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Inter-modality hubs in the Metropolitan Area of Barcelona: A comparison between the metropolitan and the local scale in a GIS tool to support urban planning decisions.

MASTER FINAL THESIS

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Abstract

Dealing with the transportation needs of urban society while simultaneously enhancing the liveability and sustainability of the city is the problem we confront today. The bicibox, a free long-term bicycle parking service, presents a unique opportunity to incorporate active mobility into transit stations while also enhancing the street life of the neighbourhoods. Therefore, the purpose of this study is to determine the extent of impact bicibox services have on the growth of the catchment area for FGC (Ferrocarrils de la Generalitat de Catalunya) railway stations in the Municipality of Sant Cugat del Vallès.

Àrea Metropolitana de Barcelona (AMB) provided data on Bicibox users for this study. To achieve the study's objectives, user data was analysed on three scales to identify user preferences, behaviours, and influence variables. Methods used for this research included graph comparison, a QGIS map, and an investigation of amenities near the mobility hub.

This thesis concluded that users prefer biciboxes that are placed directly in front of transit stations and are highly visible. Additionally, it was determined that bicycle stations that are situated right in front of a railway station, a bus station, or in the middle of both stations perform better than bicibox stations located further away from the station. The usage of bicibox was also found to have a positive effect on the expansion of the catchment areas for the FGC railway stations in the Municipality of Sant Cugat del Vallès. The catchment area's size and expansion direction were also estimated.

Keywords active mobility, railway station, user data, catchment area

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Resumen

Tratar con las necesidades de transporte de la sociedad urbana y, al mismo tiempo, mejorar la habitabilidad y la sostenibilidad de la ciudad es el problema al que nos enfrentamos hoy. El bicibox es un servicio gratuito de estacionamiento de bicicletas de larga duración que presenta una oportunidad única para incorporar la movilidad activa en las estaciones de tránsito y, al mismo tiempo, mejorar la vida en las calles de los barrios. Por lo tanto, el objetivo de este estudio es determinar el impacto que tienen los servicios de bicibox en el crecimiento de la zona de influencia de las estaciones de FGC (Ferrocarrils de la Generalitat de Catalunya) en el municipio de Sant Cugat del Vallès.

El Àrea Metropolitana de Barcelona (AMB) proporcionó datos sobre los usuarios de Bicibox para este estudio. Para lograr los objetivos del estudio, los datos de los usuarios se analizaron en tres escalas para identificar las preferencias de los usuarios, los comportamientos y las variables de influencia. Los métodos utilizados para esta investigación incluyeron la comparación de gráficos, un mapa QGIS y una investigación de los servicios cerca del centro de movilidad.

Esta tesis concluye que los usuarios prefieren estaciones de Bicibox colocadas directamente frente a las estaciones de tránsito y que estas sean muy visibles. Adicionalmente, se determinó que las estaciones de bicicletas que se encuentran justo en frente de una estación de tren, en una estación de autobuses o en el medio de ambas estaciones funcionan mejor que las estaciones de bicibox situadas en una ubicación más lejana. Además, se ha comprobado que el uso de bicibox tiene un efecto positivo en la ampliación de las áreas de captación de las estaciones de FGC en el Municipio de Sant Cugat del Vallès. También se estimó el tamaño del área de captación y la dirección de expansión.
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Keywords active mobility, railway station, user data, catchment area

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Symbols and abbreviations

Abbreviations

EU	European Union
EIT	European Institute of Innovation and Technology
AMB	Àrea Metropolitana de Barcelona
VGA	Visual Graphic Analysis

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1 Introduction

This Master's thesis research aims to evaluate bicibox stations' influence on the expansion of the catchment area of railway stations in the Municipality of Sant Cugat del Vallès, Barcelona. This research accomplishes this study by monitoring the user's behaviour data of bicibox stations, which are strategically located on the periphery of railway stations. This study intends to analyse smart hubs such as bicibox and their contribution on encourage the inter-modality between active mobility and public transportation. However, this report will concentrate on the utilization of bicibox stations in conjunction with railway stations in order to provide long-term inter-modality.

Climate change is an inescapable and pressing global issue with long-term consequences (UNITED NATIONS, 2022). The shift in weather patterns can trigger global-scale catastrophes if dramatic actions are not taken soon (Nations, 2022). Climate change poses a severe challenge to urban sustainability, putting many cities and countries in jeopardy. Environmental changes are closely linked with complex urbanization processes, and they are occurring at an unprecedented rate and magnitude (Wamsler, Brink, & Rivera, 2013). As a result, local governments are increasingly facing challenges to develop ways to incorporate adaptation techniques.

For this reason, the united nations climate change policy supplemented the Kyoto Protocol and the Paris Agreement. Similarly, EU climate policy guides regional and national activities to mitigate and adapt to climate change (Ministry of the Environment, 2022). EU aspires to be the first climate-neutral continent by 2050. These goals are expected to be met by European climate actions such as the European Climate Pact, which aims to connect, share, learn, and scale up ideas to combat climate change and raise awareness (Climate Action, 2022).

Likewise, Barcelona's Climate Strategy 2018- 2030, which was unveiled in April 2018, is a bold, Paris Agreement-compatible plan. This ambitious strategy aims to reduce carbon emissions by 45 percent by 2030 with the ultimate goal of becoming carbon neutral by 2050(GOV.UK, 2021). These bold proposals are followed up by action plans similar to increasing green space in cities by 1.6 km2, lowering private vehicle journeys by 20%, and developing sustainable mobility. These action plans fall under the five key priority areas and 18 action areas that Barcelona has established for itself to achieve the target (GOV.UK, 2021).

The European Institute of Innovation and Technology (EIT) is the European Union's research and innovation framework program (European Institute of

Innovation & Technology, 2014), which consistently works towards achieving climate goals. EIT brings industry, academia, and research organizations together to develop innovative solutions to serious global challenges. A smart hub is also one of the many flanks of the EIT urban mobility project. Its responsibility is to create and evaluate efficient and cost-effective mobility hub solutions (SMARTHUBS, 2022a). This report is also the part of the research of the EIT Urban Mobility project of Smart Hubs.

Smart hubs shared mobility solutions is a European Union-funded EIT urban mobility initiative. Six European cities with diverse urban characteristics and demographics are involved in the projects. The goal is to test and validate economically feasible mobility hub concepts that encourage inter-modality to sustainable transportation and better use of urban space (SMARTHUBS, 2022a).

Smart hubs offer an integrated product-service solution to the urban scarcity of space by physically and geographically clustering new shared modes and existing (public) transport services or parking solutions. Clustering makes it easier to access the shareable modes and gives the customer a larger view, which could influence their mode of choice. Whereas, "Inter-modality is a policy and planning principle that aims to provide a passenger using different modes of transport in a combined trip chain with a seamless journey" (Carpio-Pinedo et al., 2014). Mobility hubs are essential in combining different modes into a single, efficient system.

Whereas, inter-modality hubs will not only deal with interchange functions within buildings such as connecting underground railways, metro lines, or underground bus stations but will also primarily deal with modes of interchange that occur in urban settings (Carpio-Pinedo et al., 2014). This includes access to and distribution of various modes such as car sharing, bike sharing, pedestrian, and so on. Garca-Pastor and Carpio-Pinedo (2014) advocate for multi-purpose public transportation stations. Concentrating and connecting mixed-use activity around stations such as workplaces, retail establishments, and hotels. These high-capacity public transportation lines, not only aid in achieving critical mass, which adds value to each activity, but also transform a transit station into a true living space (Carpio-Pinedo et al., 2014).

The railway station has grown into a significant multi-modality hub between cities in recent decades with multiple modes and services within and around the building (Scheltema, 2012). The incorporation of shared modes, public transport connections, the inclusion of private vehicles, and other services in and around the railway station has managed to attract passengers, thereby, resulting in a massive increase in the catchment area of the urban inhabitants of the train station. Faster railway networks also connect regions closer together and lower trip distances, resulting in a new type of approach in which distance constraints are now minimized by time constraints (van Asperen, Rooij, & Dijkmans, 2017). Today, the train is the quickest, most convenient, and least expensive method of transportation; however, the weak link for railway transportation is its poor door-to-door connectivity (Scheltema, 2012).

Due to a lack of door-to-door service, even the convenience of cost and comfort falls short (Carpio-Pinedo et al., 2014; Keijer & Rietveld, 2000). The accessibility time and inconvenient trip to and from the railway station reduce the appeal of railway service.

However, commutes can be made by combining numerous active and/or passive means of transportation; nevertheless, regardless of any mode of transportation you choose, you must always begin and end as a pedestrian. As a result, maximizing the efficiency of diverse modes of transportation in the limited time and space available is crucial (Scheltema, 2012).

The railway network's inadequate door-to-door connection can be addressed by adopting a robust bicycling ecology to access railway stations and significantly improve trip time. This inter-modality combination can boost the appeal of the railway service while also expanding the catchment area of the railway station. Furthermore, Keijer and Rietveld (2000) have found in their study that bicycles are the most frequently used feeder means of transportation for buses, trams, and the metro. Bicycle, as a feeder mode, is significantly faster than walking and more flexible due to its 'continuous' nature. This eliminates waiting time and closes the 'travel time gap' (Martens, 2007, p. 328). It's also worth noting that more than one out of every three passengers rides their bicycles from home to the station (Keijer & Rietveld, 2000).

Bicycling is an exceptional door-to-door mode of transportation for commuters since it offers a great deal of flexibility to move wherever you want, whenever you want. Besides, it often has a high recreational value too (Scheltema, 2012). Bicycles are not only a low-cost option but also provide social benefits by promoting a healthy and active lifestyle while minimizing environmental impact and maximizing urban space usage (Department of Health, Physical Activity, Health Improvement and Protection, 2011). Besides walking, bicycling is the cleanest and most flexible solution for the city, community, and users. Additionally, cycling requires significantly fewer investments than other modes of transportation. As a result, the Metropolitan Area of Barcelona's (AMB) funding of bicycle infrastructure and bike sharing services can be considered as facilitating the commencement of a carbon reduction strategy.

The only downside of a bicycle is that it is limited in terms of distance as bicycling is mostly done on a local and regional scale. This constraint can be overcome by using an electric bicycle which stretches the distance and comfort provided. However, people prefer not to ride their bicycles for lengths greater than 7.5 kilometers and instead utilize other methods of transportation (Scheltema, 2012).

Therefore, to further enhance the benefits of bicycles and encourage general citizens to use bicycles as their primary mode of transportation, a complete ecosystem of bicycling infrastructure must be provided. To promote the bicycle and train inter-modality, placing the safe parking facilities in the strategic places is very importent. Providing safe bicycle parking can also improve the efficiency of the railway station by minimizing the necessity of feeder bus services, and lowering the clutter created by private vehicles (Keijer & Rietveld, 2000). These advantages of reduced feeder services will be even more significant for small towns like Sant-Cugat, where travel services are less frequent and distances to transit are longer (Krizek & Stonebraker, 2011, p. 164). Additionally, offering bicycle parking facilities is far more cost-effective than feeder bus services for both city and users.

With the ambition of escalating railway station and bicycle inter-modality, Metropolitan Area of Barcelona (AMB), Ajuntament de Sant Cugat Bicibox, and Carnet collaborated to launch the Bicibox project. SmartHubs, bicibox is part of a broader policy context aimed at encouraging people to ride bicycles (SMARTHUBS, 2022b). It is a free bicycle parking service provided for all citizens. It enables cyclists to register along with their bicycles (TMB, 2022b). After which, users can park their bikes for free in any of the network's cycle lockers for up to 48 hours on weekdays and 72hours on the weekends once users have registered (TMB, 2022a).

Furthermore, a bicibox is a secure covered vault-like structure for private bicycle parking and security. Its well-covered structure provides the best protection against theft, vandalism, and weather, making it ideal for long-term bike parking facilities. Bicibox networks are strategically positioned near transport routes, cycling tracks, parks, gyms, and commercial areas to ensure that users can pick up and drop off bicycles with ease and safety. It has been installed in several municipalities throughout the Barcelona metropolitan area, resulting in a network of free and secure parking spaces for private bicycles (TMB, 2022a).

A prior study was conducted in the Municipality of Sant Cugat and focused on Bicibox, one of the smart hub's projects. As a result, the Municipality of Sant Cugat, which is a part of the smart hubs pilot project to encourage the use of bicycles, will be the site of this investigation. Similar to that, this thesis will advance existing research.

This study intends to analyse smart hubs such as bicibox and their contribution on encourage the inter-modality between active mobility and public transportation. This Master's thesis also aims to evaluate biciboxs' influence on the catchment area of railway stations of Municipality of Sant Cugat del Vallès. This report will also investigate the amenities provided around the mobility hub to understand the user preferences. This study intends to accomplish this by monitoring the user's data of bicibox stations provided by the Àrea Metropolitana de Barcelona (AMB). In addition, the built environment and facilities provided around the station will be monitored to analyse their effects on user behaviours. Finally, compare the two sets of findings to determine the user preference.

The purpose of this study is to examine current railway commuters' behaviour after the availability of secure, long-term bicycle parking facilities (bicibox). The research's secondary objective is to create decision-support tools for future planners and policymakers about Smart hubs. Additionally, to provide information to help with future bicycle box installations and to identify the settings that will be most effective.

In order to accomplish the goals of the study, data will be analysed on three different scales to identify user preferences, behaviours, and influence variables. User data will be then analysed and placed on graphs to discover usage trends. The users' locations and distances will then be verified on the QGIS map. Finally, a site visit will be made to investigate the immediate surrounding of bicibox stations.

The study is organized as follows: the following chapter gives the context and theoretical foundations for this investigation. Focusing on comprehending good public space, simple accessibility, parking, and travel habits from the standpoint of cycling. On the other side, a focus was placed on comprehending the built environment necessary to promote inter-modality. The methodologies used in this investigation are detailed after that. The three different scales that data was analysed on to get results from a different angle are explained in chapter six. The final chapter then summarizes the thesis and addresses each research question in light of the results.

2 Literature review

This literature review will find the relation between the railway station, bicibox, and urban environment. It will also throw some light on how transport facilities and urban environments are integrated. To obtain a better understanding of these topics, we will start by talking about the environmental requisites for bicycle parking. Then, in order to come up with particular criteria, it will briefly review the literature on the impact of the urban environment on transportation interchanges. Thus, the goal of this literature review is to come up with a simple framework that addresses the major concerns.

2.1 Successful public space for cyclists

Scheltema (2012) in his book “ReCYCLE City” has listed the design criteria of public space to be successful into four categories and arranged them into the pyramid hierarchical structure, as shown in Figure 1. According to him, there are various influential aspects of public space to attract cyclists, which he has included in four categories.

Scheltema defines dissatisfiers as safety and directness, while satisfiers are comfort and attractiveness. It is critical to identify the satisfiers and dissatisfiers of the cycling experience in order to make biking more appealing. Dissatisfiers are a prerequisite for satisfiers, which means that only if the dissatisfiers are resolved or met will the satisfier improve the cycling experience (Scheltema, 2012).

People will not cycle unless the public area is safe, according to Gehls (Gehl, 2013). Safety is a prerequisite for appreciating public space in its entirety (TRIMIS, 2022). As a result, he has positioned "safety" as the most essential criterion in his pyramid for successful public space for cyclists. If safety conditions can’t be met, other conditions will not be fulfilled, and the public space will be valued as poor. Since cyclists are one of the most vulnerable users of public spaces, they need protection against motorised traffic. Cyclist should be given their bicycle lane. (Bertolini, L., Binkhorst, G. J., Burden, D., Eind, A., Huismans, Immers, & Walraad, 2006; Forsyth & Krizek, 2011; Gehl, 2013; Rietveld, 2000).

Furthermore, a direct link is considered a prerequisite for the one(s) listed above. For the directness of the public space, the bicycle network's coherence and consistency are critical. Using logical direction and signage, the path should be comfortable to follow. Therefore, directness belongs to the group of satisfiers. (Forsyth & Krizek, 2011; Keijer & Rietveld, 2000; Rietveld, 2000).

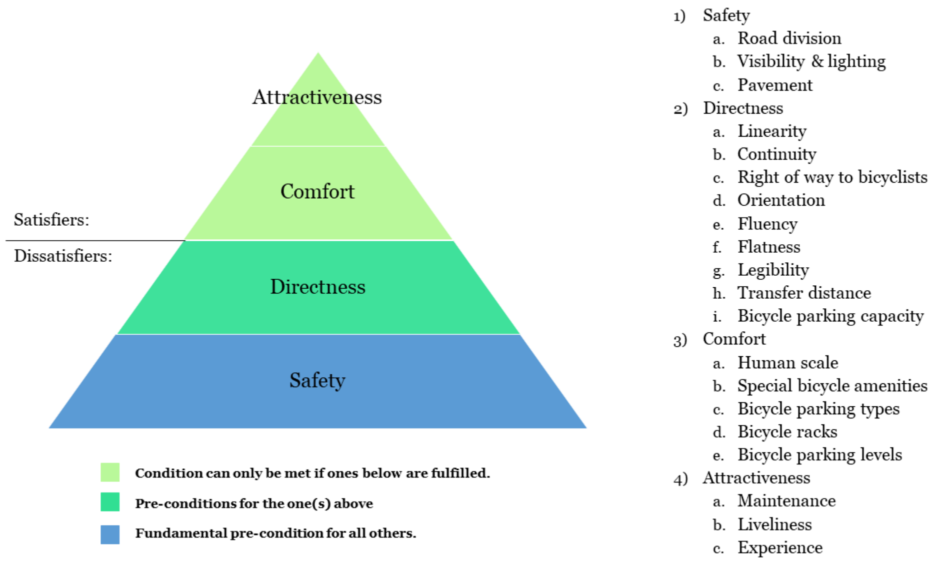


Figure 2: Pyramid for "Successful public space for cyclists" (Scheltema, 2012)

Additionally, the characteristics that belong to the group of satisfiers are comfort and attractiveness. Multiple uses of the place during the day are critical to the comfort of public space. For the safety of the cyclists, the presence of passers-by and eyes on the roadways is considered high. Furthermore, the traffic will be made more comfortable for cyclists by giving them the right of way as much as feasible. It is also further discussed, to make public space attractive for cyclists, it should be approached from the human dimension with close attention to the sense of place and scale (Forsyth & Krizek, 2011; Keijer & Rietveld, 2000; Rietveld, 2000).

2.2 Parking duration

Short-term parking generally lasts a few minutes to a few hours while long-term parking typically serves from a few hours to a few days (Pyöräliikenne.fi, 2022a). Parking users will favor the quickness and proximity of parking, as well as the ease of usage and the potential of frame locking, for short-term parking (Pyöräliikenne.fi, 2022a). On the other hand, long-term parking dependability and safety are the primary requirement (Pyöräliikenne.fi, 2022a). Likewise, quality, cleanliness, lighting, and weather resistance are additional requirements. Bicycle parking can be located both near and further away from the transit area. However, parking facilities located at a greater distance from the transit station should contain supplementary facilities (Pyöräliikenne.fi, 2022a). The following table illustrates rate the details of parking facilities.

Table 4: Significance of parking duration for parking solutions (Pyöräliikenne.fi, 2022b)

	SHORT TERM PARKING	LONG TERM PARKING
PURPOSE OF USE	Shops, visits, events	Office, housing, school and study, public transport
THE MOST IMPORTANT QUALITIES	Quick and easy	Safe and reliable, waterproof
LOCATION	Street areas, on the grounds, near the main doors, as close as possible (0-30m)	Bicycle storage, parking facilities, reasonably close to the property (30-100m)
RECOMMENDED RACK TYPES	Frame locking rack permanently mounted	Frame locking stand, canopy

2.3 Bike parking placement

Cyclists want to store their bicycles as close as possible to the train station (Heinen & Buehler, 2019). However, Arbis et al. (2015) argue that cyclists were ready to walk further for better parking, bicycle lockers, and other facilities. Although rates for lockers more than 100 meters from the entry declined by 20% (Arbis et al., 2015). As a result, bicycle parking should be close and visible to Mobility Hub users as feasible, as well as building entrances without impeding pedestrian routes or causing traffic congestion (Urban Design Studio, 2017, p. 13).

Molin and Maat (2015) suggest that if the cost of parking and the time it takes to walk increases, utility drops significantly. As a result, if the parking demand or location cannot be met, bicycles will be parked in the most convenient location for the bikers. This is known as fly parking, and it reduces pedestrian safety while also increasing street clutter.

Furthermore, according to Molin and Maat (2015), cyclists prefer highly visible areas to park their bicycles, so parking areas with camera surveillance were deemed to be as appealing as personnel surveillance. As a result, the parking area should be visible and secure, as well as clean, shaded or covered, and adequately illuminated (Urban Design Studio, 2017, p. 13).

2.4 Accessibility

Bicycle parking must be easily accessible, and it is an important criterion. Accessibility refers to the ease with which cyclists can get from the bike pathways to the bicycle parking and then on to their destination, as well as the ease with which they can discover and use parking. When arranging bicycle parking, all-important directions of arrival have to be taken into account. Parking should be strategically placed to the easily visible and accessible without exerting much physical effort. (Pyöräliikenne.fi, 2022b)

Table 5: Arrival directions (Pyöräliikenne.fi, 2022a)

ARRIVAL DIRECTIONS	Prior to the arrival of the parking, the accessibility should be known to the riders. Several directions should be considered.
DETECTION	Bicycle parking must be visible from the directions of arrival. Not around the corner, across the street, or in the middle of the car park.
GUIDANCE	It should be as intuitively as possible.
SAFETY	Arrival at the bicycle parking area should not pose any danger to cyclists or pedestrians.

2.5 Effects on traveling behaviour

Several studies have suggested a positive connection between bicycle parking availability and the likelihood of cycling to public transportation (Appleyard, 2012). According to Ferrell's (2017) observation Commuters in California are more likely to bicycle to stations with greater parking facilities. Furthermore, Halldórsdóttir et al. (2017) also witness, that the presence of a large number of bicycle parking and high-quality parking spaces raised the likelihood of cycling to a station by a factor of 2.5 in Denmark.

Cycling is also encouraged by the proximity of parking. There was a higher possibility of cycling to railway stations if bicycle parking was closer to the entrance. Additionally, 2 minutes was discovered to be a critical factor for major train stations (Geurs, La Paix, & van Weperen, 2016). Geurs go on to say that rather than guarded bicycle parking facilities, upgrades to unsecured bicycle parking facilities may result in an increase in the number of bicycles visiting the train station. Even though a shortage of safe bicycle parking is a major obstacle for cycling to the bus, train, and metro stations (Souza, La Paix Puello, Brussel, Orrico, & van Maarseveen, 2017).

According to Geurs et al. (2016), free bicycle parking facilities increase the probability of cycling to the railway station by 11% compared to paying for parking. According to Molin and Maat (2015), bicyclists prefer highly visible spots to park their bicycles. Hence, more bicycles are stored in areas where video or public surveillance is available (Molin & Maat, 2015).

2.6 Safety and Security

Appleyard and Ferrell (2017) mentioned that cyclists seek a safe and secure parking option to keep their bikes from being stolen or vandalized. The availability of secure parking facilities could encourage people to commute by bicycle often (Bopp et al., 2016). Safety at Mobility Hubs is enhanced by protected facilities, improved street crossings, strategic lighting, and slower vehicular speeds. By identifying pedestrian and vehicular issues near Mobility Hubs, transportation planners can apply mitigation techniques to provide a safe and enjoyable pedestrian experience (Sidebottom, Thorpe, & Johnson, 2009). Furthermore, having multiple entry points ensures that people with disabilities have secure and direct access to and from Mobility Hubs(Urban Design Studio, 2017, p. 37).

Several security methods can be applied at Mobility Hubs based on the typology and region environment. On-site security officers, security cameras, panic button apps for smartphones, and more options are available for security purposes (Urban Design Studio, 2017, p. 37). Natural surveillance, generally known as 'eyes on the street', at Mobility Hubs can be facilitated by maintaining unobstructed sight lines between waiting spaces and the surrounding neighbourhoods.

2.7 Build environment and transport studies

Cervero and Kockelman (1997) used the 3D’s (Density, Diversity, and Design) framework to describe transportation-urban environment interactions.

Density (‘interests per unit area’) has traditionally been regarded as a major factor in the utilization of public transportation. The idea is simple: the more built-up area there is, the more potential trip origins/destinations there are (Cervero & Kockelman, 1997). Jacobs (1961) has also suggested in her book, Density has long been considered as a fundamental condition for urban vitality as well as a precondition for long-term urbanization and economic growth (Jacobs, 1961).

However, this factor, according to Ewing and Cervero (2001) should be renamed "accessibility to destinations." In this method, the ease of access is calculated while considering the presence of several activities or attractions in a given location.

Diversity ("proportion of different land uses in a given area"), Jacobs (1961) explains diversity is one of a desirable city's most valuable assets, and it's essential to its correct functioning as a multifaceted hub of humanity; as she points out, all sorts of diversity, intricately interwoven in mutual support, are essential. Diversity also, refers to the proximity of living, working, and facilities, as well as the combination of complementary functions and the promotion of environmentally friendly modes of transportation(Carpio-Pinedo et al., 2014).

On the other hand, Ewing and Cervero (2001) again argue, "Linking where people live and work allows more to commute by foot, and this appears to shape mode choice more than sprinkling multiple lands uses around a neighborhood". With this they argue that Jobs-housing balances, rather than land-used use mix indicators, are better predictors of walk mode choice.

Design ("street network characteristics in the area"). Jacobs (1961) suggests, that an urban area that encourages pedestrian movement for varied purposes at various times could support a vibrant urban existence. Jacobs also emphasizes how diversified land uses were supplemented by small and close-knit blocks, boosting urban diversity. Smaller blocks result in more intersections, which slows traffic and reduces pedestrian travel distance (Jacobs, 1961).

Furthermore, to integrate public transport & urban planning, it is recommended to build multipurpose stations, as it connects and concentrates mixed-use activities such as offices, retail stores, and hotels around stations (Carpio-Pinedo et al., 2014). This not only helps to achieve critical mass and generate trip, which adds value to each activity, but it also transforms a transit point into a real living place (Cervero & Duncan, 2003).

A dense, compact, mixed-use, pedestrian-oriented development with adequate roadway and sidewalk connectivity will boost public transportation and bicycle intermodally (La Paix & Geurs, 2016). Other important characteristics are pedestrian-oriented buildings, which are street-facing and stimulate ground-level interest, as well as attention to place-making, which aims to create a true living place rather than merely a public transportation node (Carpio-Pinedo et al., 2014).

Cycling as a form of the connector to and from railway stations appears to be influenced by the accessibility of destinations and the built environment of transit station regions (Zhao & Li, 2017, p. 49). According to previous research, a transit passenger's maximum cycling distance tolerance ranges from 1.2 to 3.7 kilometres between the house and a transit stop (Stinson & Bhat, 2004). Furthermore, the possibility of cycling reduces considerably when the distance between the trip origin and a transit stations exceeds 2.5 kilometres (Krizek, El-Geneidy, & Thompson, 2007, p. 622). Additionally, a survey revealed that a 10-minute bicycle route was the acceptable distance from home to the transit station (Pooley et al., 2011).

Boufous et al. (2018) observed the average cycling speed was 18.4 km/h in their studies. Comparing this finding with the two previous studies average speed of cyclists on shared paths is between 15 km/h and 23 km/h (Atkins, M. V. A., and Phil Jones Associates, 2012; Virkler & Balasubramanian, 1998). The findings also indicate that riders normally adapt their speeds to accommodate pedestrians and to the conditions of the path (Boufous et al., 2018, p. 174).

Similarly, several studies have shown that the 5-minute walk, also referred to as the "pedestrian shed," is the distance that individuals are willing to walk before driving (Morph Code, 2018). Walking is likely to be faster than driving over this distance. Thus, finding locations within 400 meters is optimal (Victoria Walks Inc., 2022). A five-minute walk has a radius of 0.2 miles (around 400 meters) based on average walking speed. This is used as a rule of thumb to determine access to destinations or compute catchment areas of public transportation (Morph Code, 2018).

2.8 Built environment and interchange facility

Walking is heavily influenced by characteristics of the urban environment such as street network design, land use density and diversity, and destination accessibility. Similarly, public transportation is affected by its closeness or distance to it. This is linked to density and mixed land use: the denser the station's environment, the shorter the distance to transportation, and the greater the mix of activities that require public transportation, the greater the interaction potential (Cervero & Kockelman, 1997).

The configuration of the street network/accessibility considers not just the distance between nearby land uses and stations but also the configuration of the street network that leads to them. Hillier (1996) claims that configurational accessibility is related to a variety of factors, including land use density, land use mix, land value, urban growth, safety, and crime dispersion (Hillier, 1996).

Based on this reasoning, Space Syntax studies have created several modeling tools for urban planning and design to "construct the proper spaces," or more precisely, the right collection of potential relationships to host-specific land uses. The Space Syntax axial model can be used to determine how well transport interchanges are positioned in strategic positions within the transportation network and how well they are incorporated into the urban landscape (Carpio-Pinedo et al., 2014).

Table 6: Influence of building environment factors on transport (Carpio-Pinedo et al., 2014)

Travel mode	1st factor	2nd factor	3rd factor
Walking	Street network design	Land use density	Accessibility to destinations (diversity)
Public transport	Proximity to transport	Public space configuration, access, and visibility	

Visual Graphic Analysis (VGA) examines spaces as a continuous surface ('raster'): Analyse spaces as a continuous surface ('raster') with Visual Graphic Analysis (VGA): VGA helps determine the visual and physical accessibility of the area surrounding the interchange. It generates a variety of issues that interchange design must address like visual clarity, crossing, rest areas, and amenities, among other things (Carpio-Pinedo et al., 2014).

2.9 Interchange relationship

Intermodality in the urban environment dealt with the scale of the city and the various transportation networks. Urban context, architectural scales, and elements are being considered, besides the interchange building/area (Carpio-Pinedo et al., 2014). Based on this, this deliverable considers three aspects of the interchange:

It's not just about reducing on time spent at the hub interchange, but also about enhancing access and dispersion on the station, and, particularly in the case of interchanges in creating urbanity (Carpio-Pinedo et al., 2014).

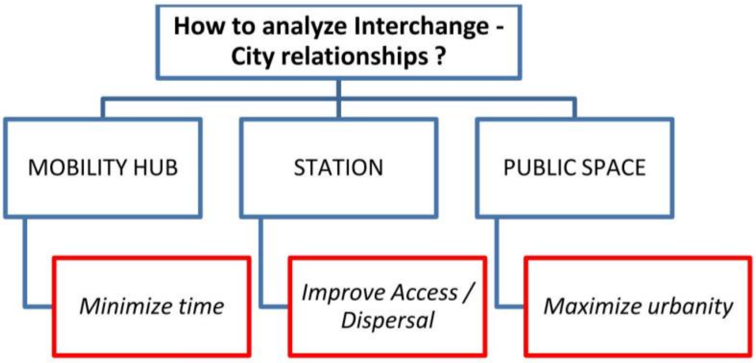


Figure 2: Interchange – City relationships. (Carpio-Pinedo et al., 2014)

- as a mobility hub (intermodality),
- as a station (access/dispersal),
- as a part of the public realm (staying-urbanity). (Carpio-Pinedo et al., 2014)

2.10 Catchment area

The catchment area of a transit station is frequently considered in the planning of public transportation to estimate the potential number of passengers (Landex & Hansen, 2006). A public transportation catchment area can be described as the areas surrounding public transportations stop or stations (Brebbia, 2008).

Criteria such as willingness to walk might be used to identify the geographical catchment region (Andersen & Landex, 2008). To estimate the number of possible travelers, it is required to know how many people live in the area, how many people work there, and how dense the population is. Furthermore, the denser the population and workplaces, the greater the travel potential, and thus the larger the catchment area (Landex & Hansen, 2006).

2.11 Summary of literature review

Previous studies taught us there are various influential aspects of public space to attract cyclists such as safety, directness, comfort, and attractiveness. People will not cycle unless the public area is safe, have direct links and are comfortable. As cyclists are one of the most vulnerable users of public spaces, they need protection against motorised traffic.

In addition, cyclists' top priorities for long-term parking are dependability, high visibility, and safety. They also prefer to park their bikes as close to the train station as possible. Cyclists, on the other hand, were willing to walk a little further for better parking, but parking beyond 100 meters saw a 20% drop in occupancy.

It was also discovered that the availability of bicycle parking increases the likelihood of cycling to the station. Furthermore, cyclists should have easy access from bike paths to bicycle parking, as well as the ability to find and use parking. Additionally, it was also noticed that a 10-minute bicycle ride from home to the transit station was an acceptable distance.

Furthermore, it is recognized that density, diversity, and design are all important factors in public transportation usage. These elements have a significant impact on pedestrians in an urban setting. It has also been discovered that individuals are willing to walk for 5 minutes before driving. The greater the density of the station's surroundings, the shorter the distance to transportation, and the more diverse the activities that demand public transportation, the larger the opportunity for interaction.

3 Methods

The methods utilized in this study are discussed in this chapter. Prior research in the field of smart hubs and the inter-modality environment has laid the groundwork for analyzing the impact of bicibox on the catchment area of railway stations in the municipality of Sant Cugat del Vallès Barcelona.

This study takes part in two layers. The first layer examines bicibox users' data using Microsoft Excel and Geographic Information System (GIS) tool. It also investigates the impact of bicibox on cyclists accessing railway stations. The second layer of the research examines the built environment and mobility hub amenities around the railway stations. The findings of these two layers of research will be compared and analyzed to draw the conclusion of the study.

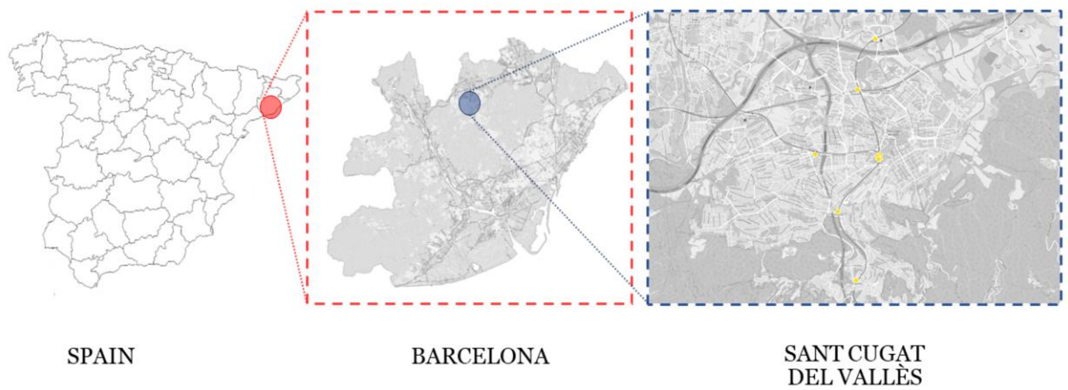
Since the 1990s, transportation planning agencies have been employing GIS software to support their transportation planning activities (Anderson, 1991). GIS is a computer system that stores, queries, analyzes, and displays geographic data. It has the potential to offer a relationship between multiple spatial and non-spatial data as well as model interactions between them (Choudhary & Ohri, 2015). It allows users to compare various data such as land use, population, and other demographic data to acquire a better understanding of the link between land use and other data in order to derive a genuine image (Choudhary & Ohri, 2015).

Similarly, this research requires calculating location coordinates, travel time calculations, catchment area, travel distance, and isochrones to evaluate user behaviors. QGIS software and ORS Tools plugins are equipped with tools to handle these required calculations. QGIS is a free and certified open-source GIS software (QGIS, 2022a). It can be downloaded from QGIS's official website https://qgis.org/en/site/. Similarly, ORS Tools plugins are capable of estimating routing, isochrones, and matrix calculations either directly from the map canvas or via point files within the processing framework (QGIS, 2022b). ORS tool can be installed through QGIS software itself.

3.1 Site Selection

The city of Sant Cugat del Vallès located in Catalonia, approximately 20 km away from Barcelona, is the study area of this research. According to citypopulation.de (2021) in 2021, the estimated population of the area was 94,012. In the same year, the population density was 1950/km². In addition, from the year 2011 to 2021, the population change in the area was 1.1 percent per year. Sant Cugat del Vallès has a total size of 48.20 square kilometers.

The municipality of Sant Cugat was selected due to previous research and testing conducted in the area. This study will also build on previous work done in the SmartHubs initiatives before moving the research forward and critically applying the indicators established in previous studies. Additionally, this research will also be part of the smart hubs pilot initiative to promote bicycle use.



Map 1: Location map of Municaipality of Sant Cugat del Vallès

Furthermore, the Municipality of Sant Cugat del Vallès has agreed to pilot test some of the existing innovative urban management tools as part of the Smart City initiative. The city has its mobility plan, which focuses on sustainable mobility and encourages the use of public transportation and environmental friendly automobiles rather than traditional vehicles. As part of the SmartHub Pilot work package in the Barcelona area, the city will establish a hub pilot site integrating shared mobility with public transportation.

3.2 Data preparation

Bicibox is a system developed by the Àrea Metropolitana de Barcelona (AMB) that allows cyclists to park their bikes safely and use public transportation. Thus, the user data of the Bicibox service in the municipality of Sant Cugat del Vallès was acquired from AMB.

Two sheets of data were received in a Microsoft Excel files:
The first sheet contains 46,000 records corresponding to bicycle parking lots at Bicibox stations in Sant Cugat between July 2020 and March 2022. A user code, parking start and ending parking times, station code, total time parked, and user address were all included in each record.

The second page contains information about 15 Bicibox stations that were operational in the Sant Cugat area between 2020 and 2022. Each record contained information such as a station code, municipality, station name, location, location type, station typology, and bicibox station capacity.

The data in the spreadsheets were organized into columns of a street name, street number, municipality, and postal code. These addresses in alphabet/text form were converted into latitude and longitude coordinates before being projected into the Qgis software for analysis.

Google Sheets with the extension tool Geocode by *Awesome Table* was used to convert addresses to coordinates. Google Sheets is a spreadsheet program that is part of Google Workspace, which is a free web-based program. Google Sheets is compatible with other Google apps as well as Microsoft Excel (Google, 2022). Geocode is a map application that allows users to extract latitudes and longitudes from addresses in a Google Sheet (Awesome Table, 2022). These features make them an ideal combination of tools for converting addresses to coordinates and utilization in this study.

Address information from multiple columns was combined into a single column for the conversion procedure. This single column of 46000 records of bicibox parking data received from AMB had to be split into five parts because the free version of the Geocode extension could only handle a limited amount of data per day. After the process of extraction of latitudes and longitudes from given addresses/data. The extracted coordinates were then arranged according to their addresses in excel sheets.

After extracting coordinates from addresses, Microsoft Excel was used to process data of user code, parking start and finish times, total parking time, user address, bicibox station code, and station location to examine user behavior and bicibox station usage. To understand user behavior and acceptance of services, the given data was translated into various graphs such as yearly usages of Bicibox stations, usage frequency and number, weekly utilization of services, and total service time.

3.3 Projecting Coordinates In QGIS

Before importing data into QGIS, the coordinate reference system (CRS) was changed to EPSG:25831. This is the area where the map of Spain is projected in QGIS. To import Microsoft Excel sheet data into QGIS, spreadsheet data was converted to. CSV format (Comma-separated values). This .CSV spreadsheet file was imported into QGIS. Railway station locations, bicibox station locations, and bicibox user locations were all projected in QGIS using the same approaches.

In addition to this, the ORS tool was used to construct isochrones to calculate travel time from railway stations for cyclists and pedestrians. Routes from the stations to the addresses of the users were also plotted. Isochrone maps and calculating journey times are a technique to analyse reachability from a starting place within a set time to better understand user behaviour.

3.4 Mobility hub amenities

The facilities available surrounding the bicibox region were examined using a mobility hub amenities table prepared by the Los Angeles Department of City Planning. This table was also recommended in the Delft University of Technology's (TU Delft) SmartHubsProject -WP4 study. There is a range of techniques for categorizing mobility hub typologies and criteria, depending on which features are valued. Since this research is centered on the built environment and interchange facilities, the mobility hub amenities table was chosen for the comparative analysis for its focus on urban context typologies.

The Mobility Hub Amenity Table is divided into seven theme categories, each with its own set of amenities. Each subject area is organized on the city's major mobility priorities (Urban Design Studio, 2017, p. 6).

The Mobility Hub Amenity Table is intended to provide suggestions and enhancements in the vicinity of current or new transit stations with facilities, activities, and initiatives that support multimodal connectivity and access (Urban Design Studio, 2017, p. 6). However, due to its context and transit duties, each place brings unique opportunities and constraints (Urban Design Studio, 2017, p. 7).

Amenities were simply classified as "Vital," "Recommended," or "Optional" based on their importance in various Mobility Hub categories (Urban Design Studio, 2017, p. 7). But the amenities' weights have not been scaled to determine priorities. These amenities were observed in the location of bicibox stations and marked in the table as "Available or Not Available”.

Table 4: Mobility Hub Amenities table. (Urban Design Studio, 2017, p. 7)

Mobility Hub Amenities	Bicycle Connections			Vehicle Connections			Bus Infrastructure		Information-Signange			Support Services				Active Uses		Pedestrian Connections	
	2.1. Bike Share	2.2. Bike Parking	2.3. Bicycling Facilities	3.1. Ride Share/Pick up-Drop off	3.2. Car Share	3.3. EV Charging Stations	4.1. Bus Layover Zone	4.2. Bus Shelters	5.1. Wayfinding	5.2. Real-time Information	5.3. Wi-Fi / Smartphone Connectivity	6.1. Ambassadors	6.2. Waiting Area	6.3. Safety and Security	6.4. Sustainable Approach	7.1. Retail	7.2. Public Space	8.1. To the Mobility Hub	8.2. At the Mobility Hub
(N) Neighborhood	●	●	■	■	○	○	■	○	●	○	○	■	○	○	○	■	■	○	○
(C) Central	●	●	○	●	●	●	○	●	●	●	●	○	○	●	●	○	●	●	●
(R) Regional	●	●	●	●	●	●	●	●	●	●	●	●	○	●	●	●	●	●	●

Legend: Vital: ● Recommended: ○ Optional: ■

Bicibox stations were visited along with the mobility hub amenity table and a map of the immediate vicinity. A mobility hub amenities table was created for each bicibox station. The bicibox stations' urban environment and commuter facilities were compared to the table's amenities and marked Available or NoAvailable in the table with some remarks. Furthermore, amenities locate were was also marked on a map for future references. The outcome of this site inspection was further compared with QGIS maps for the findings.

4 Results

Data were analysed into three scales in order to produce results:

- Municipal scale,
- Local scale and
- Site scale.

This is done to gain a better understanding of the users' preferences, behaviours, and the factors that influence their decision. To ascertain the level of performance of the service offered, as well as the reasons for their success and failure. Furthermore, to examining the differences between the results of the literature review and the current situation on the ground.

4.1 Data Analysis in Municipal Scale

A total of 46,000 records corresponding to bicycle parking lots at Bicibox stations in the municipality of Sant Cugat del Vallès between July 2020 to March 2022 were received through the Àrea Metropolitana de Barcelona (AMB). These records were used to analyse user behaviours, preferences, the performance of bicibox stations, and mobility hub amenities around the bicibox stations. The yearly, monthly, weekly, daily, and hourly demand of the bicibox stations was examined to determine user trends. Additionally, the most preferred bicibox station and their reason for success and failure were drawn.

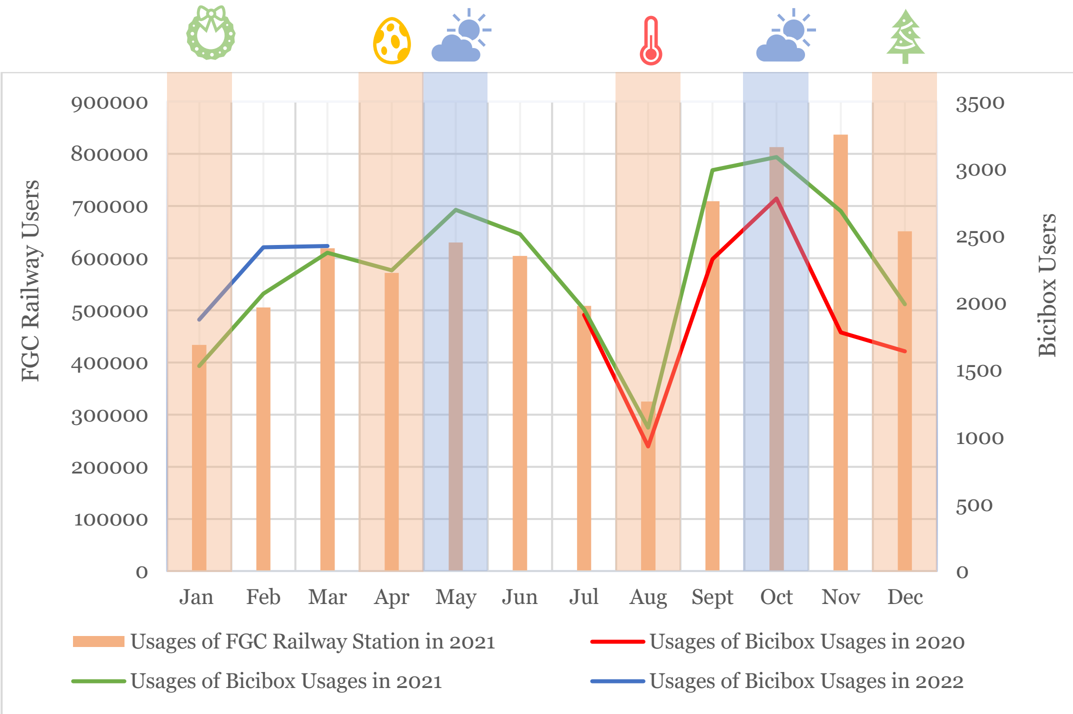
4.1.1 Monthly Bicibox Demand Analysis

A comparative graph was created between passenger data from the FGC railway station in the Municipality of Sant Cugat del Vallès for the year 2021 and users data from bicibox stations from July 2020 to March 2022. Even though the data recieved from AMB was complete for the year 2021, how ever, data for the years 2020 and 2022 was incomplete. It can be observed that FGC railway passengers and bicibox's monthly demand pattern follows a similar trend, even though the demands are seen gradually growing over years.

Analysing this graph with the seasonal calendar of Barcelona, it is evident that weather and seasonal festivities have a big impact on railway and bicibox service demand. The month of January and February begins with a national holiday, chilly weather, and just around five hours of daylight per day (Barcelona Life, 2021). Furthermore, the Christmas and New Year's holidays are extended until the middle of January, explaining the drop in railway and bicibox demand at the start of the year.

March indicated the arrival of spring and the return of the sun. As the city warms up, so does the demand for railway service and bicibox stations. Although April marks the end of winter and the city begins to get warmer, demand for both railway and bicibox stations is slightly lower due to the Easter holidays. However, demand begins to recover and shows positive signs until the end of May. May indicates the start of the summer and the tourist season. Due to the favourable weather for traveling and bicycling the demand for the railway and bicibox services are also growing considerably.

Table 5: Analysing monthly bicibox demand with seasonal calendar of Barcelona.



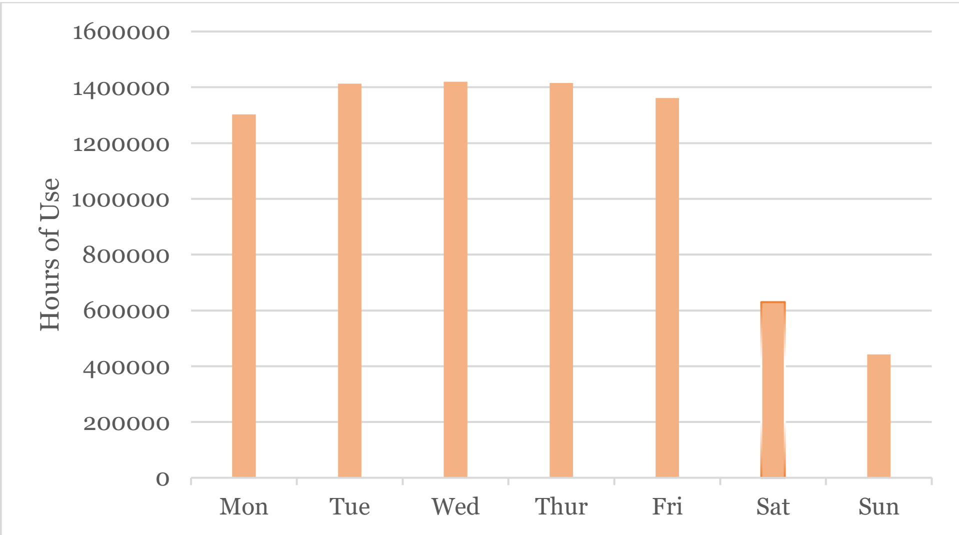
Following this, demand continues to decline until August for both the services, when it hits its lowest point of the year. This fall in demand coincides with the hottest month of the year and the summer holidays in Barcelona (Barcelona Life, 2021). People may avoid active movement due to the hot weather while decreasing the demand for both the services.

September and October are two of the most pleasant months of the year in Barcelona. With pleasant weather comes many streets festivals and parties. These months also happen to be the busiest for bicibox stations. Following that, demand steadily declines as the winter weather tightens its grip and people prepare for Christmas at the end of the year. However, for the railway stations, November seems to be the busiest month of the year as people are preparing for the upcoming holiday season.

4.1.2 Weekly Bicibox Demand Analysis

The weekly demand analysis for Bicibox was much more straightforward. We can see from the graph that demand on weekdays is nearly identical, however, weekend demand is significantly lower.

Table 6: Analysing weekly bicibox demand.



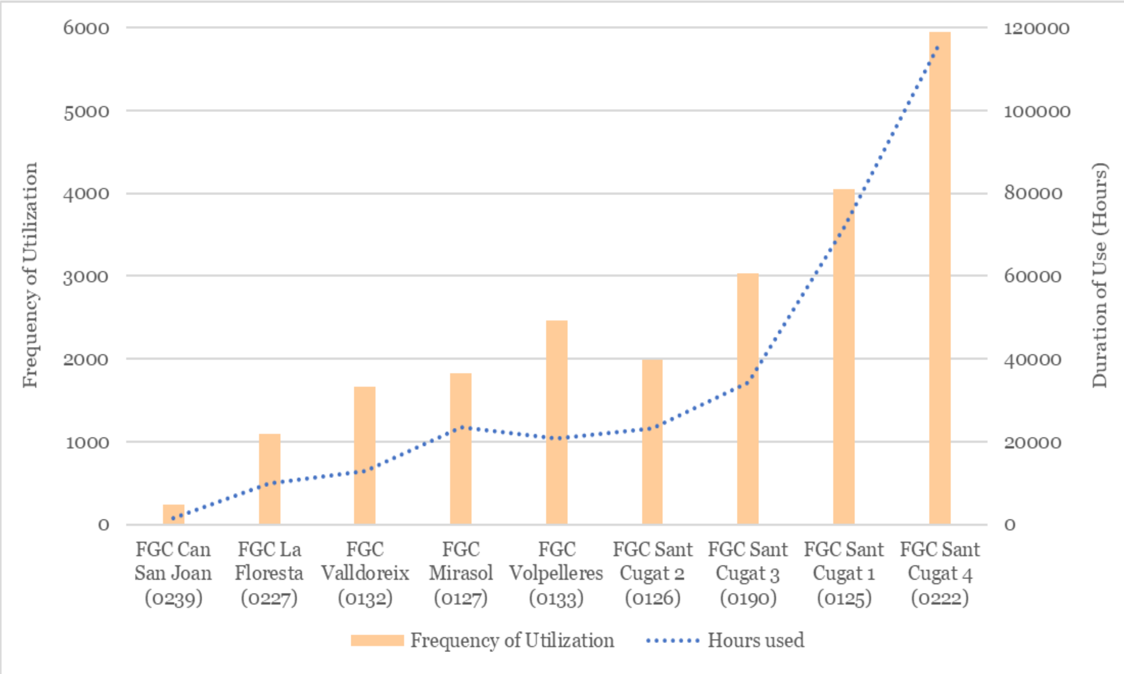
Most stores, food markets, supermarkets, and shopping malls are closed on Sundays, and most museums close after 2 p.m. Furthermore, result indicates people do not prefer to travel on Sundays. As a result, demand on Sundays is significantly lower than on Saturdays.

4.1.3 Duration of usages and Frequency of Bicibox Stations used

Two variables are being compared in this graph. The first is the frequency of bicibox used by the user, which examines the number of times a cyclist has used a specific bicibox service. It is represented by brown bars on a scale of 0 – 7000 times used. The second factor is the number of duration a bicycle is parked in a specific bicycle station. It is represented by the blue dotted lines on the scale of 0 – 120000 hours.

This graph illustrates that four bicibox stations at Sant Cugat railway station are much more frequently used than other bicibox stations, additionally the parking duration in these areas is also significantly longer. Station 0222 is the most popular among the bicibox stations despite having the least number of mobility hub amenities. Similarly, among the four biciboxes installed at Sant Cugat railway station, bicibox station 0126 has the lowest user frequency and parking duration, despite of having the greatest number of mobility hub amenities in its immediate vicinity.

Table 7: Analysing duration of usages and frequency of bicibox station used.



FGC Volpelleres' bicibox station 0133 is the most popular after Sant Cugat. However, as compared to bicibox stations in Sant Cugat, the ratio of frequency/times utilized to parking length is substantially lower. Volpelleres also has a lower-than-average presence of mobility hub amenities in its surroundings. Following that, the demand for bicibox service in FGC Mirasol, FGC Valldoreix, and FGC La Floresta gradually decreases. Furthermore, FGC Can San Joans' bicibox station 0239 is the youngest of the bicibox stations and has the least amount of used frequency and duration of use.

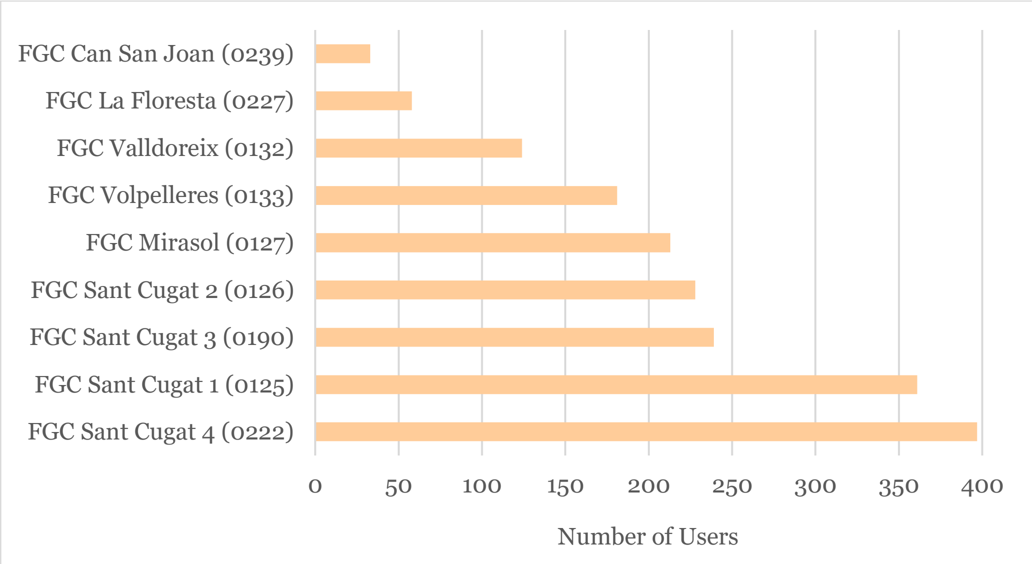
4.1.4 Number of Bicibox station users

This graph depicts the number of people who use the bicibox service at a specific station. Users prefer bicibox stations 0222 and 0125 around FGC Sant Cugat railway station. Station 0222 has approximately 400 users, while station 0125 has slightly more than 360 users. Aside from that, all other bicibox station users are relatively low and gradually decreasing.

Bicibox 0127 at Mirasol Centro, with its unique bicibox room and multiple facilities, attracts the majority of users outside of the Sant Cugat station.

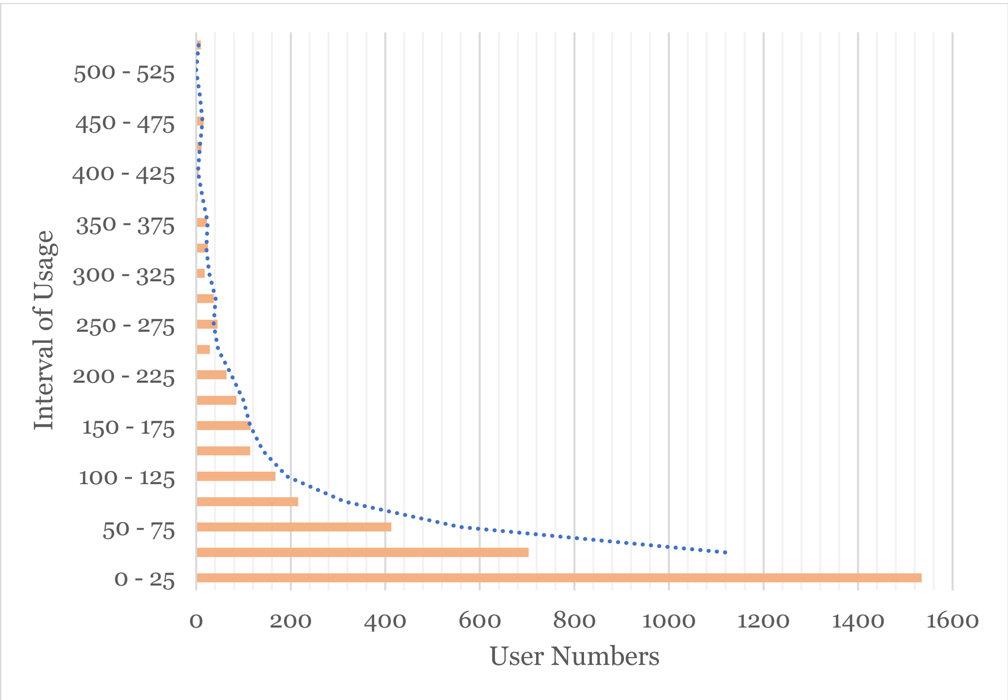
Similarly, bicibox stations 0190, 0126, and 0127 all have slightly more than 200 users. Whereas bicibox 0133 in FGC Volpelleres has less than 200 users, bicibox 0132 has the potential to attract 124 users. Similarly, bicibox stations 0227 and 0239 have the fewest users.

Table 8: Bicibox station users.



4.1.5 Recurrence of Bicibox station users

Table 9: Recurrence of bicibox station users.



The recurrence with which users use bicibox stations is depicted in this graph. The graph clearly shows that from July 2020 to March 2022, approximately 40% of 3777 total users used the bicibox service less than 25 times. The remaining 60% of users, however, use the bicibox service on a regular basis.

Bicibox service data was received for 639 days from July 2020 to March 2022 through AMB. Between this time 286 users used bicibox services more than 200. Despite the fact that the trend is downward, this graph shows that a large percentage of users use the bicibox services on a regular basis.

4.2 Data Analysis in Local Scale

After projecting coordinates for railway stations, bicibox stations, and user locations in QGIS. Isochrones were created for a five-minute walk and a ten-minute bicycling ride as acceptable travel time from home to the transit station. The ORS tool was used to create isochrones displaying a five-minute walking distance, which is represented by a green polygon shape. Similarly, a ten-minute cycling distance from bicibox stations was created and is represented by a purple polygon. These polygon isochrones will also depict the catchment area of railway stations.

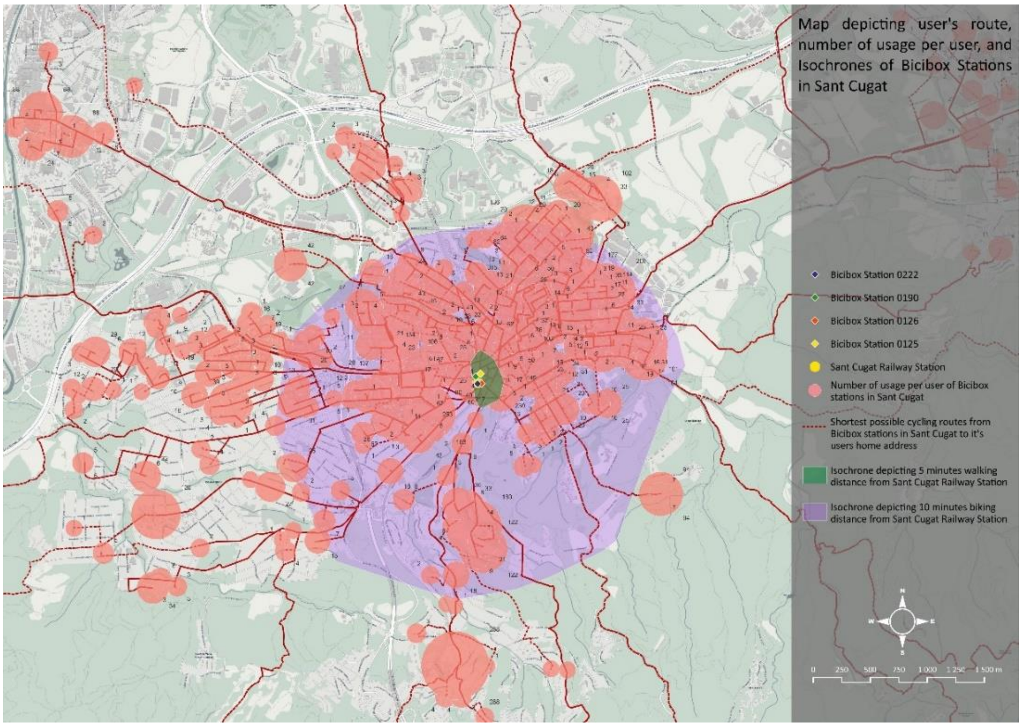
Furthermore, the ORS tool was also used to construct the shortest bicycle routes possible from bicibox stations to the user's home address. Finally, a pink circle with various radius was created to illustrate the number of users of bicibox stations. The size of the circle represents the number of usages per user of the bicibox station. The greater the radius of the circle, the greater the usage of the bicibox station by the user, and vice versa.

Pink circles laying inside the ten minutes cycling isochrones (purple polygon) are representing the users who live inside the boundary of the existing catchment area of the railway station. Similarly, these circles outside the cycling isochrones represent users living outside the existing catchment area. These are the users who are positively influenced by the bicibox service and are evidence of the expansion of the catchment area of the railway stations.

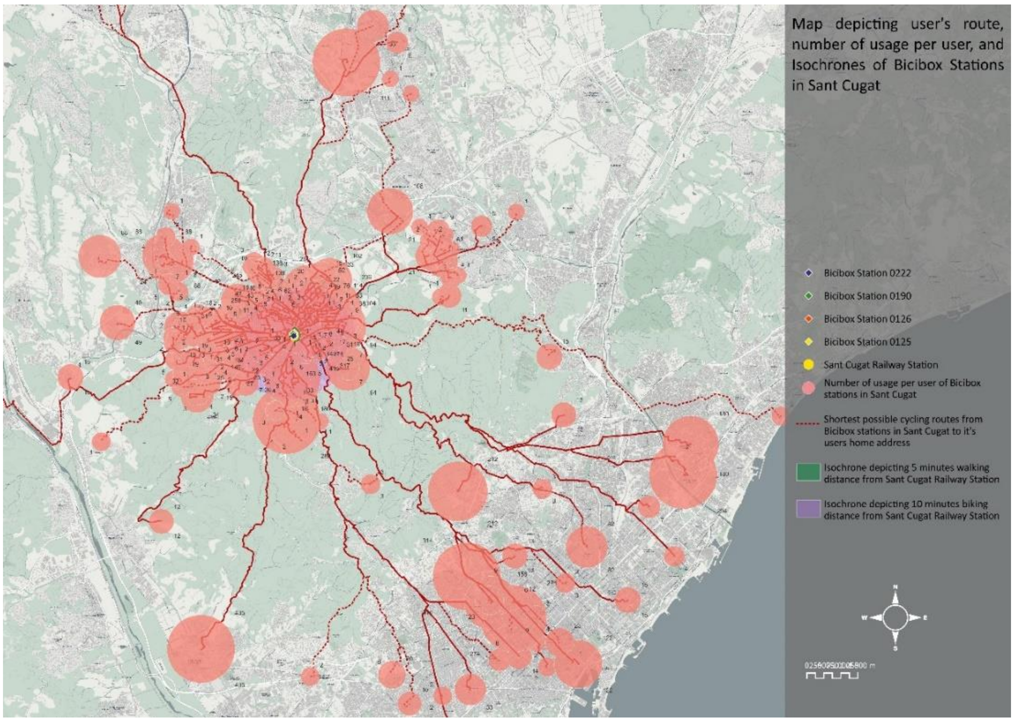
4.2.1 Usage per user of bicibox stations 0125, 0126, 0190, and 0222 in FGC Sant Cugat railway station.

The isochrones display a five-minute walking distance from railway stations and a ten-minute cycling distance from bicibox stations 0125, 0126, 0190, and 0222 in FGC Sant Cugat railway station are depicted in the given two maps. The first map is a detailed map that depicts users allocated around cycling isochrones of the Sant Cugat railway station. Similarly, the second map is a bigger picture of the first map, which attempts to illustrate all users of the Sant Cugat bicibox station.

According to the map, bicibox stations in Sant Cugat have managed to attract 26% of users from beyond its cycling isochrones. It's also worth noticing that users located beyond the cycling isochrone area are also frequent users of the bicibox services. Furthermore, bicibox stations in Sant Cugat also succeeded in drawing regular visitors from Barcelona as well. Similarly, individual detailed and bigger maps of all the other five bicibox stations in the municipality of Sant Cugat del Vallès are placed in the appendix section of this report.



Map 2: Map depicting user’s route, number of usages per user, and isochrones of Bicibox station in FGC Sant Cugat railway station.

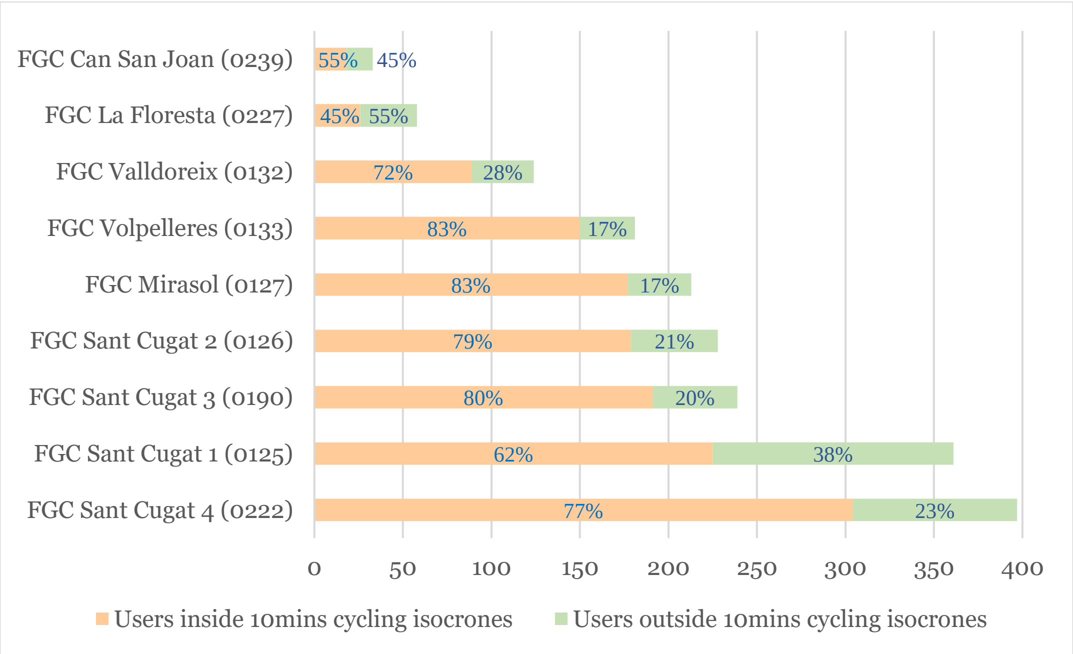


Map 3: Zoomed out map depicting user’s route, number of usages per user, and isochrones of Bicibox station in FGC Sant Cugat railways station.

4.2.2 Attracting users outside the catchment area

The graph below depicts the percentage of users living inside and outside of the train stations' catchment areas. There is a significant difference between users' percentages living inside and outside the cycling isochrones among all nine bicibox stations. However, bicibox stations 0227 and 0239, which are located in the railway stations of La Floresta and Can San Joan, respectively have the highest percentage of customers who live outside the railway station's catchment area at 55 percent and 45 percent. Aside from that, Sant Cugat's bicibox station 0125 was able to draw 38 percent of users from outside its catchment region. Similarly, the other three bicibox stations in Sant Cugat were able to attract slightly more than 20% of users from outside their catchment area. However, taking the average of all nine bicibox stations, they can attract just under 30% of users outside of their own catchment area.

Table 10: Users from 10mins cycling distance isochrones.



This answers our research question that bicibox stations in the Municipality of Sant Cugat del Vallès have a favorable impact on the catchment area of FGC railway stations.

Data Analysis in Site Scale

Following visits to all nine bicibox stations along with the mobility hub amenity table, and a map of the immediate surrounding areas. The urban environment and commuter facilities at bicibox stations were compared and noted down in the mobility hub amenities table and were marked on a map for further analysis.

4.2.3 FGC Mirasol railway station with bicibox stations 0127

Figure 3: FGC Sant Cugat railway station with bicibox station 0125, 0126, 0190, and 0222 and amenities.

The Sant Cugat railway station has four bicibox stations, two on each side of the railway track, to serve its commuters. Built environment and interchange facilities were observed for all 4 bicibox stations. Both bicibox stations 0125 and 0126 were deployed in September 2012, while bicibox 0190 was installed in November 2014 and bicibox 0222 at the beginning of 2017. Bicibox stations 0125 and 0126 are located on the commercial side of the Sant Cugat railway station, while bicibox 0190 and 0222 are located on the residential side. However, bicibox stations 0125 and 0126 are about 150-250m away from the main railway station respectively, whereas bicibox stations 0190 and 0222 are directly outside the station.

Bicibox 0125 has a 14-bicycle parking capacity and is located near a bus stop/layover zone and a train station. This makes it more appealing and convenient for users. The bicibox 0125, on the other hand, is located slightly off the main square but is highly visible to pedestrians traveling down that street. However, wayfinding could have been extremely beneficial to the users. A bicycle parking facility is also provided next to the bicibox. All the additional supporting services are not immediately adjacent to the station although they are not too far away either.

Table 11: Mobility hub amenities table for bicibox stations 0125, 0126, 019,0, and 0222.

FGC Sant Cugat 1	Bicibox Code 0125			Bicibox Code 0126			Bicibox Code 0190			Bicibox Code 0222		
Station Capacity			14			14			7			14
Railway Station	●											
Bicibox Station	◆											
Mobility Hub Amenities	Avilable	Not	Remark	Avilable	Not	Remark	Avilable	Not	Remark	Avilable	Not	Remark
Bicycle Connection												
1. Bike Share	0	X		0	X		0	X		0	X	
2. Bike Parking	X	0	5 no.	X	0	30 no.	X	0	6 no.	0	X	
3. Bicycle Facilities	0	X		X	0		0	X		0	X	
Vehicle Connection												
4. Ride Share/Pick up-Drop off	X	0		X	0		X	0		X	0	
5. Car Share	0	X		0	X		0	X		0	X	
6. EV Charging Station	X	0		X	0		0	X		0	X	
Bus Infrastructure						Bus shelter and layover zone not directly connected.						
7. Bus Layover Zone	0	X	Bus passenger should climb up and down the steep staircase.	0	X		0	X		0	X	
8. Bus Shelter	X	0		X	0		0	X		0	X	
Information Signage												
9. Wayfinding	0	X		0	X		0	X		0	X	
10. Real-time information	X	0		X	0		X	0		X	0	
11. Wi-Fi	X	0		X	0		X	0		X	0	
Support Services												
12. Ambassadors	0	X		0	X		0	X		0	X	
13. Waiting Area	X	0		X	0		X	0		X	0	
14. Safety and Security	X	0		X	0		X	0		X	0	
15. Sustainable Approach	0	X		0	X		X	0		X	0	
Active Uses						Public space include play ground.			Located in residential area therefore there is small waiting area and no cafe, retail shop and public spaces.			Located in residential area therefore there is small waiting area and no cafe, retail shop and public spaces.
16. Retail	X	0		X	0		0	X		0	X	
17. Public Spaces	X	0		X	0		0	X		0	X	
Pedestrian Connections												
18. To the Mobility Hub	X	0		X	0		X	0		X	0	
19. At the Mobility Hub	X	0		X	0		X	0		X	0	

Figure 4: Amenities around bicibox stations 0125 and 0126.

1. Maintenance facilities 2. Parking station 3. Children park
4. EV charging station 5. Parking station 6. Wi-Fi zone
7. Bus stop 8. Retail and Coffee shops 9. Real-time information.

Bicibox 0126 had the most vibrant environment of all four bicibox stations due to its immediate children's park, large public plaza, retail and coffee shops, free internet zone, trees, 30 bicycle parking spaces, and cycling maintenance facilities. Due to these amenities, it was also highly visible and easily accessible. Furthermore, of all bicibox stations, it features the most mobility hub amenities in its surroundings. However, the bus layover zone, bus shelter, and private vehicle pickup drop-off zone were slightly disconnected.

Bicibox 0190 and 0222 are located on the other side of the train station and are next to one another. Bicibox 0190 had 7 bicycle parking spaces whereas Bicibox 0222 had 14 bicycle parking capacity. Bicibox stations are highly visible for commuters and efficient for users due to theirs placement. They are placed in the residential area and have the least mobility hub amenities and services. They lacked a bus stop or shelter, as well as any other support services besides a waiting area.

Figure 5: Amenities around bicibox stations 0190 and 0222.

1. Bicibox stations
2 and 3. Parking zone
4. Private vehicle pickup drop-off zone
5 and 6. Private property
7. Bicycle parking
8 and 9. Pedestrian zone

4.2.4 FGC Mirasol railway station with bicibox stations 0127

Table 12: Mobility hub amenities table for bicibox station 0127.

FGC Mirasol	Bicibox Code 0127		
Station Capacity	20		
Railway Station	●		
Bicibox Station	◆		
Mobility Hub Amenities	**Avilable**	**Not**	**Remark**
Bicycle Connection			
1. Bike Share	0	X	
2. Bike Parking	X	0	5 no.
3. Bicycle Facilities	X	0	
Vehicle Connection			
4. Ride Share/Pick up-Drop off	X	0	
5. Car Share	0	X	
6. EV Charging Station	X	0	
Bus Infrastructure			
7. Bus Layover Zone	0	X	
8. Bus Shelter	X	0	
Information Signage			
9. Wayfinding	0	X	
10. Real-time information	X	0	
11. Wi-Fi	X	0	
Support Services			
12. Ambassadors	0	X	
13. Waiting Area	X	0	
14. Safety and Security	X	0	
15. Sustainable Approach	X	0	
Active Uses			Located in a modern multifunctional building which had most of the amenities.
16. Retail	X	0	
17. Public Spaces	X	0	
Pedestrian Connections			
18. To the Mobility Hub	X	0	
19. At the Mobility Hub	X	0	

Figure 6: FGC Mirasol railway station with bicibox station 0127 and amenities.

Figure 7: Amenities around bicibox station 0127.

1. Bus shelters 2 and 9. Bicibox 3. Bicycle stand inside bicibox stationsn
4 and 6. Public spaces 5 and 8. Bicycle parking
7. Signage

Bicibox station 0127 is located in Mirasol Centro, next to the Mirasol FGC railway station. It is a multipurpose commercial center that includes apartments, offices, public spaces, parks, and parking facilities. It is a modern, functional commercial center with a variety of mobility hub amenities within the building or its immediate surrounding. The Mirasol Centro's Bicibox is unlike any other bicibox installed. here the bicibox station is 5.3a m X 6.6m room with facilities like 24 bicycle parking spaces , 2 electrical bicycle charging points, 12 lockeselfsalf repairing sta,tion and a bicycle pump. This bicibox station was installed September of 2012.

However, the link to the train station looks to be broken due to the bicibox station's location. Furthermore, due to the absence of wayfinding and the station's location, the bicibox station is not highly visible for the commuters. In addition, the distance between the railway station and the bicibox was found to be inconvenient for the users which can be discouraging factor.

4.2.5 FGC Valldoreix railway station with bicibox stations 0132

Table 13: Mobility hub amenities table for bicibox station 0132.

FGC Valldoreix	Bicibox Code 0132		
Station Capacity	7		
Railway Station	●		
Bicibox Station	◆		
Mobility Hub Amenities	Avilable	Not	Remark
Bicycle Connection			
1. Bike Share	0	X	
2. Bike Parking	X	0	9 no.
3. Bicycle Facilities	X	0	Available of Bicitancats
Vehicle Connection			
4. Ride Share/Pick up-Drop off	X	0	
5. Car Share	0	X	
6. EV Charging Station	0	X	
Bus Infrastructure			
7. Bus Layover Zone	0	X	
8. Bus Shelter	X	0	
Information Signage			
9. Wayfinding	0	X	
10. Real-time information	X	0	
11. Wi-Fi	0	X	
Support Services			
12. Ambassadors	0	X	
13. Waiting Area	X	0	
14. Safety and Security	X	0	
15. Sustainable Approach	X	0	
Active Uses			
16. Retail	X	0	
17. Public Spaces	X	0	
Pedestrian Connections			
18. To the Mobility Hub	X	0	
19. At the Mobility Hub	X	0	

Figure 8: FGC Valldoreix railway station with bicibox station 0132 and amenities.

Biciboxes station 0132 was installed in September of 2012 at Valldoreix train station. It has a capacity of 7 bicycle parking facilities. Bicibox station is placed in a close approximation of private vehicle parking area, bus stop and railway station entrance for the convenience and attraction of the users. Due to the private vehicle parking area, bus station and access axis, bicibox seems well connected to the railway station even though bicibox station is placed slightly further from the railway entry. In front of railway station entrance, lies a retail/coffee shop and a disabled parking spot. Furthermore, bicibox uses solar panel to power its electronic devices.

There are two bicycle parking lots provided, one inside and other outside the train station. Exterior bicycle parking stand is placed close to the bicibox station. The private automobile parking also contains, Bicitancat for extra bike parking spot and facilities. Furthermore, bicibox had a decent amount of mobility hub amenities for its successful operation.

Figure 9: Amenities around bicibox station 0132.

1. Waiting area/stations 2 and 5. Bicycle parking 3. Retail/Coffee shop
4. Bus shelter 6. Public space 7. Bicycle Facilities (Bicitancat)
8. Bicibox station 9. Real-time information

4.2.6 FGC Volpelleres railway station with bicibox stations 0133

Volpelleres is one of Sant Cugat's newest neighbourhoods. In September 2012, a bicibox station with 14 bike parking spaces was installed. The Bicibox station and bus stop are just in front of the Railway station, attracting a substantially larger number of users to the bicibox station. Bicycle parking was offered both inside and outside the railway station. Furthermore, the train station structure is directly connected to the private vehicle parking lot and is also well connected by pedestrian. Most support services such as retail and coffee shops as well as public areas are distant from the railway station structure.

Table 14: Mobility hub amenities table for bicibox station 0133.

FGC Volpelleres	Bicibox Code 0133		
Station Capacity	14		
Railway Station	●		
Bicibox Station	◆		
Mobility Hub Amenities	Avilable	Not	Remark
Bicycle Connection			
1. Bike Share	0	X	
2. Bike Parking	X	0	8 no.
3. Bicycle Facilities	0	X	
Vehicle Connection			
4. Ride Share/Pick up-Drop off	X	0	
5. Car Share	0	X	
6. EV Charging Station	0	X	
Bus Infrastructure			
7. Bus Layover Zone	0	X	
8. Bus Shelter	X	0	
Information Signage			
9. Wayfinding	0	X	
10. Real-time information	X	0	
11. Wi-Fi	0	X	
Support Services			Retail shops and cafe are not available immediately but in 500m distance there is Mercadona. Public space are also not available immediately.
12. Ambassadors	0	X	
13. Waiting Area	X	0	
14. Safety and Security	X	0	
15. Sustainable Approach	0	X	
Active Uses			
16. Retail	0	X	
17. Public Spaces	X	0	
Pedestrian Connections			
18. To the Mobility Hub	X	0	
19. At the Mobility Hub	X	0	

Figure 10: FGC Volpelleres railway station with bicibox station 0133 and amenities.

Figure 11: Amenities around bicibox station 0133.

1 and 2. Bicycle parking 3. Car parking 4 and 7. Playground
5. Bus shelters 6 and 9. Public space 8. Bus stop

4.2.7 FGC La Floresta railway station with bicibox stations 0227

Table 15: Mobility hub amenities table for bicibox station 0227.

FGC La Floresta	Bicibox Code 0227		
Station Capacity	7		
Railway Station	●		
Bicibox Station	◆		
Mobility Hub Amenities	Avilable	Not	Remark
Bicycle Connection			
1. Bike Share	0	X	
2. Bike Parking	X	0	3 no.
3. Bicycle Facilities	0	X	
Vehicle Connection			
4. Ride Share/Pick up-Drop off	X	0	
5. Car Share	0	X	
6. EV Charging Station	0	X	
Bus Infrastructure			Bus passenger should climb up and down the steep staircase.
7. Bus Layover Zone	0	X	
8. Bus Shelter	X	0	
Information Signage			
9. Wayfinding	0	X	
10. Real-time information	X	0	
11. Wi-Fi	0	X	
Support Services			
12. Ambassadors	0	X	
13. Waiting Area	X	0	
14. Safety and Security	X	0	
15. Sustainable Approach	X	0	
Active Uses			
16. Retail	X	0	
17. Public Spaces	X	0	
Pedestrian Connections			
18. To the Mobility Hub	X	0	
19. At the Mobility Hub	0	X	

Figure 12: FGC La Floresta railway station with bicibox station 0227 and amenities.

Figure 13: Amenities around bicibox station 0227.

1. Retail/Coffee shop
2. Bicycle parking
3. Steep stair
4. Bicibox
5. Bus stop
6. Playground
7. Retail shop
8. Real-time information
9. Car parking

In La Floresta railway station, there are two entrances: one from the parking lot and coffee shop area, and the other from the steep stairway leading to the bus stop. Bicibox station 0227 is located in the playground/public space which includes bicycle parking as well. Retail and coffee shops are faced towards the square which is directly connected to the railway station and playground. Private vehicle pick-up drop-off area and parking area are also connected to the coffee shop area. Furthermore, the bicibox station was installed in February 2018 and had a capacity of 7 bicycle parking at a time.

Despite its proximity to the railway station, the bicibox was not clearly visible to commuters. The link between the bicibox, bicycle parking, and railway station, on the other hand, was fairly straightforward, making it very easy to utilize the bicibox service.

4.2.8 FGC Can Sant Joan railway station with bicibox station 0239

Table 16: Mobility hub amenities table for bicibox station 0239.

FGC Can San Joan	Bicibox Code 0239		
Station Capacity	7		
Railway Station	●		
Bicibox Station	◆		
Mobility Hub Amenities	Avilable	Not	Remark
Bicycle Connection			
1. Bike Share	0	X	
2. Bike Parking	X	0	3 no.
3. Bicycle Facilities	0	X	
Vehicle Connection			
4. Ride Share/Pick up-Drop off	X	0	
5. Car Share	0	X	
6. EV Charging Station	0	X	
Bus Infrastructure			
7. Bus Layover Zone	0	X	Bus passenger should climb up and down the steep staircase.
8. Bus Shelter	X	0	
Information Signage			
9. Wayfinding	0	X	
10. Real-time information	X	0	
11. Wi-Fi	0	X	
Support Services			
12. Ambassadors	0	X	
13. Waiting Area	X	0	
14. Safety and Security	X	0	
15. Sustainable Approach	X	0	
Active Uses			
16. Retail	X	0	
17. Public Spaces	X	0	
Pedestrian Connections			
18. To the Mobility Hub	X	0	
19. At the Mobility Hub	0	X	

Figure 14: FGC Can Sant Joan railway station with bicibox station 0239 and amenities.

Bicibox station 0239 in FGC Can Sant Joan railway station was installed in February 2020, it is one of the newest additions in bicibox network. The FGC Can Sant Joan railway station is a small station with a bicibox and bus station directly outside the station building, making the bicibox station very visible. It also had a private vehicle parking area and bicycle parking facilities directly in front of the building. Railway station was also well pedestrian connected to the station. Despite the lack of a public square or plaza as a public place, it has a small woodland park beside the station.

On the other side of the station, support services like retail and coffee shops are provided with again parking area. Wayfinding and free internet service were not available, yet the bicibox was highly visible and convenient for users due to its location.

Figure 15: Amenities around bicibox station 0239.

1. Bicibox station 2. Bus stop 3. Bicycle parking
4 and 8. Car parking 5. Public spaces 6. Entrance of station
7. Bicycle and car parking 9. Retail/Coffee shop

4.2.9 Marking the mobility hub amenities

After visiting the bicibox stations, the mobility hub amenities table was compared to the bicibox stations' immediate urban environment. The presence or absence of facilities around the bicibox stations is indicated in the amenity table as "Available or Not Available."

Furthermore, in order to take a quantitative approach, data represented in string such as "Available" and "Not Available" were converted into numbers 1 and 0. If the amenities are available, the value is 1, otherwise it is 0. This allows us to quantify the presence of mobility hub amenities near the bicibox and compare the facilities present around each individual bicibox station.

After converted into a quantitative table, it can be noticed that bicibox stations 0126 and 0127 have the most mobility hub amenities in their surroundings, whereas bicibox station 0222 has the fewest. This table reveals an interesting finding: bicibox station 0126, which has the most amenities, and bicibox station 0222, which has the fewest amenities, are both installed at FGC Sant Cugat railway station. Furthermore, it was discovered that the bicibox station 0222 with the fewest amenities was the most popular among users. Similarly, bicibox stations 0126 and 0127, which had the maximum amenities, was underperformed.

Table 17: Marking the mobility hub amenities table for all the bicibox stations.

Mobility Hub Amenities	Neighborhood	Central	Regional	FGC Sant Cugat 1 (0125)	FGC Sant Cugat 2 (0126)	FGC Sant Cugat 3 (0190)	FGC Sant Cugat 4 (0222)	FGC Mirasol (0127)	FGC Volpelleres (0133)	FGC Valldoreix (0132)	FGC La Floresta (0227)	FGC Can San Joan (0239)
				Avilable /Not	Avilable /Not	Avilable /Not	Avilable /Not	Avilable /Not	Avilable /Not	Avilable /Not	Avilable /Not	Avilable /Not
Bicycle Connection												
1. Bike Share	●	●	●	0	0	0	0	0	0	0	0	0
2. Bike Parking	●	●	●	1	1	1	0	1	1	1	1	1
3. Bicycling Facilities	■	◎	●	0	1	0	0	1	0	1	0	0
Vehicle Connection												
4. Ride Share/Pick up-Drop off	■	●	●	1	1	1	1	1	1	1	1	1
5. Car Share	◎	●	●	0	0	0	0	0	0	0	0	0
6. EV Charging Station	◎	●	●	1	1	0	0	1	0	0	0	0
Bus Infrastructure												
7. Bus Layover Zone	■	◎	●	0	0	0	0	0	0	0	0	0
8. Bus Shelter	◎	●	●	1	1	0	0	1	1	1	1	1
Information Signage												
9. Wayfinding	●	●	●	0	0	0	0	0	0	0	0	0
10. Real-time information	◎	●	●	1	1	1	1	1	1	1	1	1
11. Wi-Fi	◎	●	●	1	1	1	1	1	0	0	0	0
Support Services												
12. Ambassadors	■	◎	●	0	0	0	0	0	0	0	0	0
13. Waiting Area	◎	◎	◎	1	1	1	1	1	1	1	1	1
14. Safety and Security	◎	●	●	1	1	1	1	1	1	1	1	1
15. Sustainable Approach	◎	●	●	0	0	1	1	1	0	1	1	1
Active Uses												
16. Retail	■	◎	●	1	1	0	0	1	0	1	1	1
17. Public Spaces	■	●	●	1	1	0	0	1	1	1	1	1
Pedestrian Connections												
18. To the Mobility Hub	◎	●	●	1	1	1	1	1	1	1	1	1
19. At the Mobility Hub	◎	●	●	1	1	1	1	1	1	1	0	1
				11	12	7	6	12	8	10	8	9

Legend: Vital: ● Recommended: ◎ Optional: ■

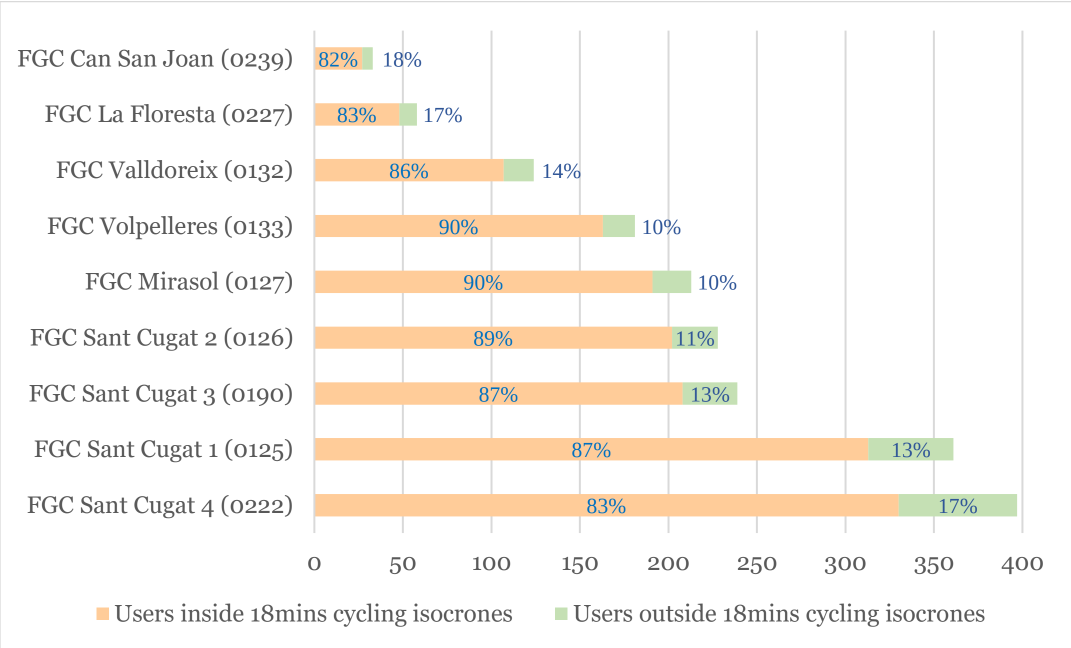
5 Discussion and Conclusions

5.1.1 Estimating the New catchment area

After gaining a deeper understanding on the ten-minute cycling isochrones of railway stations, site analysis, user behaviors, user locations, and the proportion of users lived inside and outside the isochrones boundary, both the new catchment area and the catchment area's direction of growth are estimated.

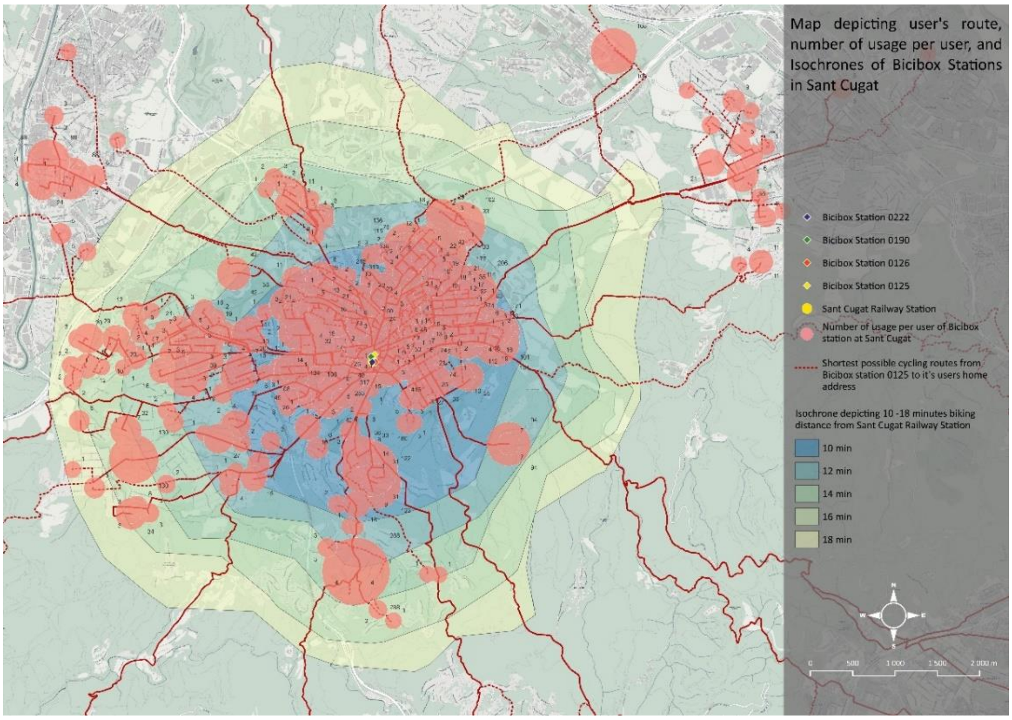
Railway station isochrones were gradually increased from ten minutes of cycling distance to every two minutes of interval (12, 14, 16), and the percentage of users accommodating inside the increasing isochrones was noticed. It was discovered that isochrones should be enlarged by 18 minutes of cycling distance to accommodate a minimum of 80% of users within the isochrones for every railway station.

Table 18: Users from 18mins cycling distance isochrones.



As shown in the graph, FGC Volpellores, FGC Sant Cugat 2, and FGC Mirasol all have around 90% of users inside isochrones that have been enlarged up to eighteen minutes of cycling distance. In the same way, the extended isochrones at FGC Sant Cugat 1 and 2 have accommodated 87 percent of users. At the FGC Valldoreix train stations, almost 85% of users are inside the enlarged isochrones. In addition, roughly 80% of users at the FGC Can

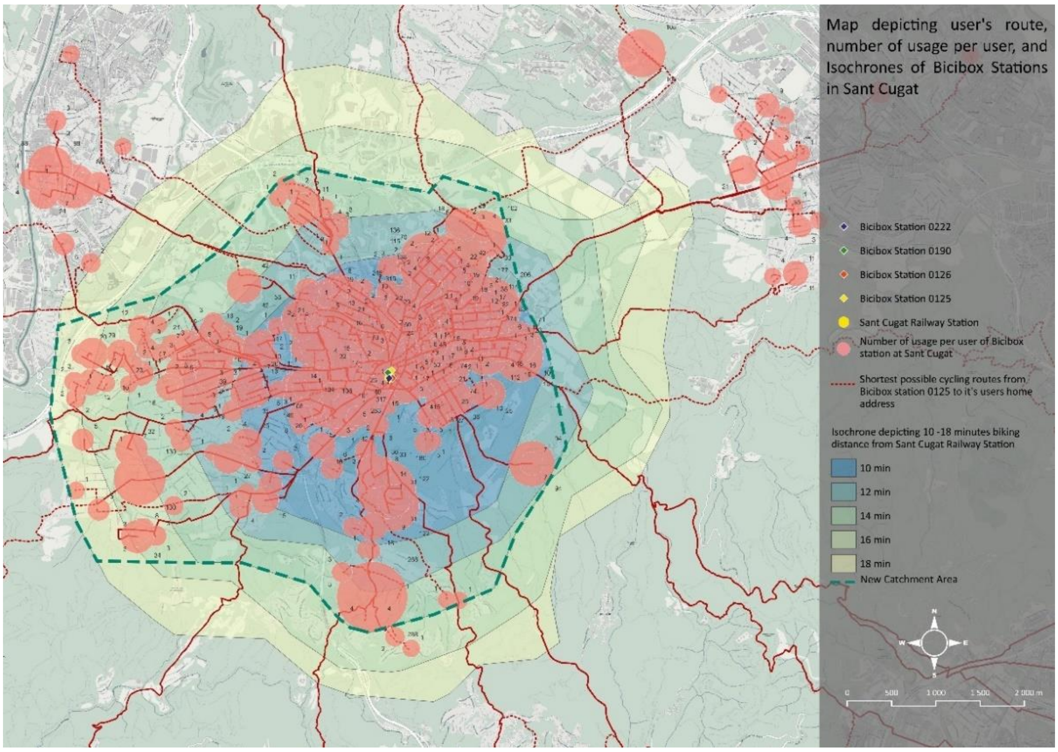
San Joan, FGC La Floresta, and FGC Sant Cugat train stations are within the increased isochrones.



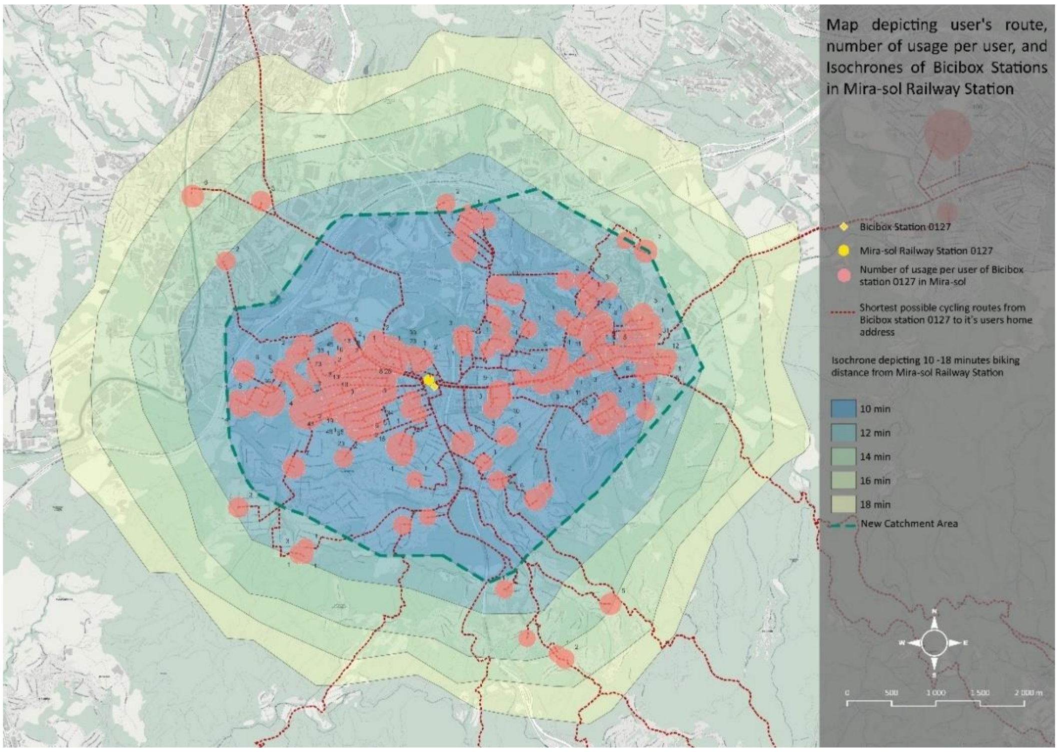
Map 4: Map depicting 10 to 18 minutes of isochrones of FGC Sant Cugat railway station.

On the QGIS map, isochrones of 10, 12, 14, 16, and 18 minutes were created and indicated with blue, green, and yellow colors respectively. Users' locations inside the isochrones can be observed from the map. Furthermore, on the map, it can be seen that users are mostly positioned up to 10 minutes isochrones in the east direction of the railway station. Users in the west direction, on the other hand, are positioned as far as 18 minutes isochrones. Users are attracted upto 14 minutes of isochrones in the north direction, and the same is true in the south direction. We can deduce from this map that the FGC Sant Cugat railway station's new catchment area is increasing more rapidly towards the west direction. Similarly, it is extending up to 14 minutes in the north and south directions, while it is still just under ten minutes in the east direction. With this informations catchment area of FGC Sant Cugat railway station was estimated.

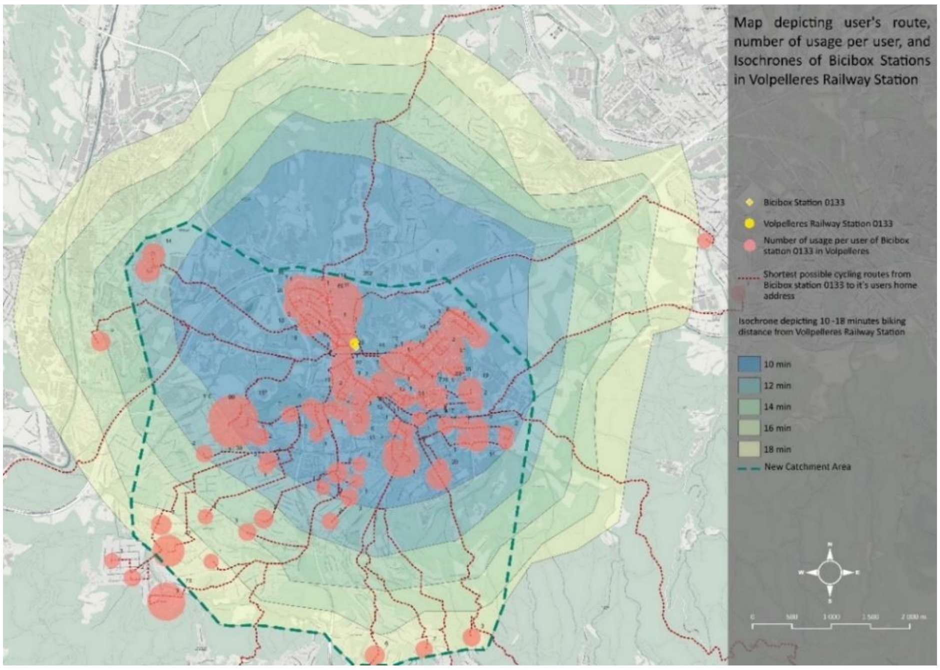
Similar procedure was followed to estimated catchment area of all the other six railway stations of Sant Cugat del Vallès. The boundary of the estimated catchment area is indicated by green dashed lines.



Map 5: Map depicting estimated catchment area of FGC Sant Cugat railway station.

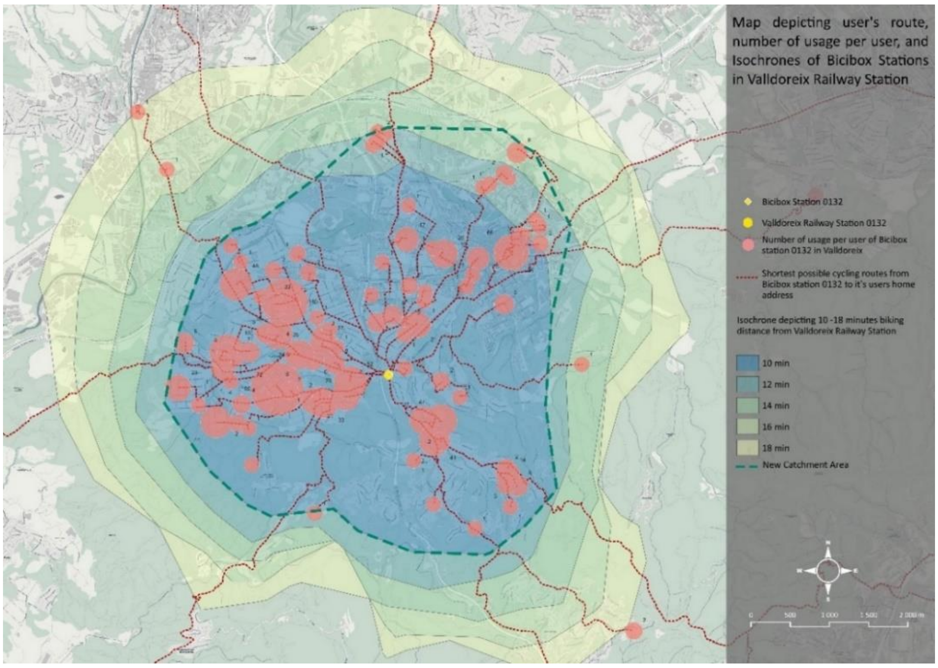


Map 6: Map depicting estimated catchment area of FGC Mirasol railway station.

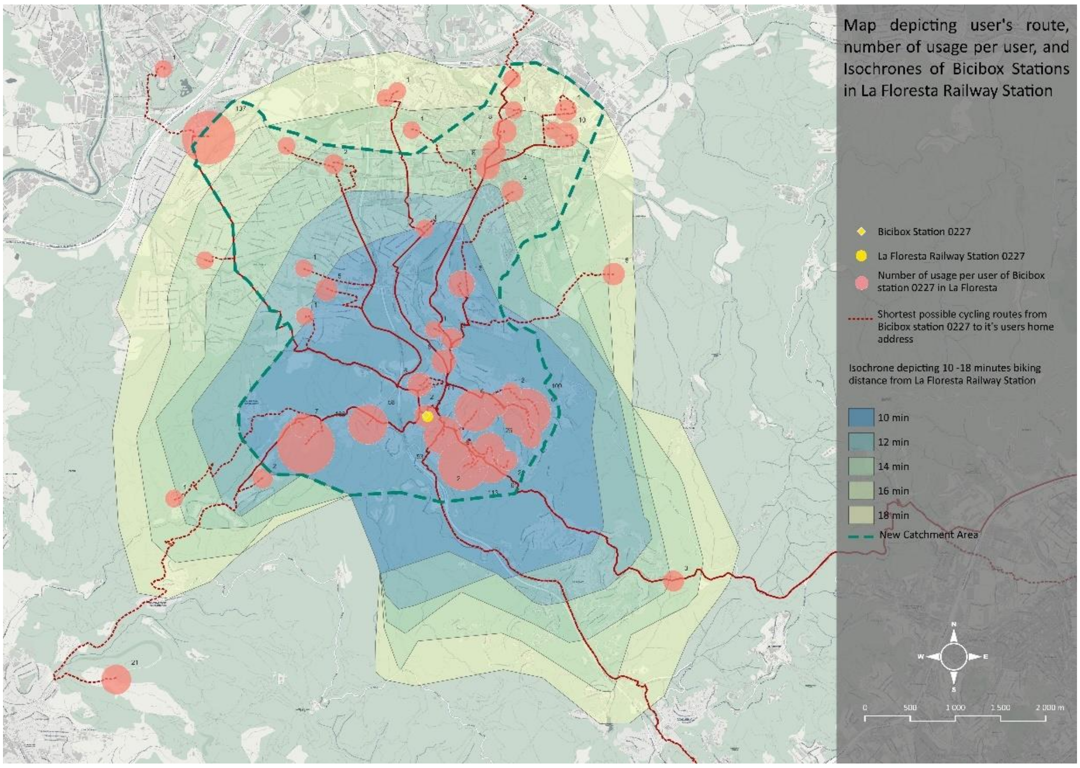


Map 7: Map depicting estimated catchment area of FGC Volpelleres railway station.

The majority of FGC Volpelleres railway station users appear to come from the south direction. The catchment area in the south was expanded up to 18 minutes of cycling distance. On the other hand, the Mediterranean Highway appears to cut off users' access to the railway station on the northern side.



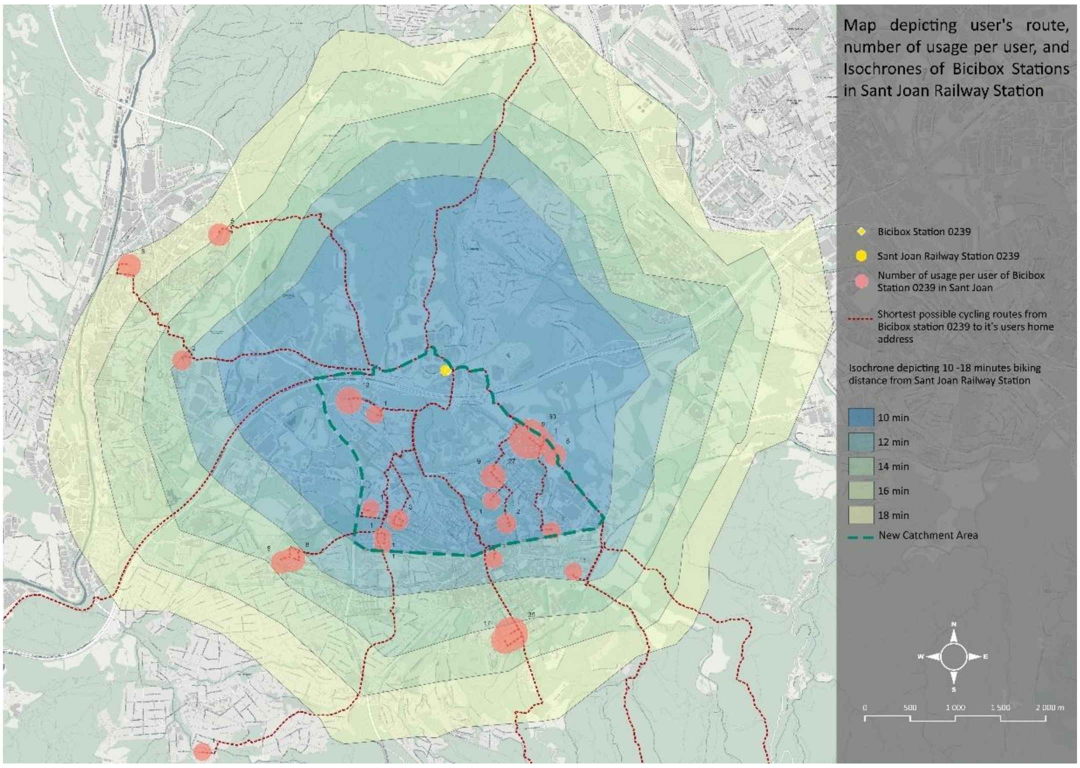
Map 8: Map depicting estimated catchment area of FGC Valldoreix railway station.



Map 9: Map depicting estimated catchment area of FGC La Floresta railway station.

Due to the large wooded area, rocky terrain, and low-density area on the south side of the FGC La Floresta railway station, it was obvious that the catchment area did not expand towards the southward direction. Furthermore, since the city is significantly denser towards the northern side of the railway station, the majority of users are also coming from the north direction. It was also observed extension of catchment areas are mirroring the shape of the city itself.

The FGC Sant Joan railway station's bicibox is the newest addition to the network and based on the map and data, it also has the fewest users. The catchment area is comparatively fairly limited and is primarily focused south of the railroad station. Even though the Mediterranean Highway passes by the FGC Sant Joan train station from the south, the majority of its users travel in that same direction. Additionally, it is obvious that the city is significantly denser in the south.



Map 10: Map depicting estimated catchment area of FGC Sant Joan railway station.

According to these QGIS maps, bicycle stations in the Municipality of Sant Cugat have been successful in aiding the expansion of the FGC train stations' catchment areas. it is also believed that the catchment areas of five out of the six FGC train stations have extended its catchment farther than ten minutes cycling distance isochrone. The estimated catchment area can also be observed in terms of its shape, size, and growth direction through these maps. With this it can be concluded that the main objective of this master's thesis, which was to assess the impact of the bicibox station on the catchment area of the FGC train stations in the Municipality of Sant Cugat was achieved.

5.1.2 Conclusion

The purpose of this master's thesis was to assess the impact of bicibox stations on the catchment area of FGC railway stations in Municipality of Sant Cugat del Vallès. It investigated the amenities available near the mobility hub to better understand user preferences. The initial goal of the study was to investigate bicycle parking behaviour at transit hubs. A further objective of this research was to create decision support tools for future policymakers and planners about Smart hubs.

Data were analysed on three different scales to determine user preferences, behaviour, and influence factors in order to achieve the study's goals. To start with, data were graphed and analysed to determine user trends. The users' locations and distances were then verified on the QGIS map. Finally, the site was visited to investigate the immediate vicinity of bicibox stations.

The graphs showed that the bicibox user demand trend follows the monthly passenger flow of the FGC railway station. It is also clear that seasonal festivities and the weather have a significant influence on the demand for train and bicibox services. Additionally, it was noted that bicibox stations in FGC Sant Cugat saw higher use than any other bicibox stations and were also successful in drawing in a larger user base. Likewise, the bicibox station 0222 was the most popular among all four bicibox stations that were installed in the FGC Sant Cugat train station. Furthermore, based on the 639 days of data received for the bicibox service, we could observe significant portion of users utilizes the bicibox services frequently, as evidenced by the 286 users who used the bicibox service more than 200 times over the course of 639 days. This result fulfills the secondary objective of this study, which was to investigate bicycle parking behaviour at public transport stations.

It was also discovered that bicibox stations located directly in front of a railway station, a bus station, or in the middle of both stations perform better than bicibox stations located further away from the station. Clustering transport facilities makes it easier to access the shareable modes and gives the customer a larger view, which could influence their mode of choice (Carpio-Pinedo et al., 2014). This demonstrates that a direct link is required to attract cyclists (Scheltema, 2012). Additionally, the availability of a bus and train connection will give the cyclist more options and promote Intermodality. The combination of the bus and train stations will also assist bicibox service draw in a lot of people.

Additionally, it was identified that biciboxes stations like 0222, 0190, and 0133 that were highly visible by passengers at the railway stations performed significantly better than those with visual barriers. Similar results were seen in the research done by Arbis et al.; Heinen and Buehler (2015; 2019). As a result, bicycle parking should be close and visible to transit users (Urban Design Studio, 2017, p. 13). This was also stated in the city of Helsinki's Bicycle Traffic Planning Guide (Pyöräliikenne.fi, 2022b). Parking should be positioned strategically so that it is both easily visible and accessible without requiring much physical effort (Pyöräliikenne.fi, 2022b).

When the immediate surroundings of bicibox stations were compared to the mobility hub amenities table, it became clear that the most popular bicibox station 0222 had the fewest mobility hub amenities in its immediate surroundings. At the same time, bicibox station 0126, which had the most mobility hub amenities was functioning comparably poorly to the other three bicibox stations installed in FGC Sant Cugat railway station. This suggests that, in addition to the presence of amenities in the immediate surroundings of the bicibox, the location, directness, and visibility of the bicibox play a larger role in attracting users. This meets the secondary research goal of understanding user preferences and looking into the amenities offered around the bicibox station.

Graphs and maps revealed that, on average, all nine bicibox stations were able to attract approximately 30% of users from outside of their isochrone of 10-minute cycling distance. Furthermore, it is also revealed from the QGIS map of estimating the new catchment area of the FGC railway station that the catchment area of five out of six FGC railway stations in the Municipality of Sant Cugat has extended its boundary beyond its isochrone of ten minutes cycling distance. These findings indicate that Bicibox stations have undoubtedly aided in attracting users beyond the capacity of the railway station alone, as well as in the expansion of the railway station's catchment area. This concludes the main objective of this master's thesis, which was to assess the impact of the bicibox station on the catchment area of the FGC train stations in the Municipality of Sant Cugat.

This study concluded that the use of bicibox had a favorable impact on the growth of the FGC railway stations' catchment areas in the Municipality of Sant Cugat del Vallès. The size and direction of expansion of the catchment area were also analysised. This report also revealed the amenities available around the bicibox and their effects on the user's preference.

Additionally, during the study period it was noted that there weren't enough bicibox-related publications, studies, facts, and advertisements for users to learn about the service. The major issue observed during the research period was the lack of sufficient consumer marketing or advertising for the bicibox services. Additionally, users were also found to be poorly informed. During the site visit, it was also noted that there was no wayfinding or signage to alert users about the presence of biciboxes nearby. Solving these issues can enhance the users flow of the bicibox and improve the inter-modality.

It was also discovered that the bicibox's location, land use, Density, Diversity, and Design of its surroundings all play a significant role in the success of its service as mentioned by Cervero and Kockelman (1997). In order to create decision support for future policymakers and planners considering Smart hubs, it is recommended that future studies investigate more about location, land use, Density, Diversity, and Design of the surroundings of the bicibox station. This will also assist further research to comprehend the immediate users, and users' availability, and develop users' profiles to narrow down the target groups.

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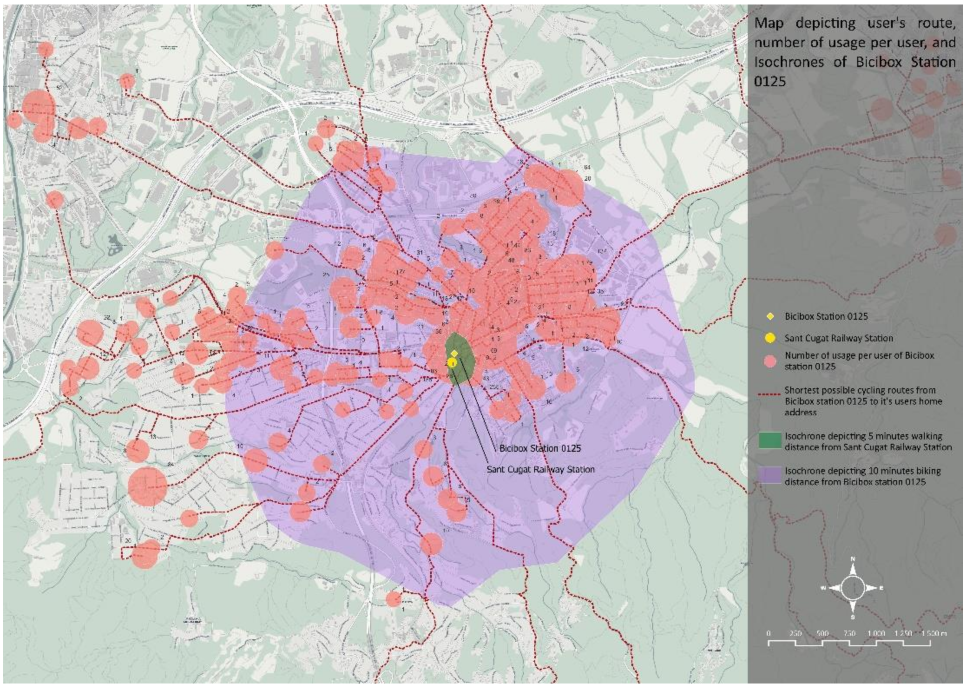
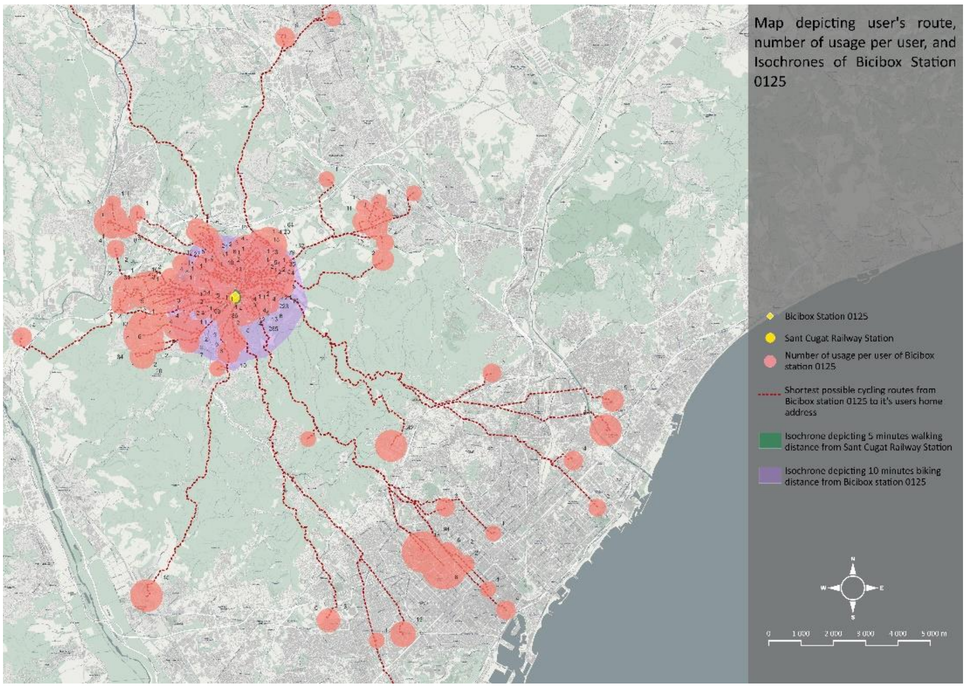
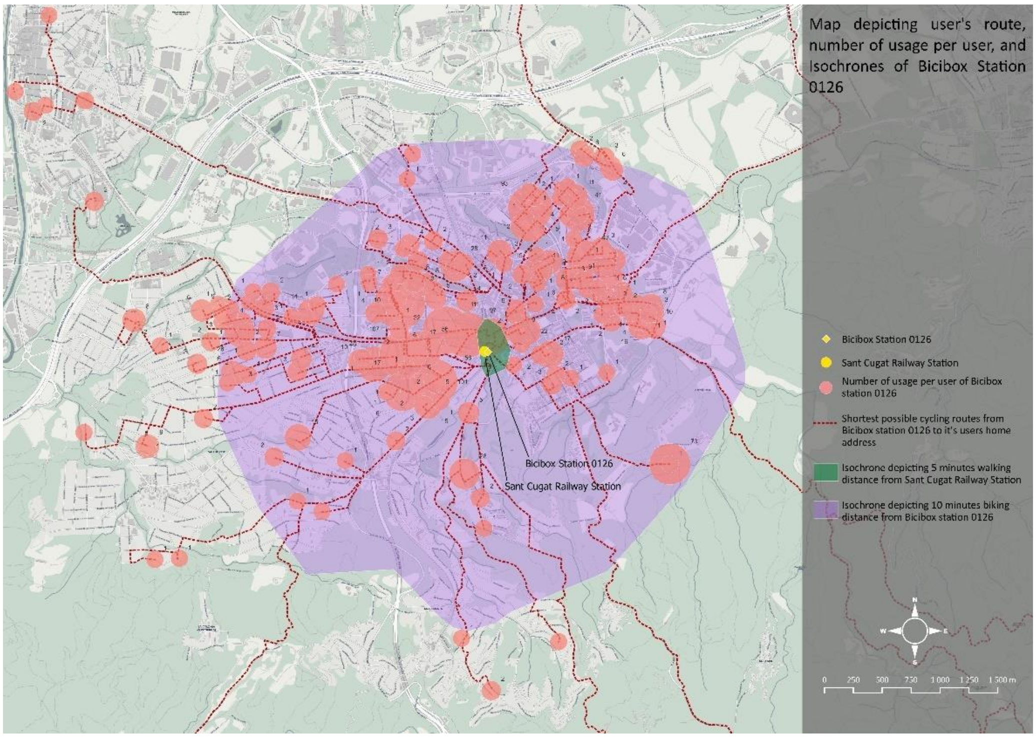
6 Appendix



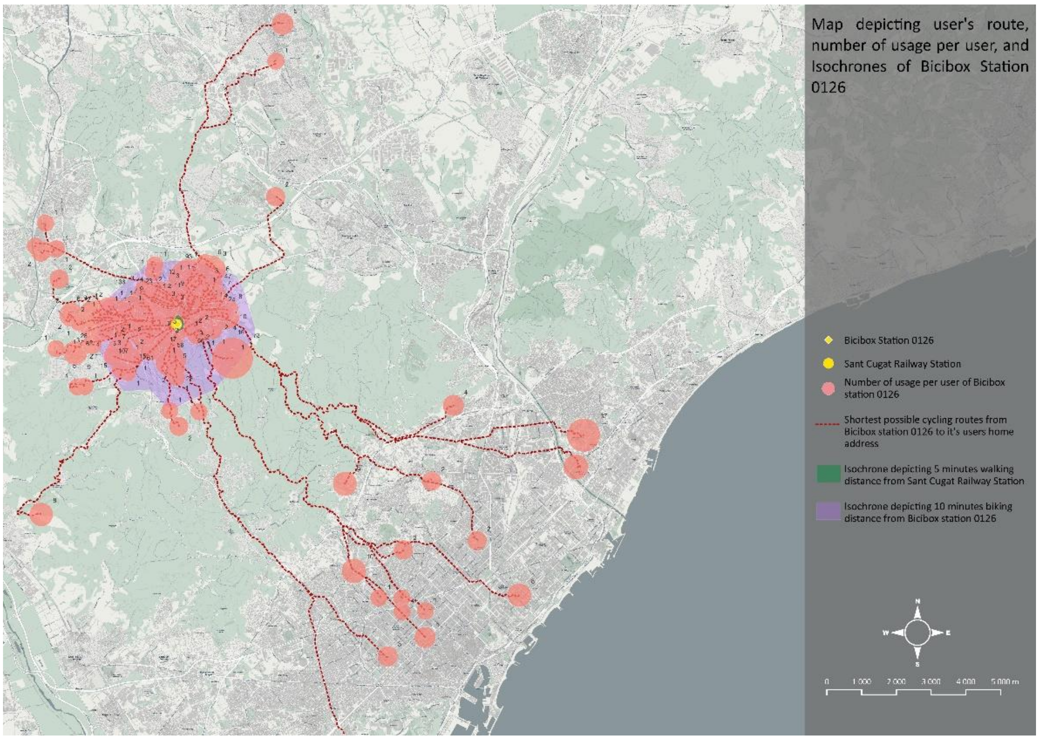
Map 11: Map depicting user's route, number of usages per user and isochrones of Bicibox station 0125 in FGC Sant Cugat railway station.



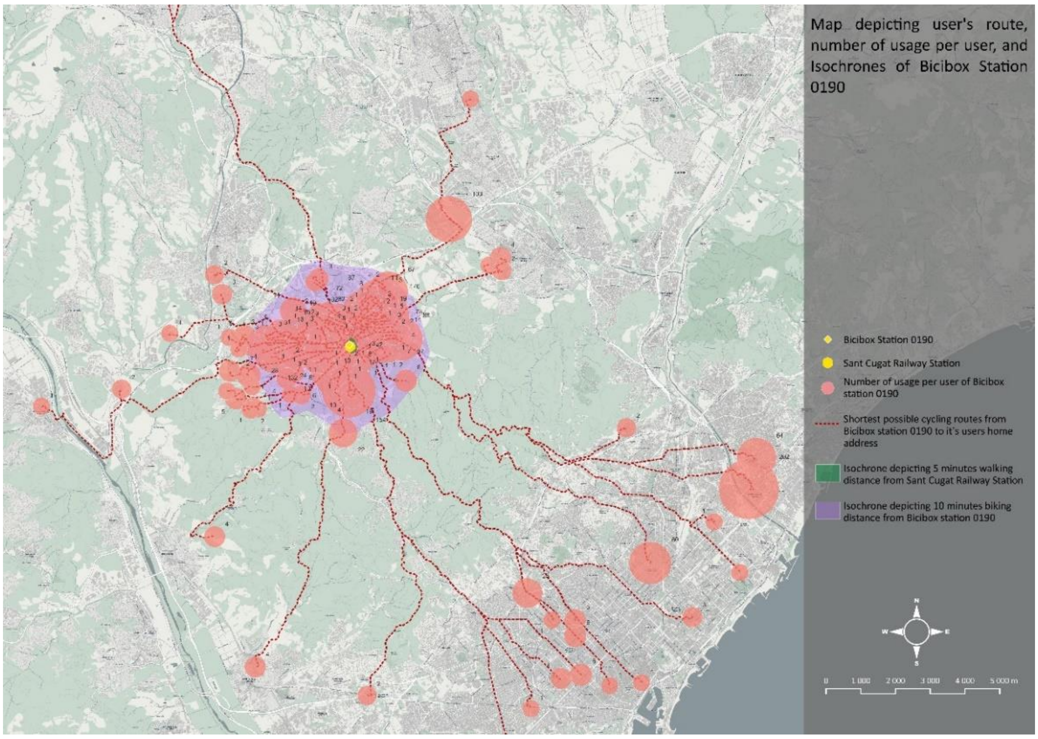
Map 12: Zoomed out map depicting user's route, number of usages per user and isochrones of Bicibox station 0125 in FGC Sant Cugat railway station.



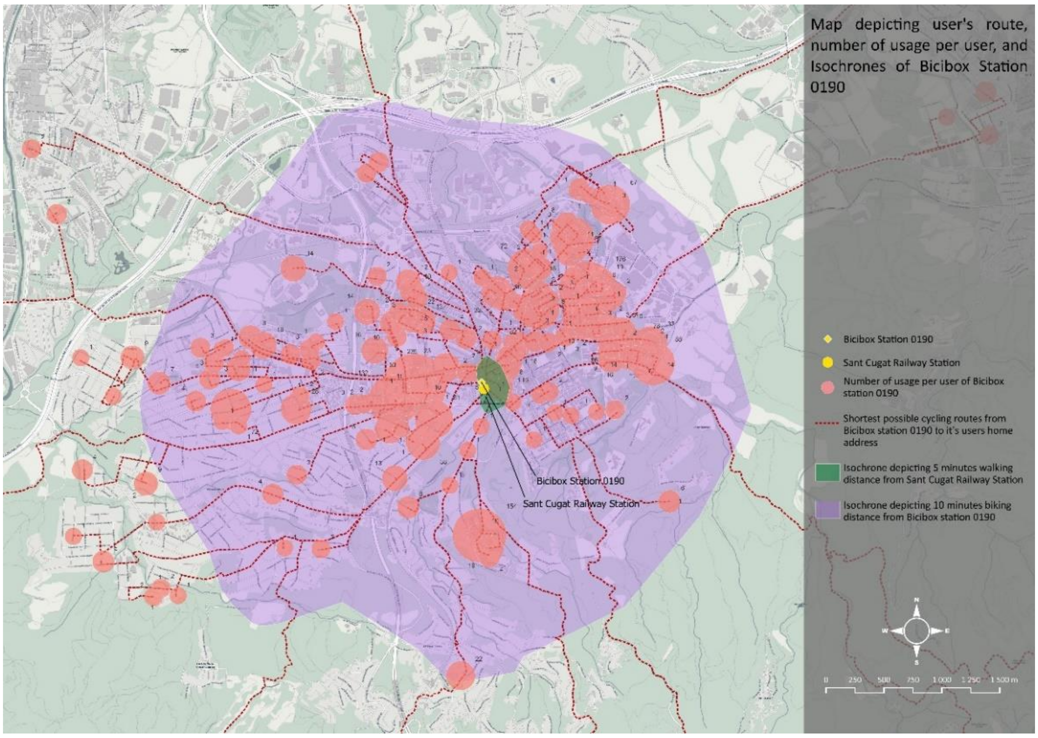
Map 13: Map depicting user's route, number of usages per user and isochrones of Bicibox station 0126 in FGC Sant Cugat railway station.



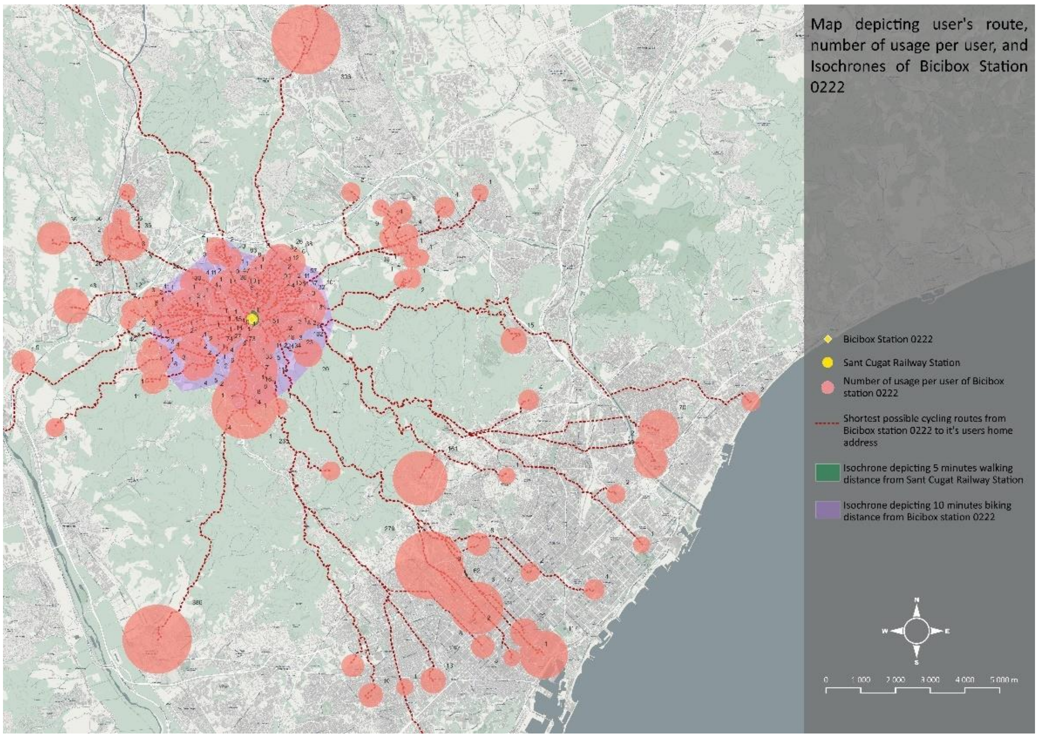
Map 14: Zoomed out map depicting user's route, number of usages per user and isochrones of Bicibox station 0126 in FGC Sant Cugat railway station.



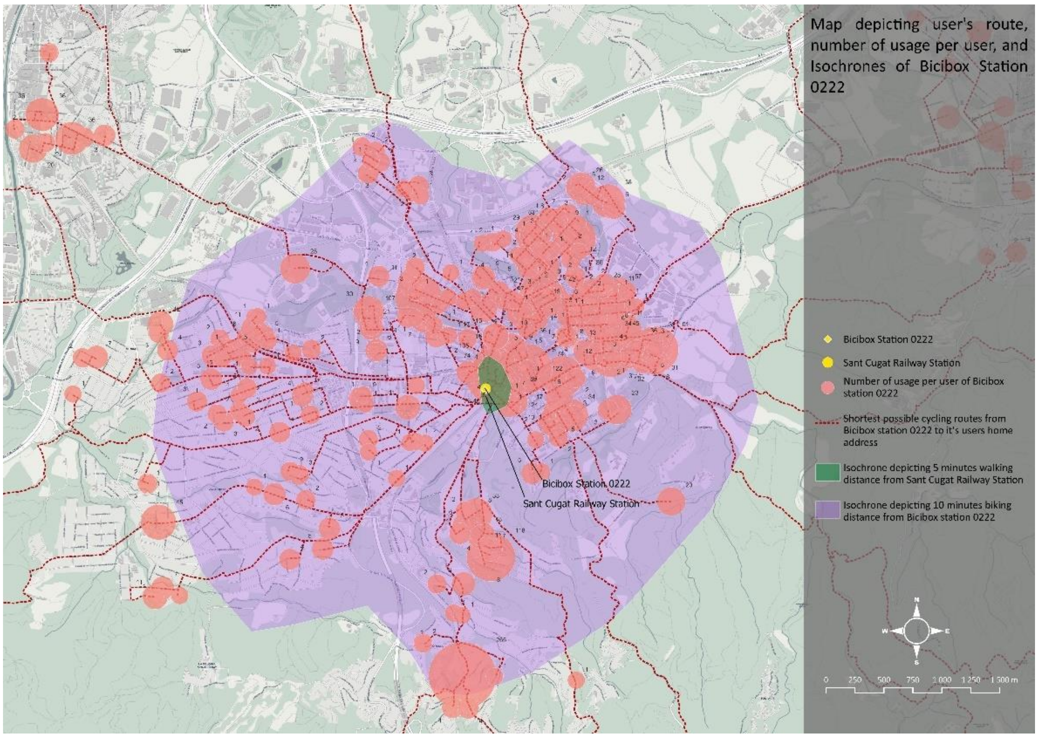
Map 15: Map depicting user’s route, number of usages per user and isochrones of Bicibox station 0190 in FGC Sant Cugat railway station.



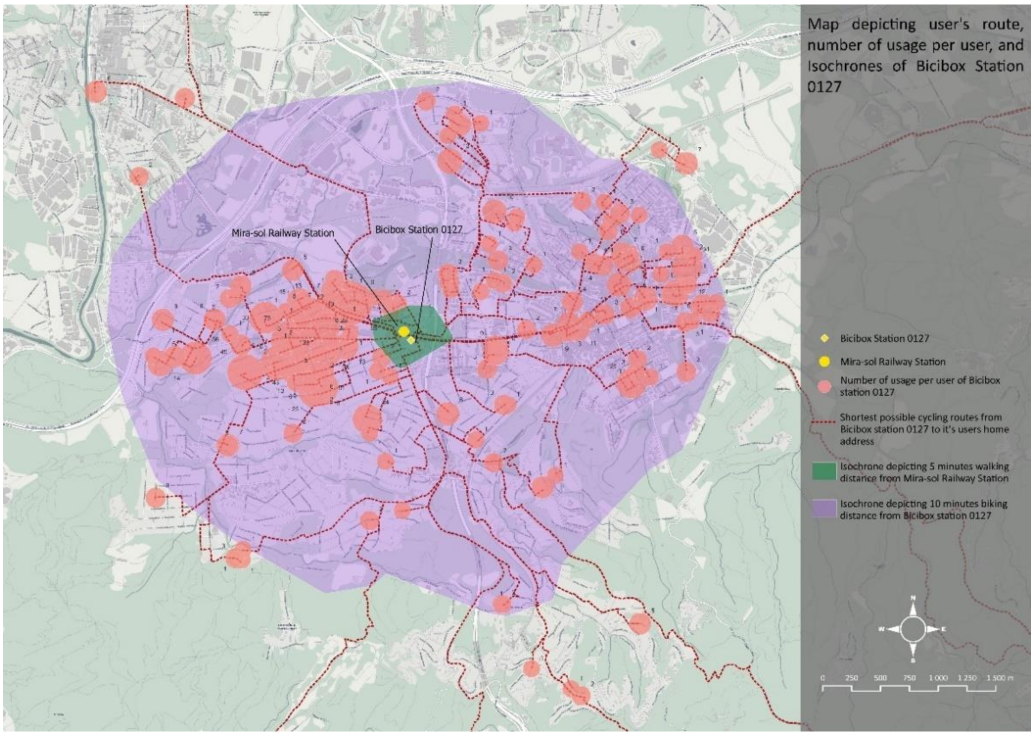
Map 16: Zoomed out map depicting user’s route, number of usages per user and isochrones of Bicibox station 0190 in FGC Sant Cugat railway station.



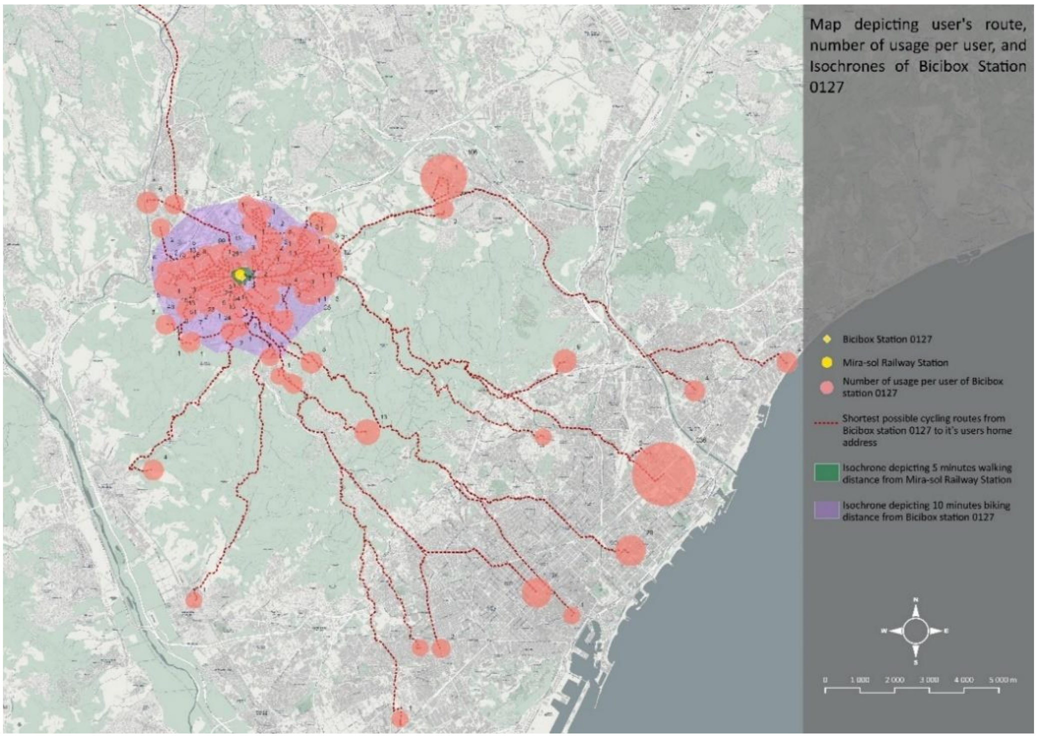
Map 17: Map depicting user's route, number of usages per user and isochrones of Bicibox station 0222 in FGC Sant Cugat railway station.



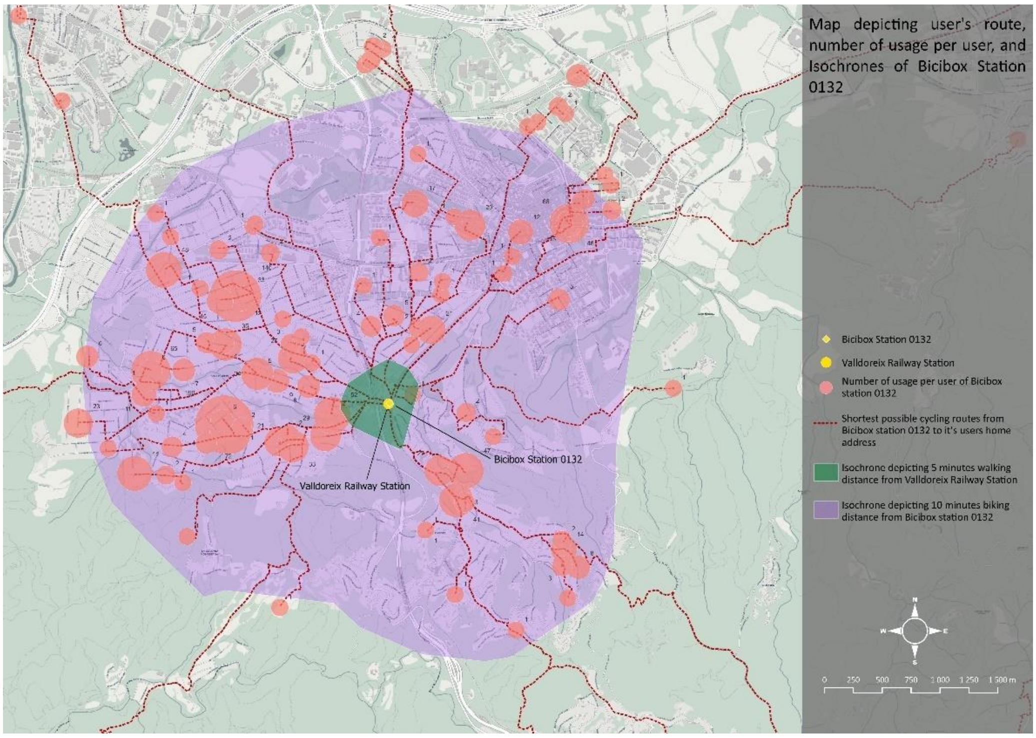
Map 18: Zoomed out map depicting user's route, number of usages per user and isochrones of Bicibox station 0222 in FGC Sant Cugat railway station.



Map 19: Map depicting user's route, number of usages per user and isochrones of Bicibox station 0127 in FGC Mirasol railway station.



Map 20: Zoomed out map depicting user's route, number of usages per user and isochrones of Bicibox station 0127 in FGC Mirasol railways station.



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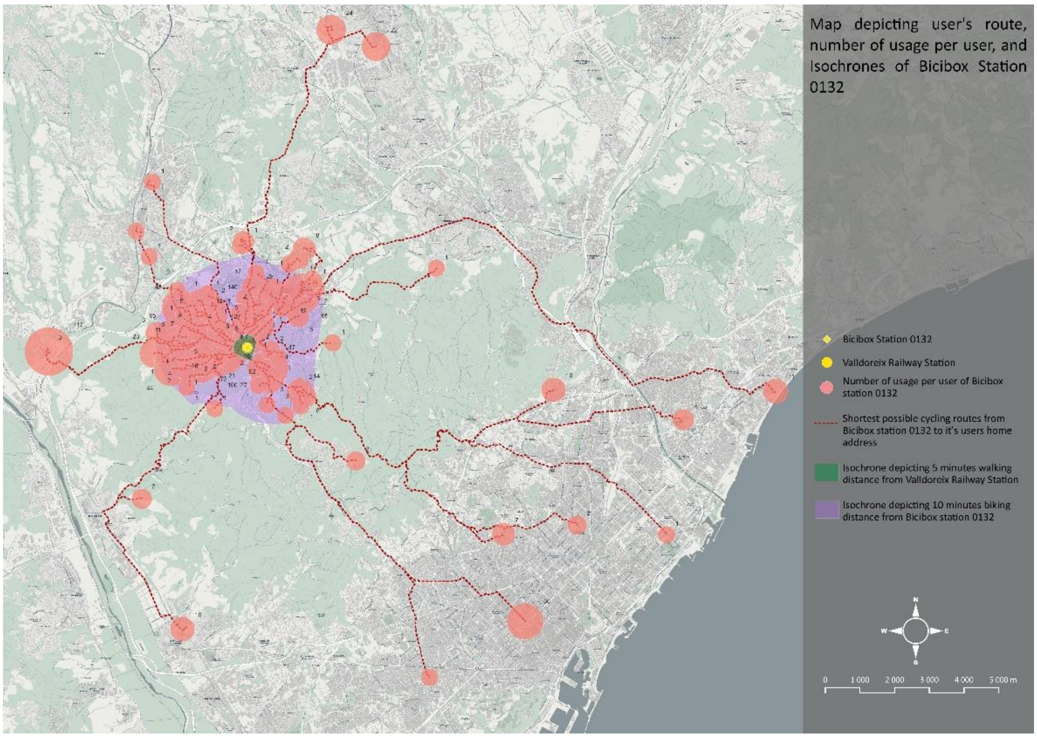

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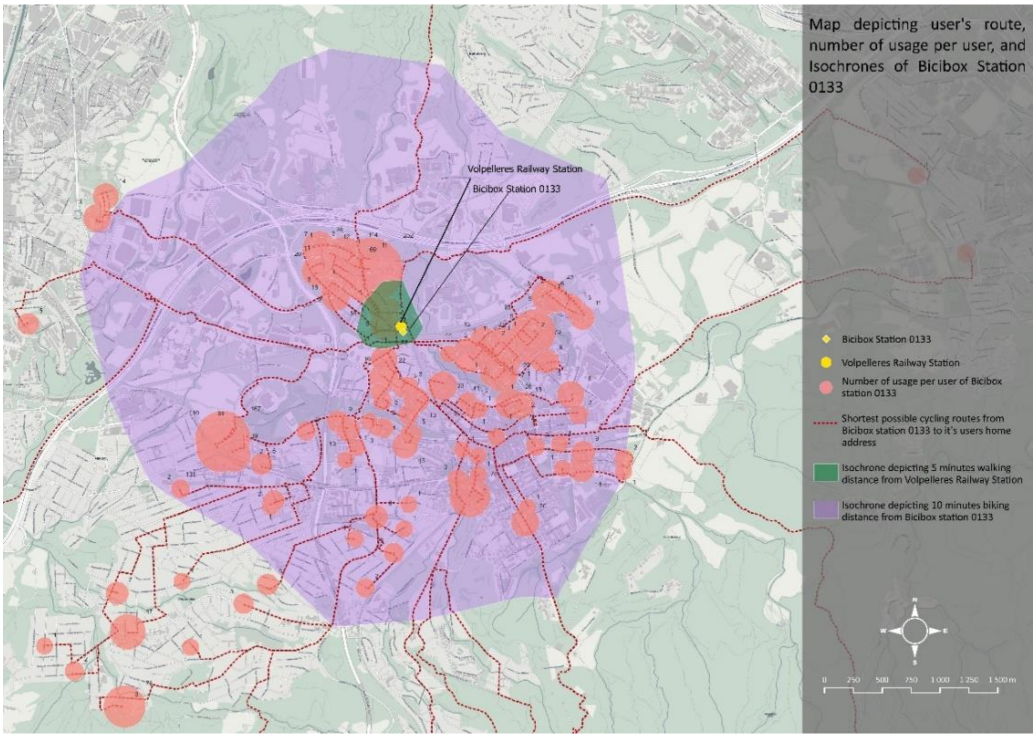
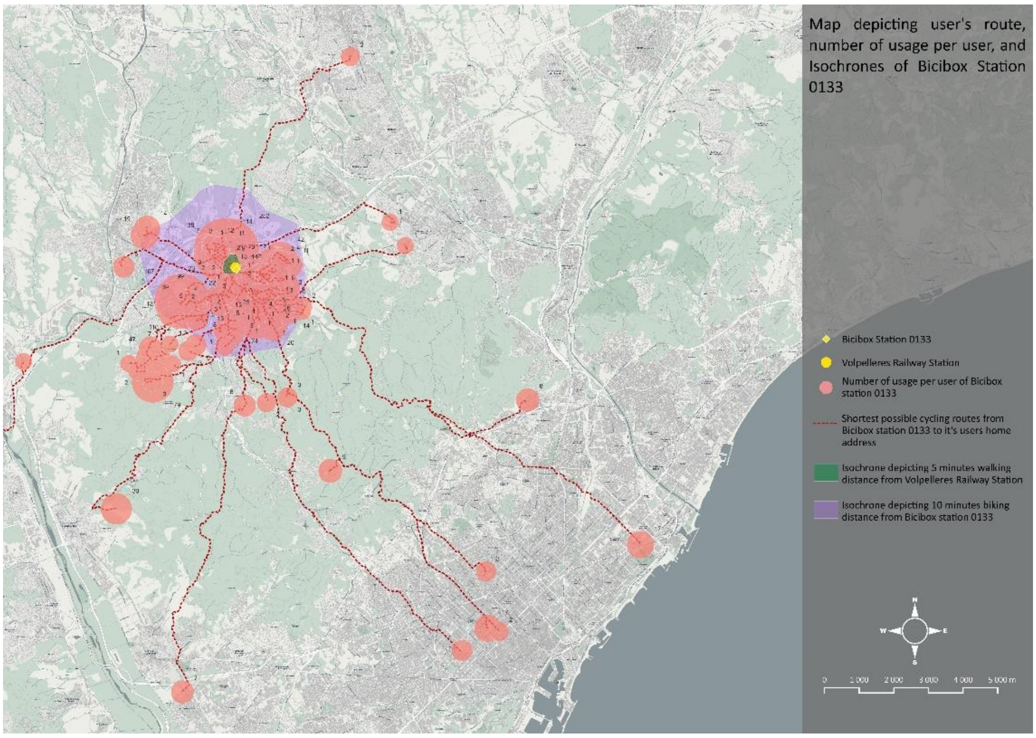
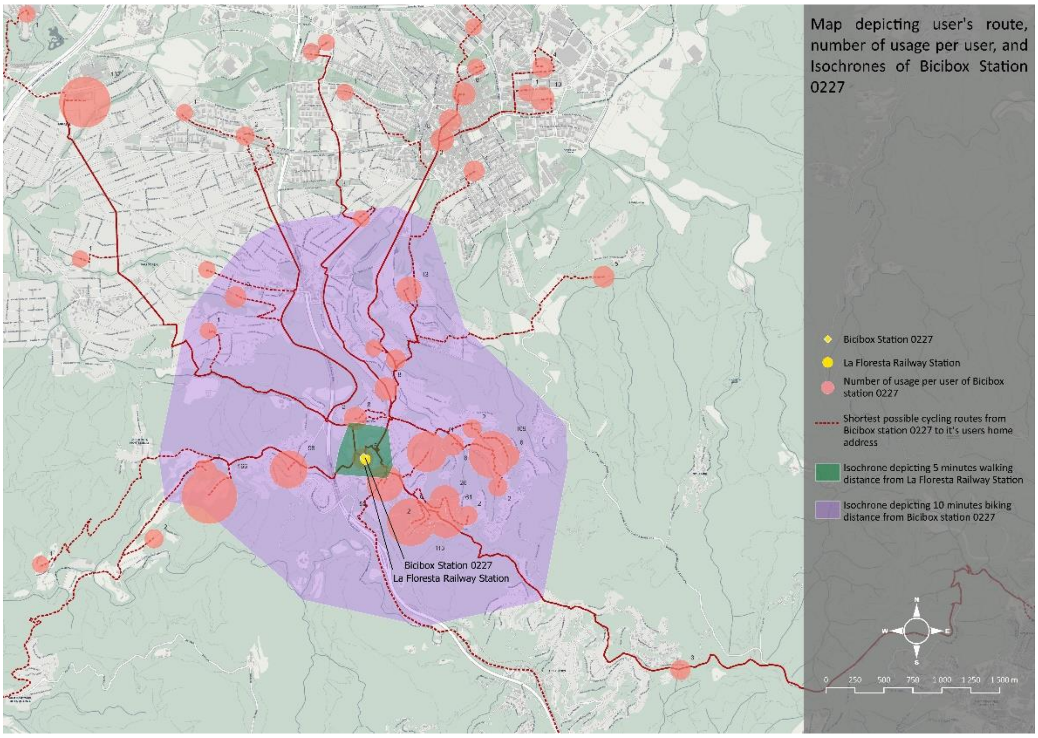


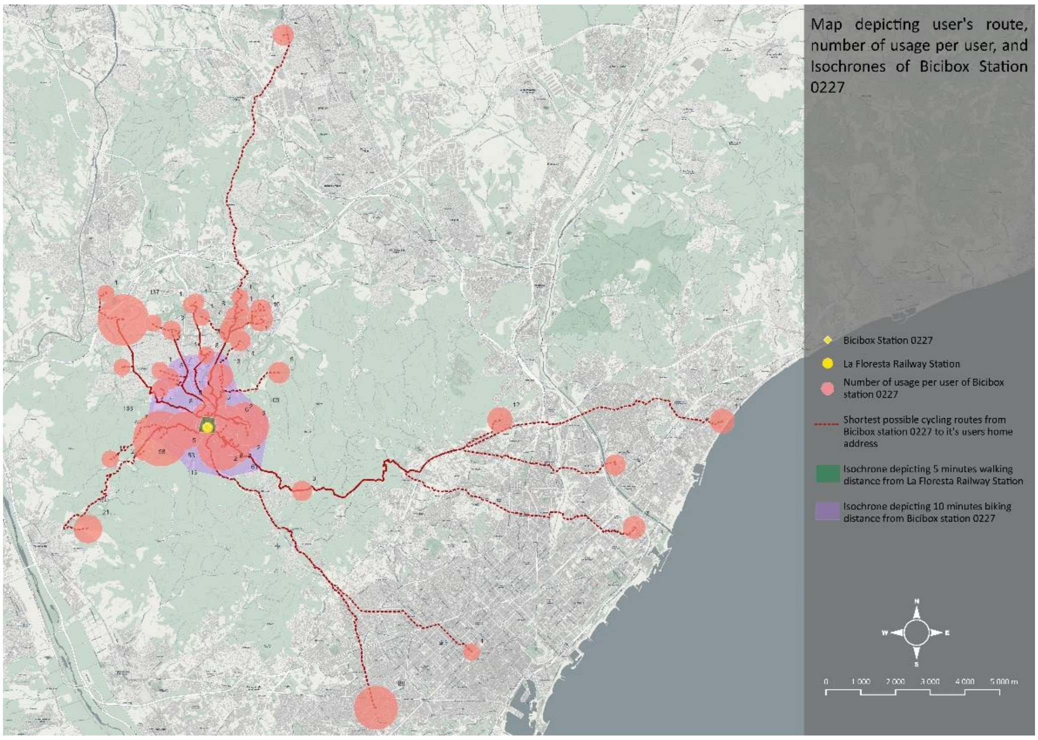
Map 23: Map depicting user’s route, number of usages per user and isochrones of Bicibox station 0133 in FGC Volpelleres railway station.



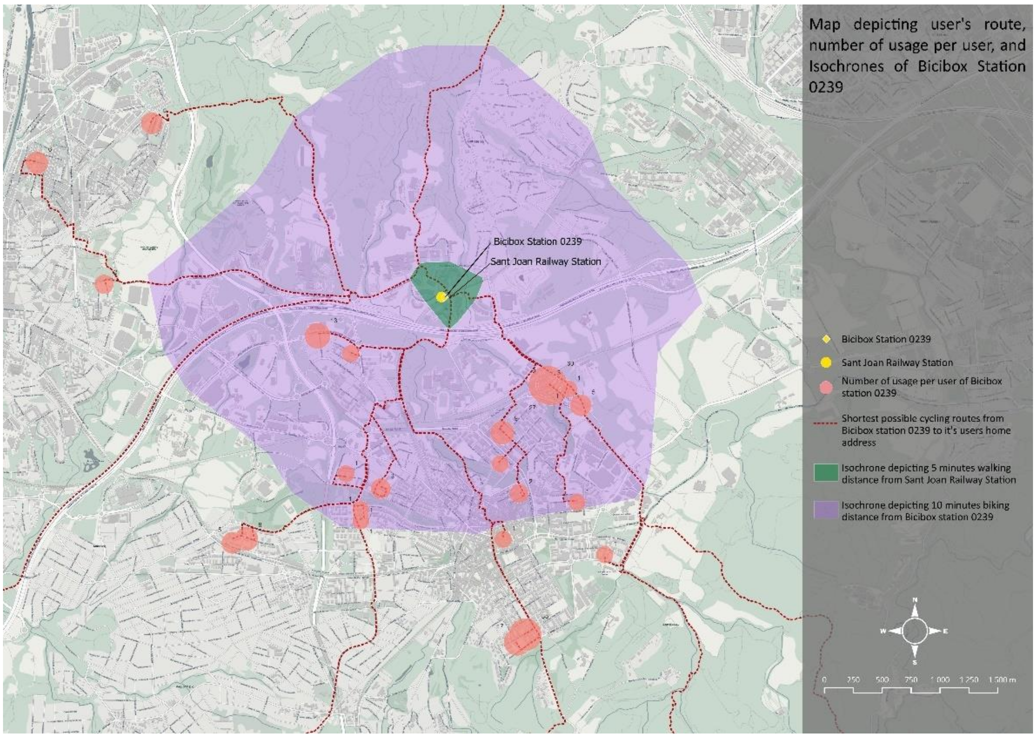
Map 24: Zoomed out map depicting user’s route, number of usages per user and isochrones of Bicibox station 0133 in FGC Volpelleres railway station.



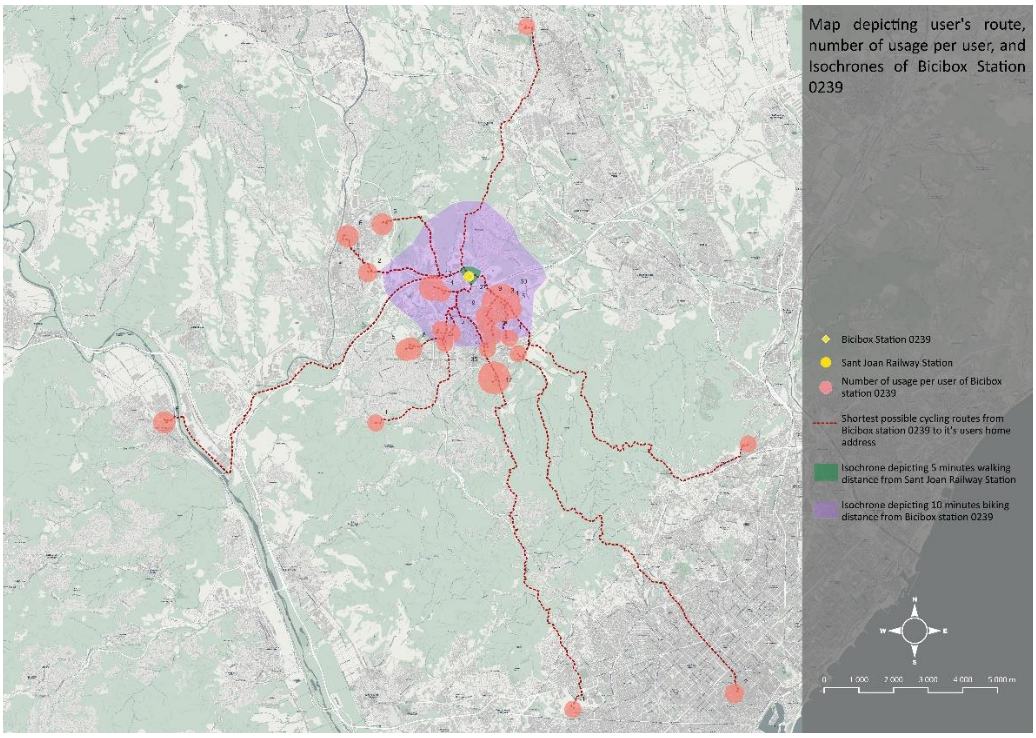
Map 25: Map depicting user's route, number of usages per user and isochrones of Bicibox station 0227 in FGC La Floresta railway station.



Map 26: Zoomed out map depicting user's route, number of usages per user and isochrones of Bicibox station 0227 in FGC La Floresta railway station.



Map 27: Map depicting user's route, number of usages per user and isochrones of Bicibox station 0239 in FGC Can San Joan railway station.



Map 28: Zoomed out map depicting user's route, number of usages per user and isochrones of Bicibox station 0239 in FGC Can San Joan railway station.

6.1 Thesis Placement

My master's thesis placement was in CARNET, which stands for Cooperative Automotive Research Network. It is a Barcelona-based knowledge hub for automotive science and technology focusing on urban mobility. Carnet is also the home of the UPC Technology Center, The Future Mobility Research Hub, which was founded by SEAT, Volkswagen Group Research, and UPC (CARNET, 2022). It is a forum for collaboration among the mobility industry, local universities, and institutional partners, with strategic goals such as managing urban transportation, strengthening the automotive sector, and creating a network to pursue research funding (CARNET, 2022).

CARNET is also dedicated to finding, promoting, and introducing new talent and knowledge to the automotive industry. This is done by acting as a bridge between industry, universities, and students. It also helps students conduct industry-relevant research and strengthens the connection between colleges and society.

My thesis placement in CARNET officially began on April 8th, 2022 and ended on July 13th, 2022. Approximately 30 hours per week were dedicated to working for CARNET. During this period, my focus was on my thesis research topic biciboxe Stations in the FGC railway stations of Municipality of Sant Cugat del Vallès. Research was done on a several level of scales to understand the user behaviour and to support urban planning decision. Beside this, I also attended numerous internal meetings as well as meetings with various stakeholders to share my study and findings.

Bicibox is a system created and administered by Barcelona Metropolitan Area (AMB) to make the city more sustainable and environmentally friendly. Bicibox is also a component of the Smart Hub project, which is one of the EIT urban mobility initiatives' flanks.

My thesis advisor was Dr. Inés Aquilué Junyent, Urban Planning Officer at CARNET. Dr. Ines proposed this research topic in conjunction with the EIT project SmartHub. Previous work in the SmartHub project served as the foundation for this research, which attempts to build on prior work done in the area. Dr. Inés Aquilué Junyent guided me, and shared her ideas, information, and data throughout this research process.

In addition to the technical information, I have presented in the report, this thesis research assisted me in organizing my thought process and developing my arguments. It has also helped me to focus on the ideas and develop the methods to realize those ideas. Furthermore, this entire research process has taught me self-discipline, self-motivation, and effective time management skills.