysis of the key results, a discussion that will identify lessons learnt and suitable policy and industrial recommendations, and a conclusion section that will epitomise the genuine contribution of this work to academia, policy and practice.

2. Literature Review

Cycling is being promoted as a travel mode with the capacity to increase sustainable transportation, alleviate environmental problems and support healthier lifestyles [20]. It is viewed as an integral part of any urban mobility policy intervention package looking to increase the quality of life in modern cities [21]. One natural promoter of cycling is bike-sharing [22], a sustainable mobility initiative that dates back to 1968, with the famous "White Bicycles" system in Amsterdam [23]. Bike-sharing has boomed over the last decade, especially with the introduction of dockless fleets, because of its potential to complement public transport services and provide affordable and green first- and last-mile travel solutions. As a matter of fact, bike-sharing has, according to recent research [24], experienced the fastest growth of any mode of transport in the history of the planet.

The possible benefits of bike-sharing include, among others, flexible mobility, emission reductions, physical activity benefits, reduced congestion and fuel use, individual financial savings and support for multimodal transport connections [25]. These benefits are difficult to measure per se because bike-sharing schemes are parts of complex multimodal transport systems and cannot be easily examined in isolation. Lately however, there is more and more evidence about some quantifiable bike-sharing gains. For example, recent research concludes that bike-sharing programmes have significant positive externalities in terms of economy, energy use, the environment and public health [26]. A panel dataset

analysis of 96 urban areas in the US that have introduced local schemes argues that these schemes can reduce peak-hour congestion, at least in the context of larger cities [27]. The promotion of bike-sharing scheme use among car drivers can significantly increase health benefits [28]. Bike-sharing has great potential to reduce energy consumption and emissions based on its rapid development; in 2016 alone, bike-sharing in Shanghai saved 8358 tonnes of petrol and decreased CO_2 and NOX emissions by 25,240 and 64 tonnes, respectively [29]. A review of the existing evidence suggests that bike-sharing can increase cycling levels but, in principle, needs complementary pro-cycling measures and wider support for sustainable urban mobility in order to thrive [30].

In contrast, according to Nikitas (2019) [11], problems typically associated with bike-sharing include: (i) systematic underuse, (ii) vandalism and theft, (iii) lethargic and complicated planning procedures, (iv) sluggish or over-ambitious scheme expansion usually referring to station-based and station-less systems, respectively, (v) a one-bike-fits-all business model which may not be ideal for all populations and environments, (vi) strict cycling regulations including compulsory helmet use for some countries (e.g., Australia), which make schemes impractical or at least reliant upon a supporting rent-a-helmet mechanism, (vii) political friction if local authorities (or residents) are unwilling to forsake street parking space for bike stations, (viii) road traffic safety concerns generated by the co-existence of bicycles with other modes in a heavily car-dominated environment, but also the pedestrians versus bicycles narrative in mixed usage situations and (ix) lack of adequate cycling infrastructure (e.g., bike lanes, cycle paths, parking racks) that could complement and promote a bike-sharing scheme.

There is an extensive and still growing body of research about the traditional dock-based bike-sharing [31], but the sustainability performance of new-generation dockless schemes has not been thoroughly examined as of yet [32]. A Dutch study found that station-based business models are well institutionalised but harder to scale up, while the dockless model has the greatest scaling potential if institutional adaptations and geo-fencing technologies are successfully implemented [33]. This study also reported that peer-to-peer sharing is likely to remain a niche with special purpose bikes. In dock-based schemes, satisfaction is flawed by a set of factors such as the mechanics of the bikes, the picking and dropping system, and the apps used to organise the service [34], while dockless shared mobility models are potentially useful in generating participation but face substantial technical, analytical, and communication barriers [35]. The rapid expansion of dockless bike-sharing may be the reason behind a large-scale renaissance of the very concept since 2016, however, this is coincident with the serious oversupply of bikes [36] in many programmes. In these lesser used schemes, the presence of unusable bicycles increases the level of user dissatisfaction [37], while overuse is one of the most important issues faced by bike-sharing systems operating in China [38]. Bike-sharing usage is a key determinant of scheme success and has been studied by the literature. Some researchers [39] suggest that weather-related variables, land-use and built environment characteristics have significant effects on the overall bike-sharing usage. Larger bike fleets are associated with higher usage but also with diminishing marginal impact (i.e., each new bike may induce fewer new trips), while high land-use mixtures, easy access to public transportation, more supportive cycling facilities, and free-ride promotions positively impact the usage of dockless bikes [40]. Increasing bike-sharing fleet size does not necessarily increase performance according to other studies (e.g., [41]). Bike-sharing systems should also be carefully developed to appreciate the quality and timely interplay between the physical design of the system and the provision of services being offered [42].

Despite some progress, there is a need for more research as a means of evaluating the dynamic concept of bike-sharing as it spreads across the globe. On the one hand, there is still relatively limited evidence on existing schemes as to whether they achieved their objectives [30] and secured passenger satisfaction, since the vast majority of implemented schemes has not been closely examined as of yet; the reported findings in the literature are generated from less than 10% of the existing schemes. On the other hand, there is a paucity of research with large numbers of people who are not bike-share users, notwithstanding that these studies are critical to bike-sharing user growth [43]. The economic efficiency of public bikes is also being heavily questioned [44]. Theft, vandalism and uncivilized usage

of public bicycles is a massive barrier, especially for dockless fleets, that can single-handedly endanger some schemes' economic viability [45,46]. A better understanding of the planning and management of bike-sharing as a key ingredient of smart cities, in conjunction with citizen's perception, is yet to be attained [47]. This can be partly achieved by generating a comprehensive evaluation framework and indicator system for researchers and operators to improve the sustainability performance of bike-sharing in practice [48].

The present study aims to fill in this important research gap and provide a comprehensive policy, business and academic guide that will indicate how bike-sharing schemes can be effectively safe-guarded from future failures. This work underlines that bike-sharing can survive its recent failures and be a tool supporting efforts, to some modest degree at least, aiming to restructure the still car-dominated mobility paradigm.

3. Methodology

This work adopts a two-stage methodology for generating evidence-based findings that could be widely representative and generalisable. It is a research effort analysing primary, secondary and news feed data that allows the author to develop an empirical and theoretical understanding of how bike-sharing can address current flaws and inefficiencies and re-establish its reputation as a pragmatic long-term transport alternative.

The first part of the work is based on quantitative evidence from two survey-based studies held in Gothenburg, Sweden (mid-sized city, ~520,000 residents) and in Drama, Greece (small city, ~60,000 residents), looking at acceptability and usage determinants. The two surveys, conducted and analysed by the author, captured road user attitudes for Gothenburg's 1000-bike station-based scheme Styr & Ställ that was established in 2010, and for a hypothetical small-scale forthcoming city-centre scheme in Drama. The combined sample refers to 1175 respondents that could be users, future users or non-users of the local schemes; 535 respondents in Sweden and 640 respondents in Greece. Both samples allowed the generation of statistically significant correlations for the two survey studies and thus sample sizes are deemed satisfactory. The choice of the cities aimed to: (i) address the severely understudied context of bike-sharing acceptance for non-metropolitan urban environments and (ii) understand differences between cities like Gothenburg with an established pro-cycling culture that are familiar with shared transport initiatives versus cities novel to shared use mobility that only recently started to develop pro-cycling initiatives, like Drama. Another factor that makes this comparison interesting is the contrasting contexts of Northern Europe (higher salaries, higher GDP, lower temperatures, more rainfall) and Southern Europe (lower salaries, lower GDP, higher temperatures, less rainfall). Some aspects of this work, including detailed statistical analysis, have been covered extensively in [1] and [11] for Gothenburg and Drama, respectively, but they have not been compared systematically with each other and contrasted with the latest bike-sharing developments that have aspired a sense that public bicycle schemes are losing their edge.

The two surveys have almost identical formats and thus contain questions and sections easily comparable with each other. The survey in Drama has 19 main questions organised in four parts, referring to: the respondents' general travel behaviour choices; their views on bicycles and cycling; their attitudes towards public bicycles and their suitability for the city of Drama; and their socio-demographic characteristics. The survey in Gothenburg had similar questions organised in the same order as the questionnaire in Drama, with the addition of an extra thematic part regarding the respondents' actual public bicycle experience. Five-point Likert-scales were used to record responses, varying from strongly agree to strongly disagree with a neutral mid-point. The time needed for completing the survey in both cases was approximately 10 to 12 minutes. Since pre-notification [49] and financial incentives [50] enhance response rates, both were adopted. The incentive was an entry into a prize-draw, whilst several reminders through social media alerted the volunteers to fill in the questionnaire. Also, the introduction of each survey discussed why its completion could be a meaningful and timely task for the respondents. The surveys were both available to the public in an online form; hard copies were

also used in Drama to make sure that groups not having access to computers or the internet (which is far more typical in Greece than Sweden) are represented. The response rate for the hard copy part of the study in Drama was 13%.

Perhaps more importantly though, this paper identifies, lists and discusses for the first time the key findings of an extensive state-of-the-art analysis of the latest developments in bike-sharing operations, using exemplary bike-sharing case studies from across the world. Some of these case studies refer to successful implementation and service delivery stories, and others to systems that failed to establish commercially viable operations capable of adding value to the image of the city hosts. The originality and value of this case study approach is highly significant since the academic literature of local success and failure stories is extremely limited to date; this work analyses in depth, using for the first time academic lenses, these anecdotes as reported by local media and technical literature.

This unique mixed method approach allows the delivery of some important theoretical and empirical lessons, valuable to transport academics, urban policy-makers and mobility providers. These could be applicable to a broader context, at least for similar urban environments and bike-sharing schemes to the ones negotiated in the present work.

4. Results

4.1. Primary Data Analysis

This part of the article provides evidence that if bike-sharing is introduced, operated and promoted adequately, it can be acceptable in small and medium sized cities (including those that have yet to establish a pro-cycling culture), even for people not intending to ever use them. Usage or intended usage rates were, in contrast, significantly smaller than acceptance rates. The two common key usage barriers refer to road safety concerns and the lack of adequate cycling infrastructure. It is safe to argue that bike-sharing is not for everyone to use and not a relevant or feasible choice for many trips. Acceptability, however, is argued to be equally, if not more, important than strict usage-related criteria for measuring success; people's willingness to "allow" their cities to invest more in bike-sharing was very high (and was relatively unrelated to actual or potential usage of their local scheme) due to bike-sharing's potential to add to their city's capacity to be sustainable. This overwhelming local community acceptance should therefore underpin a drive to create win–win synergies between bike-sharing providers and city hosts, since the underusage of schemes should signify that these might not be commercially successful when only supported by subscriptions and short-term rentals, and need the addition of other streams of income to prosper.

These are valuable lessons providing robust evidence that bike-sharing is not a fundamentally flawed concept that somehow emerged because of a rush to establish relatively affordable sustainability-centric mechanisms; it is a sound shared use mobility initiative that in some cases suffers from mismanagement, a lack of long-term vision and ability to create channels with the city hosts and local communities, and unrealistic profit expectations.

4.1.1. Studying Bike-Sharing in Gothenburg

Gothenburg's dock-based Styr & Ställ is assessed as being a worthwhile institution by more than 90% of the city's residents, despite usage rates reflecting some level of participation to the scheme by only a quarter of the study's sample [1,51].

More specifically, the vast majority of the respondents believed that Styr & Ställ is an affordable travel mode with the capacity to promote healthy living, improve road traffic conditions, make cycling more popular, complement the city's other public transport services and help the city becoming more liveable. Also, 85.3% of them recognised bike-sharing's potential to make people's travel behaviour less car-dependent. The most important finding of the survey however was that the participants acknowledged the significance of bike-sharing for their city; 92.4% agreed or strongly agreed that the scheme is good for Gothenburg and 93.5% disagreed or strongly disagreed with the notion that

Styr & Ställ is a sub-standard transport initiative. Even the respondents that had never used it before or self-reported no (or little) intention to bike-share in the future were positive towards the scheme. Many respondents were also supportive of the scheme's further expansion through more bike-sharing investments by the local authorities, and considered that the scheme is a viable public service for the city; 86.5% and 96.1% agreed or strongly agreed with these notions, respectively. Also, only 6.5% of the people that had actually used the scheme considered that there is something fundamentally wrong with it. It was almost a unanimous decision for Gothenburg respondents that their local scheme is a good addition to their city's transport system that needs to continue its operations and expand further to more destinations.

Despite these high acceptability rates, the majority of the respondents rarely used the scheme even as a secondary travel option; 76.8% of the respondents stated that they never use the scheme while only 2.8% use it as their main mode choice. Nonetheless, longitudinal data collected for four full operating years of Styr & Ställ (based on respondents' self-reporting capacity) indicate a small but distinct annual increase in the number of participants that used the scheme, especially for those using it as a main or a secondary travel alternative to their typical modal choice. This underuse indicates that there is, in theory, a massive untapped potential for utilising, in real usage terms, the scheme's wide acceptance [1].

The reasons for which the respondents in Gothenburg do not bike-share frequently or at all have also been captured (each respondent was limited to give only two reasons when filling in the survey). A considerable 14.9% of the respondents answered that limited road safety could act as an obstacle for them in using bike-sharing, while 30.9% felt that a lack of good bike-sharing-related infrastructure was an issue. Improving safety and enhancing bike-sharing and pro-cycling infrastructure, therefore, are of vital importance for the attractiveness of a local scheme. Another 16.9% of the respondents thought that cycling was not ideal for the city, and 11.5% that bike-sharing was not convenient for all purposes. Nevertheless, the most popular response (i.e., 41.1%) was that respondents had no need to bike-share because they had their own bicycle. Figure 1 presents the full set of these results. A detailed statistical analysis solely focused on this study is presented in the author's recent work [1,51].
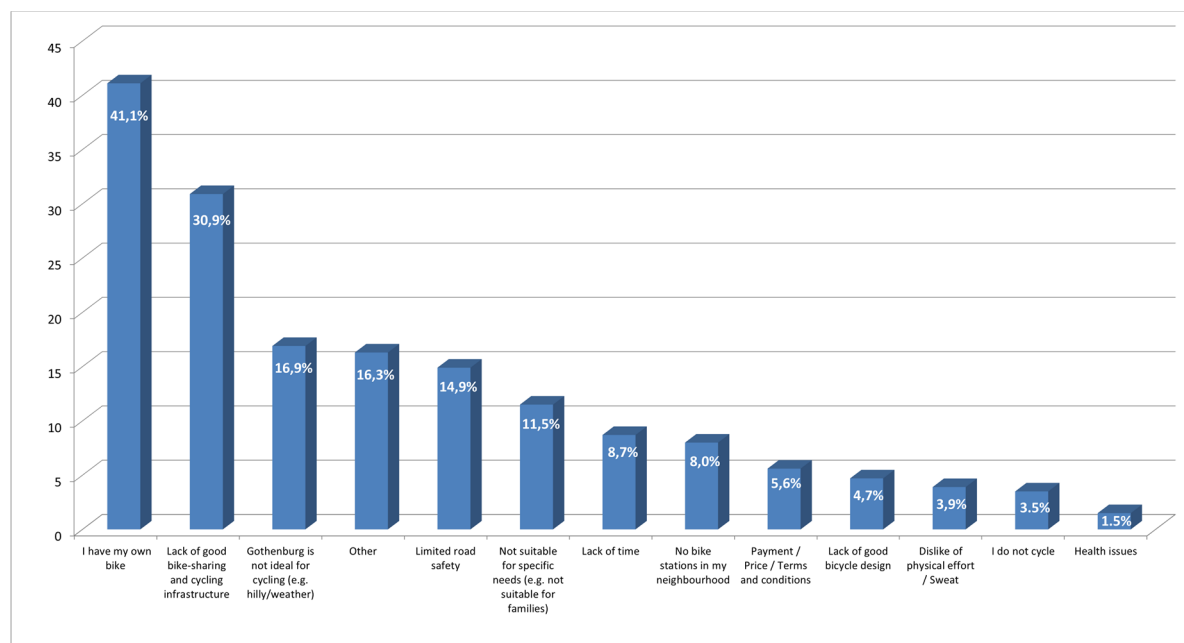

Figure 1. Reasons for not using bike-sharing frequently or at all (Gothenburg, Sweden).

4.1.2. Studying Bike-Sharing in Drama

The survey results from Drama were in many ways very similar to Gothenburg's key findings. Close to 90% of Drama's respondents thought that bike-sharing could be a good scheme for their city, despite lower usage intention rates that could have been still significantly exaggerated due to unintended optimism bias [11].

Overall, Drama's respondents recognised that bike-sharing could be beneficial for their city. The vast majority of them considered that bike-sharing is a sustainable modal option that could improve road traffic conditions, complement other means of public transport, offer an inexpensive transport option for the society, promote wellbeing, make cycling a more popular travel choice and reduce people's reliance on automobiles. However, perhaps the strongest finding, directly referring to the public acceptance of an eventual scheme, was people's disagreement to the notion that "public bicycles constitute an investment that they would not like to see being materialised". In absolute numbers, 86.5% of the respondents disagreed or strongly disagreed with this notion; only 5.1% agreed or strongly agreed and 8.4% were neutral respectively. The respondents self-reported relatively high levels of potential usage with expected usage on a somewhat frequent basis being 46.9%, and "rarely or never" being 31.5%. Still, these rates, which may be too optimistic, were considerably smaller than the reported acceptance rates.

The main reasons according to the respondents of Drama for being reluctant to cycle and potentially use public bicycles are principally associated with the lack of bike-friendly urban infrastructure and the feeling that currently there is only limited road safety for cyclists. Almost one in every two respondents made the case for each of these two specific answers, making clear that physical and cognitive barriers associated with the way a cyclist is hosted in one's respective urban environment constitute the key in giving up the ideas of cycling and bike-sharing. Well-designed bike-sharing infrastructure therefore and the establishment of a safer pro-cycling urban environment would be critical for making a local scheme a more attractive choice. It is true that the construction of bike lanes, bike roads and bicycle racks has only recently been initiated in the city of Drama; thus, these specific attitudes were well justified [11]. Dislike of physical effort was chosen by 12.5% of the respondents, lack of time by 13.8% and cycling and bike-sharing not being suitable for the city by 21.9%. Figure 2 presents the full set of these results. A detailed statistical analysis solely focused on this study is presented in the author's recent work [11].
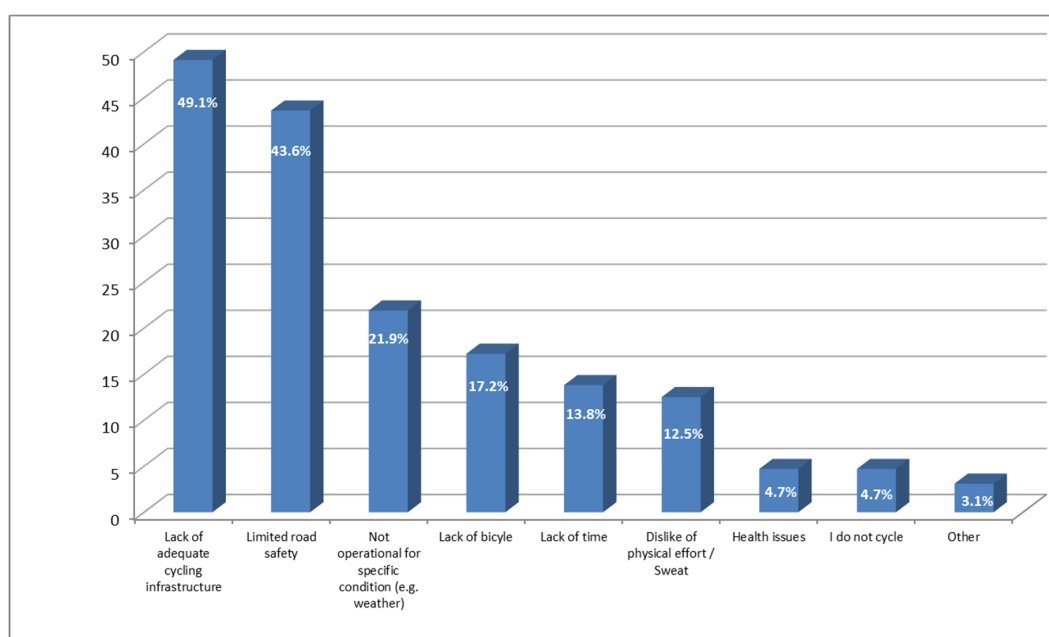

Figure 2. Reasons for not cycling and being reluctant to eventually bike-share (Drama, Greece).

4.2. Case Study Analysis

This part of the analysis concentrates on the examination of successful and unsuccessful bike-sharing applications as a means of identifying best and worst practice examples. This will allow the author to generate a set of policy and industrial recommendations that would inform the people responsible for local bike-sharing systems about the things that they need to do and need to avoid when establishing and running them.

Perhaps the most critical problem for conventional bike-sharing schemes is that station-based operations do not allow door-to-door convenience; traditional dock-based bike-sharing assumes that users can rent a bike from one of the existing bike-sharing stations and return it either to the original station or another station in a different location after using them. Schemes like Seattle's (U.S.) Pronto paid the price (among other reasons, including local politics, hilly topography and mismanagement) for its poorly and sparsely placed docking stations, and the lack of a systematic and incremental expansion strategy, by ceasing its operations [52]. Research found that subscribers used Pronto bikes more at stations that had more scheduled bus trips nearby; thus, bus–bike integration helps in promoting bike-sharing, but at the same time some users may shift to using buses during peak hours and rainy weather [53].

Over the last five years, many operators are actively trying to solve this door-to-door problem by providing station-less, maintenance-free, intelligent bicycles that lock and unlock through the use of mobile applications (i.e., dockless bike-sharing). This transition is led mainly by a few Chinese bike-sharing start-ups including Mobike and Ofo, a pair of operators with a combined valuation likely to have exceeded the £3bn threshold in 2018, since they have been supported by two of the biggest internet giants, Tencent and Alibaba.

Mobike has bike-sharing operations in 200 cities and 16 countries around the world and is responsible for as many as 30 million daily trips, with a fleet of 8 million bikes including electric options [54]. As of July 2018, Ofo claimed to have around 15 million bikes in operation in more than 300 cities across 22 countries, as well as 250 million global users, however, since then it has considerably scaled down its operations outside China [55].

Introducing, with an unprecedented speed, hundreds of schemes of this new breed of door-to-door bike-sharing systems, in China, wider Asia and finally over the last two to three years in North America, Australia and Europe, the homeland of conventional public bicycle programmes, has the power, in theory, to transform the world of cycle hire. This transformation can replicate to a degree the one that saw Uber and other similar ride-sourcing initiatives changing the car-sharing landscape by replacing many of the trips associated with carpooling and taxi-related services. Nevertheless, this monumental, and in many cases somewhat rushed, "embracement" is neither unproblematic nor without a fair share of early fiascos and overwhelming question-marks that have recently disrupted the rise and somewhat stigmatised the public image of bike-sharing.

4.2.1. Stories of Failure

In November 2017, China's third biggest bike-sharing company and the first dockless bike-share system to launch in the U.S, Bluegogo, went bankrupt, creating for the first time a dark cloud over the future of dockless bikes. The bankruptcy of a company that grew at an incredible pace to compete with Mobike and Ofo, peaking at 350,000 bicycles in China alone and poised to conquer San Francisco, raised concerns that there are simply too many bikes at very low prices on offer and insufficient demand. Bluegogo collapsed leaving vast bike-share graveyards that challenged the "sustainability" and "eco-friendly" value of the dockless bike-sharing concept, after falling $30 million in debt and struggling to repay customer deposits, with the surviving bikes being sold for as low as $5 per piece [56]. Bluegogo's chief executive apologised for this collapse saying that he had been "filled with arrogance" [57], which practically meant that the company had unrealistic revenue expectations, expanded too soon on an unsustainably big scale and was mismanaged.

Wukong Bicycle, a minor Chinese start-up of 1200 bikes in the notoriously hilly Chinese city of Chongqing, went out of business after only six months of operations in July 2017, since 90% of its bikes were lost, presumed either missing or stolen. This was the direct consequence of the operators' fatal mistake to not install GPS devices in their fleet [58]. Beijing-based bike-sharing firm 3Vbike also went bankrupt in June 2017 after losing more than 1000 of its bikes in just four months of operations; not having its own mobile app to track the bikes and having to depend on a cycle location tracking function on its WeChat page was the key reason for this downfall. This scheme also failed to gain traction due to limited fundraising; the owner had to purchase the bikes himself in the absence of other investors [58].

The operations of the Mobike Manchester scheme, the first of its kind in the UK, launched in June 2017, is another story of misfortune for the concept of dockless bike-sharing. In a span of 15 months, Mobike had to cease its operations in Manchester because of "unsustainable" losses from theft and vandalism, making this the first time the Chinese operator has abandoned a city because of anti-social behaviour. Manchester Mobikes have been found dumped in canals and bins, vandalised, and others have been stolen, making the company representatives suggest that the system has been "misunderstood" [58] and that "the learning is already being put to good use for creating a more suitable scheme in the not too distant future" [59].

Ofo, in an even more dramatic fashion, was forced to withdraw from most of its UK market including the cities of Norwich, Sheffield and Oxford, and as of January 2019 from London which was home to 3,000 Ofo bicycles. The company admitted that its UK business was loss-making and needed to move to a different direction [60]. Perhaps this retreat proves again that supply should not exceed demand and that international bike-sharing concepts should adapt to the city host for local applications. In the case of London, there was also direct competition with a well-established and popular dock-based system that has strong links with the city.

Similarly, Hong Kong-based bike-sharing operator Gobee shut down its operations in France in February 2018 after suffering what the company called a "mass destruction" of its fleet. Gobee, which had 2000 bikes in Paris alone and claimed around 150,000 users across the country, reported that 3400 of the company's bikes have been damaged and more than 1000 have been stolen [61]. Gobee pulled out of Belgium for similar reasons meaning that this was not an isolated country-specific issue.

OBike, another start-up with international reach, also exited from some of its key markets, with the most important ones being in Singapore and Melbourne, Australia, during 2018. These cities having a long track record of supporting environmentally friendly urban growth are now trying to ensure responsible bike-sharing use, introducing stricter licensing regulations that prevent visual pollution and unsustainable public space intrusion. Complying with these regulations, and in other cases with the helmet rules that govern bicycle use in Australia, can be expensive as it requires investments in technology, security, and management. Operators like OBike may sometimes decide that this extra investment is excessive, so they concentrate on other cities with softer regulations.

Another obvious case of mismanagement is the so-called Velib-gate, where a city project with a new operator intending to enhance the very popular local scheme in Paris, France went seriously wrong, creating huge technical and political issues. A notable dysfunction was the cyber-attack that Bycyklen suffered in Copenhagen, Denmark, which saw all its smart bikes being hacked. This caused serious operation disruption, since the only way to make the bikes usable again was to reboot all 1850 of them individually.

These fiascos have generated concerns about the long-term viability of bike-sharing and mainstream allegations that there is now a body of evidence proving that bike-sharing has been opportunistic or even failing as a concept. Recent research [62] concludes that most schemes typically benefit the privileged, help little to increase mass cycling transport and are used as easily deployable technological (false) solutions to contemporary problems, while advancing unjust tendencies to privatise public space and services.

4.2.2. Stories of Success

Nonetheless, as the primary data research has indicated there is much more than failure, misfortune and negativity associated with bike-sharing operations; there is also hope and genuine potential for improvement that could help to restore the image of bike-sharing. There are many examples indicating that bike-sharing can still be a viable transport option inspiring modal shift and making bicycle usage more popular and mainstream.

The government of the city of Hangzhou in China launched Hangzhou Public Bicycle in January 2008 starting with 2800 bicycles, 30 fixed stations, and 30 mobile stations (stations which can be moved to meet demand). This scheme went on to become the world's largest bike-sharing system with 100,000 bicycles and 4100 stations, as of December 2018. This scheme has been successful in acting as a complement to existing public transit and as a tool for modal shift; members exhibited a higher rate of auto ownership than non-members meaning that bike-sharing was attractive to car owners [63]. Some of its key success factors are: the low subscription fee, the availability of bicycles throughout the city, the subsidies from the local authorities, the fact that this was an initiative that the local transport agency created and is still a not-for-profit scheme (i.e., riding is free for the first 60 min), its complete integration with the other public transport services, its high-quality real-time information system, the upgrade of the bike hardware and the existence of a green corridor that promotes cycling in general. Hangzhou, a city with a registered population exceeding 9 million, widely considered as an emerging technology hub (home to the e-commerce giant Alibaba) also hosts some dockless bike-sharing fleets from Mobike, Ofo, Hello Bike and Qibei. Researchers [64] argue that Hangzhou Public Bicycle has already become rooted in the city as one of the public transportation modes, and because of its stable performance and the city's features fit for cycling, the habit of riding bikes has been awakened in Hangzhou. This has, in turn, provided an ideal environment for free-floating bikes to come into use.

Introduced in 2011, originally as Barclays Cycle Hire, London's bike-sharing scheme is a station-based system that can be accessed by anyone with a credit or debit card, with daily usage charged at £2 for unlimited journeys of up to 30 min. Santander Cycles offer the option of annual membership charged at £90 (~25p per day). The scheme, after incremental strategic expansions, now spreads across 100 km^2 of London and is the largest cycle hire scheme in Europe, with 11,500 bicycles available across 750 docking stations [65]. It has approximately 240,000 active members making over 10 million annual bicycle hires, and its continued expansion is viewed as a central component of the Mayor's policy to transform London's transport system into one which is based on sustainable modes [66]. Therefore, the scheme is subsidised and promoted heavily by Transport for London and is well-linked with all the public transport modes of the city. Santander Cycles have demonstrated the capacity to normalise the practice of cycling in city life; its users are not solely representatives of particular social cohorts such as sporty people [67]. Also, the scheme has become more equitable over time; it encourages women to use it, and with the eastern extension increased the share of trips made by residents in poorer areas, features that have been partly offset by increased prices [68]. As a whole, this is an award-winning intervention recognised not just for its impact on transport in England's capital city and its sustainability value, but also for its innovative design, the public relations exercise and the accurate delivery timescales.

Dublinbikes is a public bicycle rental scheme, which has operated in Dublin, Ireland since June 2009. At its launch, the scheme, which is sponsored by JCDecaux in exchange for 72 free advertising spaces around Dublin, used 450 bicycles organised in 40 stations. Now, the scheme has 114 stations and 42,000 active annual subscribers, and is one of the cheapest schemes in Europe with a €25 annual fee. Dublinbikes is widely considered as one of the most successful local applications in the world, as reported regularly in media [14,69,70], however occasionally there were reports suggesting that progress has stalled. Synergies with industry have been notable for the Dublin scheme. Coca-Cola Zero was a commercial partner with Dublinbikes for three years (June 2014 to June 2017), with Just Eat taking over in July 2017 for the next three years with plans to invest €2.25 million in the scheme over its tenure; in both cases the name of the scheme was rebranded accordingly.

Bicing, the local scheme of Barcelona, Spain, inaugurated in March 2007, is another system that is broadly regarded as successful. With 424 stations situated every 300 to 400 metres across the city, and more than 6,000 bicycles and electric bicycles, the initiative managed and maintained by the City Council and Clear Channel is an inexpensive option (annual fees range from €35 to €50). One of its unique features is that it is not a scheme for tourist use; it is open only to local subscribers and is marketed as an ideal complement to the traditional public transport of the city, intended to cover the small daily journeys that take place in Barcelona. A sign of early success was the fact that the usage and expansion targets were accomplished surprisingly fast. Bicing's initial foresight referred to reaching 15,000 subscribers at the end of the first year of operations, and 400 stations after a 10-year cycle, but the reality was that almost 100,000 subscribers subscribed in less than 12 months from the scheme's launch while the 10-year expansion plan happened in only 1.5 years [44]. The scheme is financed by subscriptions and by the local on-street parking control system profits. The system has been viewed as one that allows, through its digital footprints, the possibility to gain an understanding of human behaviour and city dynamics [71], and as a system with greater benefits than risks to health that reduces carbon dioxide emissions [72].

BIXI Montréal is a bike-sharing scheme serving Montreal, Canada. It launched its operations in May 2009, originally managed by Public Bike System Company (PBSC), to become North America's first large-scale bike-sharing scheme and an award-winning innovation. However, PBSC had to file for bankruptcy at the beginning of 2014 after problems including program mismanagement, breach of contract litigation and the surmounting of debt. BIXI Montréal from that point forward became a non-profit organisation owned and managed by the city of Montreal with 7250 bikes and 600 stations. The annual subscription costs $94. BIXI members can get a $15 discount on the local car-sharing service; packaging bike-sharing with car-sharing services is used as a promotion tool. BIXI attracts a substantial fraction of the population, accounting for more than one million trips annually [73] and is more likely to attract younger and more educated people who currently use cycling as a primary transportation mode [74]. The implementation of BIXI was associated with a shift toward active transportation, even if modal shift was complex and not simply the result of a discrete transition from one mode to another [75]. Also, research found that the accessibility of the bike-sharing docking stations in neighbourhoods was high, despite awareness inequalities that have decreased over time [76], something that is a key for increased usage. The city of Montreal announced that the service would be expanding in 2019 with 60 new stations offering 2625 docking points and 1000 additional bicycles in new areas.

Some of the schemes that have been labeled as good practice examples include among many: the French schemes Vélo'v in Lyon and Bicloo in Nantes with some of the highest annual growth rates in rentals and subscribers; many of the China-based operations of Mobike and Ofo; New York's (US) CitiBike system that averages 8.3 trips per bike and 42.7 trips per 1000 residents; Mexico City's (Mexico) Ecobici bike-share system and JUMP electric bikes and scooters that have spread in 19 cities in US and four in Europe.

5. Lessons to Be Learnt

The primary data analysis provides strong statistical evidence that bike-sharing is still a timely and meaningful proposition for urban policy-makers, and that it is widely accepted even from those citizens not expected to be scheme subscribers or occasional users. The survey respondents coming from two very different urban environments, in terms of size, socio-economic characteristics and pro-cycling culture, support in an almost identical degree (at around 90% of the sample) the notion that their respective cities should invest (i.e., Drama) or continue to invest (i.e., Gothenburg) in local bike-sharing schemes. This clearly reflects the acceptance of the bike-sharing concept and the general public willingness to see local city-specific schemes supported by their city hosts. Usage (or intended usage) rates are not mirroring acceptability rates closely; they are significantly lower. If there is a critical mass of scheme subscribers, however, this work makes the case that usage should not always

be considered as the sole success parameter of a scheme; acceptability is equally important. The author also identified some of the key reasons that may make people reluctant to bike-share with traffic safety and insufficient bike-friendly infrastructure concerns being the two most critical.

The case study analysis identifies that inflexible standardised business models and operation strategies lacking the ability to tailor their offering to different areas, largely adopted from China, are not suitable for all urban environments. Dock-based systems, despite their inability to provide door-to-door services, seem to do better than dockless schemes for now, although the two can complement each other and work together, as seen in Hangzhou. Expansion tactics that have been over-aggressive, defied established competition, did not actively seek the collaboration and support of the hosting cities and were not adequately justified by travel demand data have failed. Schemes that were tailored to the city host needs, were integrated with or complemented the public transport provision, had a clear incremental expansion strategy, kept relatively inexpensive prices, secured the support of the local authorities, forged synergies with commercial partners and embraced technology have been successful and set the bar for the industry.

Some key recommendations that this work can provide, primarily to operators but also to cities looking to host sustainable and long-lived bike-sharing schemes, that will add value to their image suggest that they should:

- Make unique city-specific plans for delivering each scheme. The "one business model fits all" approach is fundamentally flawed. The ability to tailor, to some degree, an offering to reflect the character of a city and the norms of its citizens is critical.
- Prioritise the scheme's long-term success over easy profit and unrealistic revenue return expectations; bike-sharing should be user-centric and not profit-centric if it is to succeed.
- Realise that that the bulk of benefits that a bike-sharing scheme can deliver refers to avoiding the negative externalities of excessive car usage. This is a profit worth paying so operators should actively seek the support of the cities when possible in subsidies and supporting infrastructure. Profits from subscriptions and rentals may not be enough for a scheme's long-term commercial viability so there is a need to establish other streams of funding.
- Work together (operators and cities) so that the latter will be incentivised to support their local schemes. Private–public partnerships can work.
- Seek strategic commercial collaborations like the London and Dublin schemes. Extra financial support and a brand adding value might be a key in sustaining business.
- Acknowledge that an oversaturated bike-sharing market can be lethal. Travel supply should mirror travel demand. This is critical, especially for smaller providers, although bigger operators could also face problems as evidenced by the examples of Bluegogo primarily and Ofo to a smaller extent. When there is established competition, a new scheme needs to offer a different "twist" to what is already available (e.g., electric bicycles) in order to have success potential.
- Invest more efforts in regulating the responsible usage of bikes. Anti-social behavior, theft and vandalism have plagued many schemes and led to their closure. Protection mechanisms and penalties for vandalism and theft should be in place from day one. Cities should support these efforts with better policing.
- Initiate market research and education campaigns to understand better users and non-users and promote bike-sharing culture to encourage people to adopt a positive attitude towards these bikes. Cultural engagement from the outset is a prerequisite for success.
- Focus on providing fair and affordable fares, member subscriptions, and "ways out".
- Finance better business planning and bike management; companies need to constantly innovate to stay on top of this very dynamic market.
- Acknowledge that dock-based systems, for now at least, have been more successful in securing long-term viability than most dockless schemes. The option of docking stations, and enough

people on the ground to ensure that schemes are reliable and serve their purpose, should be provided when possible.

- Appreciate that technology is not always a panacea; it is only one of the several tools in the toolbox of successful bike-sharing provision [77]. However, mobile apps, rental machines, GPS tracking, and locking systems are of vital importance for scheme success and should be modern and user-friendly.

- Concentrate on providing better bike-sharing infrastructure; bikes (and stations when applicable) should be well-designed, attractive, safe and prevent anti-social behaviour.

- Diversify the provision of bikes so that some of them are more suitable for usually underserved populations. More specifically, explore ways to increase female participation in schemes by offering some bikes with more feminine designs. Also, introduce electric bicycles, pedal assist systems, tricycles and other inclusive vehicles, and make bike-sharing technologies more easily accessible (e.g., easier pick up and drop off services) as another way [11] to enable some individuals, and especially older people who can be open to a transport intervention if they feel that it is pro-social [78], to engage.

- Collaborate with city and even national authorities to resolve concerns referring to limited traffic safety for cyclists and inadequate pro-cycling infrastructure provision. Complementary to the schemes, bike-friendly road infrastructure (e.g., bike lanes, bike racks, bike prioritisation) and wider bicycling investments are very important for supporting bike-sharing and alleviating traffic safety concerns.

- Manage the distribution of bikes more effectively and responsibly. Operators need to be more accountable about visual pollution. In exchange, cities could be more flexible with their regulations (e.g., easing helmet use regulations or supplying shared use helmet schemes).

- Help and push the relevant decision-makers to establish more pro-cycling national and local legislation and governance.

6. Conclusions

This work provides an evidence-based roadmap, generated by blending two "twin" survey studies and a best-practice versus worst-practice international case study comparison. This mixed method approach intends to help a still growing, but somewhat jeopardised and stigmatised, mobility innovation to avoid a path that leads to an unsustainable and short-lived future. This paper disengages "scheme success" from a strict usage rate perspective, and informs policy-makers and scheme suppliers that citizens want to see systems that deliver sustainability benefits being supported by the local authorities. This result, combined with field evidence that bike-sharing schemes could be underused and thus may not be commercially profitable when income depends solely on subscription and short rental rates, signifies the need for establishing strong links and commercial partnerships with the city hosts and private industries interested to associate their brand (and pay for it) with bike-sharing, respectively. The city support can therefore take the form not only of complementary cycling infrastructure investment and more bike-friendly legislation, but also of direct city funding under the precondition that schemes meet local authority and general public expectations.

More importantly though, this study generates policy and business lessons "reading carefully through" the current public bicycle practice, by identifying successful and unsuccessful bike-sharing implementation cases. These lessons include, among others, the need for: tailored, according to the explicit host requirements, system design and expansion strategy; city-operator and commercial partner synergies; more bike-friendly infrastructure and legislation; pro-active cultural engagement of the local communities; anti-theft and anti-vandalism measures; easy to understand and fair usage terms; enhanced fleet management; and realistic profit expectations.

All in all, this paper's intended contribution is to function as a policy-minded survival guide for establishing, running and securing the future financial and operational viability of bike-sharing schemes, something that could be of significant value to academics, mobility providers and policy-makers.

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