Escola de Camins
Escola Tècnica Superior d'Enginyeria de Camins, Canals i Ports
UPC BARCELONATECH

STUDY OF FARE INTEGRATION OF BICING IN THE STI SYSTEM

Treball realitzat per:

Adriana Martínez Vidal

Dirigit per:

Àlvar Garola Crespo

Màster en:

Enginyeria de Camins Canals i Ports

Barcelona, 20/09/2017

Departament d'Enginyeria Civil i Ambiental

TREBALL FINAL DE MÀSTER

ABSTRACT

Urban mobility has recently become one of the main issues of local administrations and transport authorities. The public transport market has notice a clear increase in the mobility volume, since people's tendency is to move to more complex and diverse daily trips. As a result, the demand of an extensive, intensive, flexible and integrated public transport system is becoming one of the main priorities for city halls and transport authorities.

New flexible systems such as public bike sharing (PBS) appeared in many European cities as a solution to provide a complementary mode to cover last-step of trips inside congested areas. Between 2001 and 2011, above 400 schemes were implemented in the west part of Europe (European Commission, 2011). One of the keys of its success is its proper integration with other modes, which can be differentiated in three different levels:

- Physical integration, which responds to allocation of stations near each other to make easier transfers.
- Integrated information, providing information about possible transfers between modes
- Fare integration, referred to provide a global fare system for different modes.

This project aims to study the particular case of Bicing, the large public bike sharing scheme launched in Barcelona in 2007. Defined as flexible, practical and sustainable way to travel, Bicing is known as one of the most popular schemes in Europe.

The system is properly integrated with the other modes operating in the city, since its stations are located close to principal hubs in the city and clear information about the scheme is provided. However, no fare integration has been achieved, since the access to the bike sharing is only available to residents and through an electronical card.

As a main point of this project, the possibility to fare integrate Bicing under the already consolidated fare integrated system (STI) in Barcelona will be studied. The main motivation is the recently forecast to launch an electronical card called T-Mobilitat that will supply the existing transport tickets in Barcelona, and could delete all access barriers with Bicing.

The document will be separated in three parts, in order to firstly organize all available data and as a result of its analysis, study the possibility of fare integrate the scheme.

On the one hand, Bicing data will be collected in order to analyze its demand, supply and financial patterns. On the other hand, the already consolidated performance of the STI system will be analysed, so its financial characteristics can be understood and particularized for each of the integrated modes. As a result, the potential demand and the range of competitiveness of Bicing scheme will be deduced as well as the possibility or not to integrate the scheme into the STI. Different scenarios to study the impact will be exposed, subject to the available data.

INDEX

LIST OF FIGURES

LIST OF GRAPHICS

LIST OF TABLES

INTRODUCTION

Public Bike sharing systems (PBS) are an increasingly popular transport mode in many European cities since its first release in 1998 in La Rochelle (France). Between 2001 and 2011 about 400 schemes were implemented in the west part of Europe (European Commission, 2011).

Bicing is the flexible sharing system implemented in Barcelona since 2007. Defined as an easy, practical and sustainable way to travel through the urban area of Barcelona, it provides good connections for a first or last step of a daily trip. Its supply consists of 6.000 bikes divided into 420 stations, spaced an average distance of 300m.

Lately, the City Council has also launched a pilot trial for an electric bike sharing scheme, managed also under same conditions as the normal one. Since this new system is still under development, it will not be the object of this study.

The proper integration between all public transport modes is one of the main challenges of transport authorities, especially in such urban conurbations as Barcelona. Mobility has turn into a more complex and necessary issue, since people are tending to increase its mobility in complexity and diversification. As a result, a correct public transport organization and cooperation between the main actors is needed.

Particularizing this awareness to Barcelona, the transport authority ATM *(Àrea de Transports Metropolità)* founded in 2001 the named Integrated Fare System (STI). The main aim was to uniform the fare policy in the city and its influenced area, and promote cooperation between all public operators in the city. As a result, an integrated dense scheme is located in the city under the ATM management. Transfers in the STI between different modes take place daily, becoming an important part of the global public system performance and financing.

As part of these integration policy, Bicing scheme is one of the transport modes which has not been fare integrated yet. As will be explained through examples implemented in Europe, the survival of these flexible schemes partially depend on its appropriate integration between this new mode and the conventional ones. The correct allocation of Bicing stations and the already integrated information between it and other modes (especially Metro), show that the fare integration can be close to happen. Moreover, the transport authority is planning to launch a new electronical card similar to the ones operating in Paris or London that will substitute the current transport tickets and will delete all access barriers between Bicing and other modes.

The main goal of these project is to study the possibility of integrate Bicing into the STI, under the assumption that the new electronical card will delete all access problems between the scheme and the traditional modes.

In order to do so, the scope of the project will be organized in three parts:

- **PART I,** which will consist on an introduction to bike sharing schemes and a research of European Examples. The main basis of these flexible transport mode and its financial patterns will be exposed as well as the significance of a proper integration on them. The particular case of Bicing system in Barcelona will be analysed from available data regarding demand and economical facts. In this first part, the financing status of the service and the user profile are the factors to be taken into account to proper understand its role inside the daily mobility in Barcelona.

- **PART II,** as a global overview of the public transport system in Barcelona and the integrated transport public STI. Some indicators for the demand, supply and costs will be carried on in order to understand the significance of each mode in the global system. The main aim is to focus into the intermodality between modes and the STI financial characteristics.

- **PART III,** Integration of Bicing scheme in the STI. Focusing in the hypothesis that integrating Bicing into the STI will attract intermodal trips, a comparison between modes will show the potential intermodal chains that can be induced to Bicing. The impact in terms of demand and financing of the service will be estimated, and the limitations of a fare integration will be exposed.

PART I

Previous analysis of bike sharing schemes
Particular analysis of Bicing

1. BIKE SHARING SYSTEMS OVERVIEW

Bike-sharing system, as a public bicycle system, is a defined not conventional system, in which bicycles are made available for share use to individuals (Wikipedia (2017)). These systems are not timetable based and offer higher flexibility for users than the conventional modes, since they are the own drivers.

Public Bike sharing (PBS) are becoming popular in many European cities since the first system appear, in 1998 in La Rochelle (France). From there, and especially in the last 10 years, Municipal Authorities have promoted this mode as a part of intermodal transportation chain in European urban areas. Between 2001 and 2011 about 400 schemes were implemented in the west part of Europe (European Commission, 2011).

The main goal behind all bike sharing implementations is an intermodal transport strategy as well as reducing pollution and congestion in the city. Authorities present this new system as a flexible, non-polluting and fast mode for moving inside cities.

These kind of transport systems are divided according to financial/business models, pricing, policy, owners or scale; since its set of schemes in Europe and in the entire worlds is large. However, in terms of its scale-extension they can be classified into two groups:

- **Local bike sharing systems**, providing a small-scale service in located communities. They have been founded by a few enthusiastic through free and low-tech offers. Local systems are normally linked to small size cities, or to cities which already have a bike tradition, so the service focus more in sporadic users or tourists.

- **Large-scale bike-sharing system**, usually linked to large urban areas and with major funding requirements and high usage rates. In these systems, PBS are shown as part of the public transport, and they are somehow integrated with the other modes operating in the city.

1.1 MAIN PRINCIPLES

The main principles of these kind of non-conventional systems are self-service system, short-term availability, one-way-capable bike rental offer in public spaces, valid for several target groups and with an specific network characteristics (European Commission, 2011):

- **Non-conventional system**, since its implementation start once the public transport modes were already established in the city. They differ in many characteristics from the conventional metro, bus and trains.

- **Self-service system**; since users are its own drivers and the access infrastructure is minimum. They usually are conformed by outside stations, and no staff is required.

- **Short-term availability**, since there is a limit of permitted travelled time to ensure exchanges.

- **One-way-capable bike rental offer in public spaces,** since they are located in public spaces and users move from A to B; without needing to return the bike to the first origin.

- **Valid for several target groups,** independently of the purchasing power of users, due to its lower price. Usually, the main reason for using these systems is linked to flexibility and speediness.

1.2 MAIN CONDITIONANTS

According to (European Commission, 2011), two categories of influencing factors on the outcomes of these kind of transport systems can conditionate its schemes:

- **Endogenous factors,** defined as policy design factors. They correspond to institutional and physical design factors, such as implementing the system station or non-station based, type of operator, contracts and ownership as well as the financing sources. In general terms, endogenous factors can be easily modified and adapted to the users and the city requirements.

- **Exogenous factors,** which are specific characteristics of the area and not easily changed. Some examples can be found in the mobility characterization of the city, its demography, size, climate and economic factors.

FIGURE 1.2-1. – COMPONENTS OF A BIKE SHARING SCHEME (SOURCE: EUROPEAN COMMISSION, 2011)

1.3 COSTS AND BENEFITS

The reasons for implementing this type of system in an urban area directly depends on the perspective of all involved stakeholders.

From different European experiences, some direct and indirect benefits can be demonstrated, such as a notable increase in the cycling modal share as an alternative to conventional modes. Moreover, bike sharing systems avoid congestion either in the public and private transportation as well as have uncountable health benefits.

As part of economic effects, they offer advertising opportunities, since a large number of bike sharing systems use either the bike-fleet or stations for advertising, becoming a popular form of financing the system.

On the other hands, some costs are usually linked to these transport systems. They usually have high implementation costs and *"refloating"* is needed in most schemes. Moreover, a previous policy of awareness is needed so society get use to the new system. Specially in countries located in the south of Europe, where there is not a bike tradition.

1.4 BUSINESS MODELS

Business structure of bike sharing schemes may differ in terms of the provider of the infrastructure and bike fleet and the operator.

According to (European Commission, 2011), contract types can be divided into four types, in terms of its model of infrastructure and operator:

	Infrastructure	Operation
Option A1	Contractor	
Option A2	Contractor A	Contractor B
Option B	Contractor	Municipality
Option C	Municipality	Contractor

FIGURE 1.4-1. – TYPES OF FINANCIAL PATTERNS (SOURCE: EUROPEAN COMMISSION, 2011)

Where Option A1 is the most common contract type.

In almost all cases, public authorities are involved either as local authorities or public transport authorities since integration with other modes is a key of success and they have financial problems.

The way of involving transport operators or public authorities as main owners, either can be found through a direct funding or indirectly to public-private partnerships (PPPs). Thus, subsidies or co-financing contracts (concessions) are needed for most part of the bike-sharing systems.

1.5 INTEGRATION LEVEL

As mentioned before, the correct integration between conventional public transport modes and bike sharing schemes enables transfers between them, and ensures the success of the system as a first/last stage mode.

Three level of integrations can be distinguished:

- **Physical integration**, by meanings of the location of bike stations in relation to main stations or halts. In systems with physical integration bike schemes are implemented as a parallel service to existent public transport in peak hours and therefore, the stations are located near public transport stations.

FIGURE 1.5-1. – GARE DE RENNÉS, LA ROCHELLE (SOURCE: SCNF)

- **Integrated information** of bike sharing such as available bikes per stations or its location combined with public transport information: websites, apss etc.

FIGURE 1.5-2. – SIGNING TO BICING-STATION FROM THE METRO (SOURCE: EUROPEAN COMMISSION, 2011)

- **Fare and access integration,** for schemes whose access is available with the same public transport ticket. Fare integration refers to pricings or discounts for public transport users who also use the bike sharing system.

FIGURE 1.5-3. – NAVIGO TRANSPORT PASS FOR ACCESSING VÉLIB IN PARIS (SOURCE: VELIB)

2. BICING

Bicing is an urban transport mode based on the bike sharing principles. Defined as an easy, practical and sustainable way to travel through the urban area of Barcelona, it provides connections between multiple points in the city without smoke, noise and congestion externalities. This bike sharing system has been operative in Barcelona since its implementation in 2007.

It is also known as one of the largest public bike sharing schemes installed in a European city, being comparable to the Velib-system in Paris or Vélo'v in Lyon.

FIGURE 3.-1. – BICING BIKE SHARING SYSTEM IN BARCELONA (SOURCE: BICING)

Bicing system is owned by the City Council of Barcelona and operated through an advertisement contract with Clear Channel (USA), which already owns several schemes in Europe.

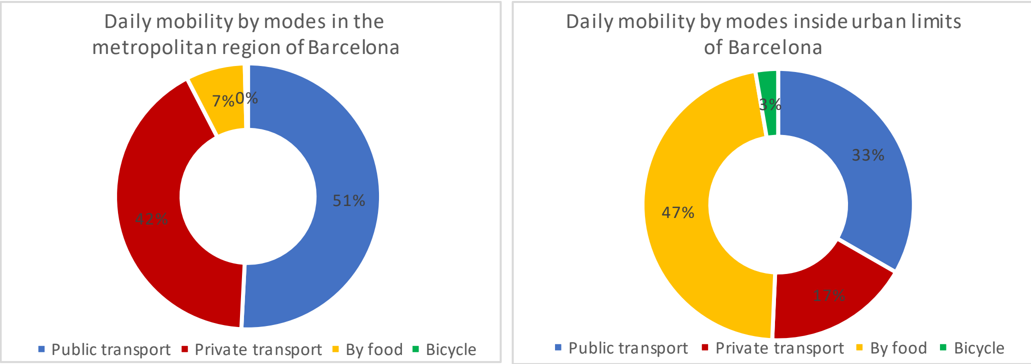
The main objective that motivated its implementation, was improving interchanges between different modes of transport, and promoting bikes as a common mode of transport. Thus, behind its implementation, a campaign of promoting the use of the bike inside the city was carried on through the construction of new km of cycle-roads, several parkings near main stations such as Bicibox and other policies.

The called Bicing started as a pilot trial on the 22nd March of 2007 with a total amount of 750 bikes and 50 stations located near Metro stations and major parking areas. In one year, the system improved its offer, by increasing its number of stations and bikes 8 times, achieving the number of 6.000 available bikes and 400 stations, all located inside the urban limits of Barcelona.

Recently, a pilot trial for electric bike sharing system was launched on February of 2015. Being still a pilot trial, the electric bike sharing system is not an issue of this project.

2.1 MAIN BACKGROUNDS AND PRINCIPLES

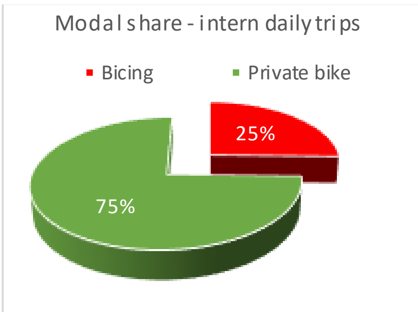
The area of Barcelona covers a total amount of 101 km^2 and 1,6 million inhabitants. 2,7 million trips take place every day; and a total amount of 18,8 millions if considering its entire area of influence (Ajuntament de Barcelona, 2016):



GRAPHIC 2.1 1. – DAILY MOBILITY BY TYPE OF MODE IN THE METROPOLITAN AREA OF BARCELONA (LEFT) AND INSIDE BARCELONA (RIGHT) (SOURCE: OWN CONSTRUCTION FROM DATA PROVIDED BY AJUNTAMENT DE BARCELONA, 2016)

As seen above, private transport modes have an important paper in the daily mobility in Barcelona. As a result, high pollution levels and congestion either in the public and private transport are continuously registered.

The city hall tried to insert a global strategy of sustainable mobility in the city and raise the level of social awareness and political commitment for the air quality in the city. The implementation of Bicing was part of this quality air plan, by focusing on increasing the bicycle uses in the city (current the 4% according to Ajuntament de Barcelona, 2016).



GRAPHIC 2.1 2. – DAILY MOBILITY BY TYPE OF MODE IN THE METROPOLITAN AREA OF BARCELONA (LEFT) AND INSIDE BARCELONA (RIGHT) (SOURCE: OWN CONSTRUCTION FROM DATA PROVIDED BY AJUNTAMENT DE BARCELONA, 2016)

As seen above, from the bike modal share inside the city, Bicing occupies the 25% of the bike trips in a working day, by meaning just a 0,7% of the modal share regarding intern trips and 0,4% for the metropolitan region. Its main principle is to provide an alternative to these diary trips by providing a new flexible service which is just able for locals. Its main principles are to potentiate the intermodality between transport modes and increase the sustainability of the trips taking place in the city.

2.2 SYSTEM MANAGEMENT

As described in Chapter 1.4 (*Bike sharing system's overview, business models*), the general management of this system is possible through a private-public partnership between local administration and a private operator.

As a rule, Bicing scheme is owned by the city hall *Ajuntament de Barcelona*, which lets its management to its public municipal service company *Barcelona Serveis Municipals* (BS:M). The first contract was established in 2007, with the first run of the system. Clear Channel award the rights of operating the scheme for 10 years.

Clear Channel Spain, is a communication and advertising company with a large presence in many cities located in Spain. The company also invest in bike sharing schemes all over the world and in Europe.

The contract between Clear Channel and BS:M was linked to an advertisement contract. The private company was responsible to invest in the installation of the system (a first amount of 2,23 million euros per year) and cover its annual costs, and in return the rights for advertisement in bus shelters, newsstands and other street furniture are under its control.

The launch of the service was financed with the incomes obtained from the "green area parkings" introduced in 2005 and from user subscriptions.

Moreover, a sponsoring contract was included in 2014, awarded by Vodafone. Vodafone provide a yearly investment of 1,4 million of euros in covering costs for the system and in return, it owns the rights as the exclusive sponsor of Bicing from the 1st of April to three years. The agreement includes advertisement rights in the fleet and infrastructure of the service.

Figure 2.2-1. – Examples of the sponsor rights of Vodafone (Source: Bicing)

Nowadays the service receives still receives high subsidies from different public sources.

Recently, the City Council has decided to enlarge the contract with Clear Channel, for two more years while they work in a new bidding for the system. The new contract includes a pilot prove of an electric bike scheme (La Vanguardia, 2016).

2.3 ACCESS AND PERFORMANCE OF THE SERVICE

Theoretically, the scheme is limited for residents and the access is allowed through an electronical card after registration. Despite the scope of use is limited to Barcelona (since its stations cover this area), any individual can use the scheme as long as he owns a Spanish NIF and provides an address inside Barcelona. Therefore, tourists are not allowed to use it and mainly just residents can complete the registration.

Long -term subscription is the only available option.

Users pay two different types of fees for using the bike sharing scheme:

- **Annual fee** of 47,16 € which is charged once they are registered in the system and provides the access fee.
- **Usage fees** charged once a trip exceeds the 30 minutes free of charge, with 0,74€ per 30 extra minutes.

The subscription includes a smart card for 4,54€, which is the main basis to access the system and in all cases, the first 30 minutes of each journey are free of any extra charge.

2.4 CHARACTERIZATION OF THE SERVICE

The service is characterized through the owned supply, provided through a fleet of bikes and stations spread all over the city; daily users, which conforms the demand of the system, and the financial terms that conditionate the performance of the system.

2.4.1 Supply

As mentioned before, the supply of the system is conformed of the owned bike-fleet and stations, as well as through the lanes exclusive for bike's use.

The area of application is limited exclusively to the urban area of the municipality of Barcelona, according to what is stablished in the municipal ordinances.

The current service owns a total amount of 6.000 bikes in 466 stations, being the bike-station rate about 12,9 available bikes at each station. The stations are divided into 3 crowns, in order to provide an efficient logistics strategy. Some close stations are clustered and managed as a single one, to plan the rebalancing. As an average, the distance between stations is equal to 300m.

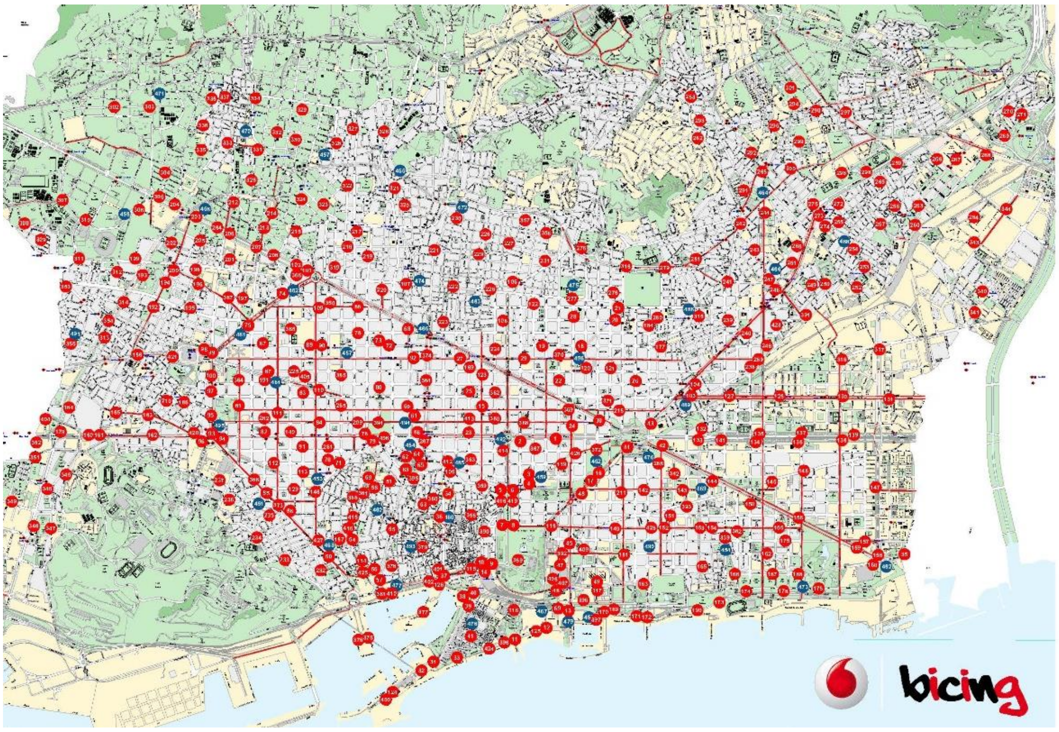
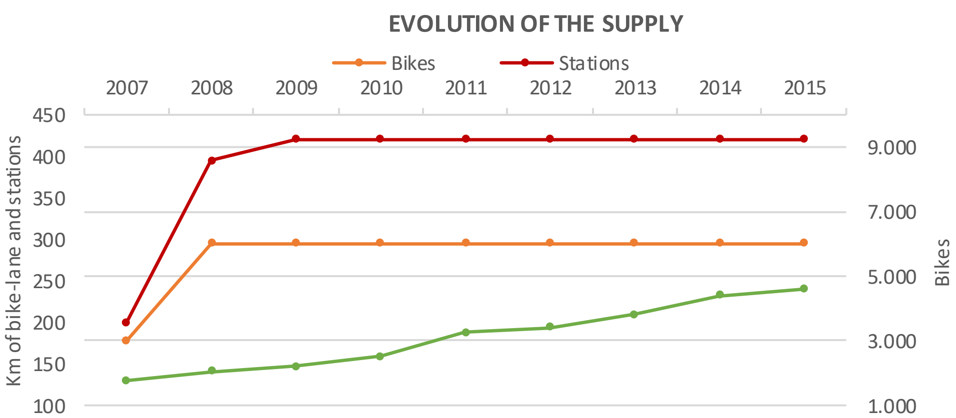


FIGURE 2.4-1. – BICING-STATIONS LOCATED IN THE URBAN LIMITS OF BARCELONA (SOURCE: BICING)

The figure above shows the evolutions of the bike-fleet, stations owned by Bicing as well as the evolution of the bike lanes implemented in Barcelona between 2007 and 2015:



GRAPHIC 2.4 3. – EVOLUTION OT THE SUPPLY OWNED BY BICING-SYSTEM (BIKES AND STATIOSN) AND THE KM OF AVAILABLE BIKE-LANES IN BARCELONA BETWEEN 2007-2015. (SOURCE: BS:M, 2016A)

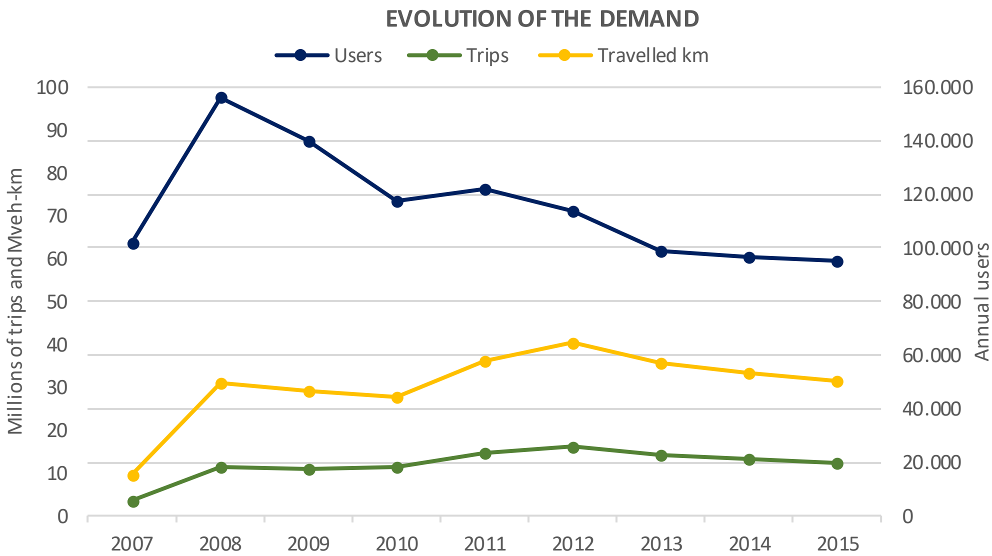
As seen, the total number of bikes and stations remains stable since the system was consolidated in the city in 2008. On the other hand, the implementation of km exclusive for bikes experienced a linear growth between 2007 and 2015, being the slope higher for the period 2010-2015, with an average of an annual increase of a 8%.

2.4.2 Demand

As a main difference between traditional modes, the demand is defined according to three different terms:

- **Annual subscriptions,** which correspond to physical persons that pay the annual fare and own a Bicing-card.
- **Annual trips,** which are understood as total number of trips registered in a year. This rate is the one comparable to the typical demand data from other modes.
- **Travelled veh-km,** which are the sum of all trip-km. The rate is also comparable to other modes, being for this case equal to users-km, since the mode occupancy is one person/bike. The rate is also useful to study the consolidation level of the system as a transport mode option.

The following table sums up the evolutions of these three terms representing the demand and performance of the service: annual users registered, annual trips and total travelled km per year:

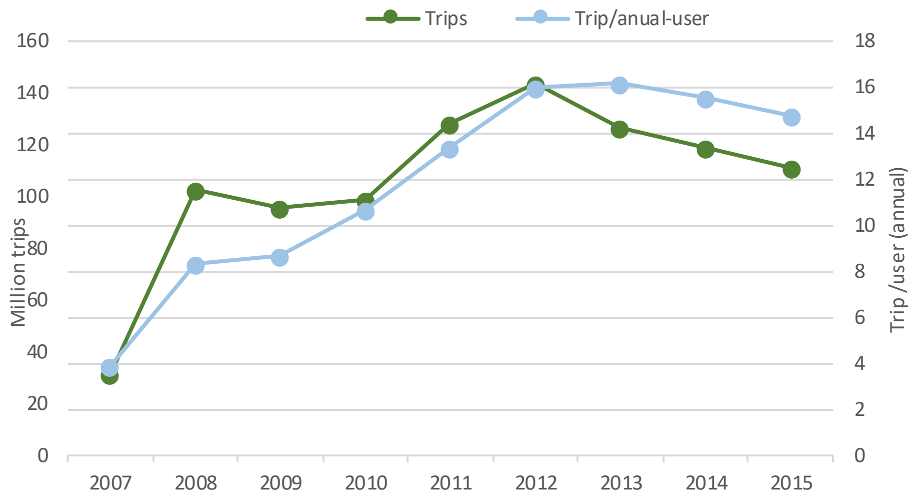


GRAPHIC 2.4 4. – EVOLUTION OF THE DEMAND IN TERMS OF USERS, TRIPS AND TRAVELLED KM. (SOURCE: BS:M, 2016A)

According to the graphic, the total number of users started to decrease in 2008 until 2015, with a maximum of around 156.000 subscriptions in 2008. From there, an interannually decrease of a 7% between 2008 and 2015 is found.

Regarding trips and annual travelled distance, the two curves present and oscillated behavior, since they experienced relative maximums and minimums between 2007-2012. However, from 2012, the general tendency is to decrease about -8% for both curves.

As a conclusion, the recent demand evolution is negative (2012-2015), with an interannually decrease of -8%, whereas the average trip/user decreases softly (-2%):



GRAPHIC 2.4 5. – EVOLUTION OF THE DEMAND IN TERMS OF USERS, TRIPS AND TRAVELLED KM (SOURCE: OWN CONSTRUCTION FROM BS:M, 2016A)

Therefore, the system is on the one hand becoming a more consolidated mode for its users and part of its daily mobility, but with an oscillating behaviour of annual subscriptions.

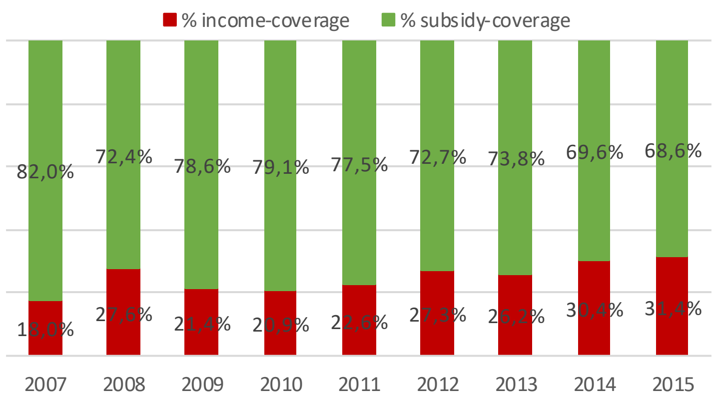
2.4.3 System financing

Bicing-service is financed through the incomes coming from annual subscriptors and since 2014, through the sponsorship-investment from Vodafone. Moreover, the City Councill participates in the financing of the scheme with annual subsidies, that permit covering the total annual costs.

FIGURE 2.4-2. – GLOBAL OVERVIEW OF THE MODE OF FINANCING THE SERVICE (SOURCE: OWN CONSTRUCTION)

The global running costs correspond to the cost of bike-redistribution (30%), maintenance (22% for bikes, 20% for stations) and administrative costs (28%) (European Commission, 2011), being the coverage ratio from own incomes about the 23%.

The evolution of the coverage ratio is shown below, including the sponsorship incomes:



GRAPHIC 2.4 6. – COVERAGE RATE AS THE RATE BETWEEN INCOMES AND SUBSIDIES. (SOURCE: BS:M, 2016A)

As seen, the tendency is to decrease the subsidies dependency of the service, through new financial patterns such as sponsorship and advertisement rights.

As a conclusion from financial patterns of Bicing, it is needed to say, that the only revenues come from annual subscriptions, which have a low price per day or trip. There is not any short-time subscription, since the City Council make an agreement with the bike-rental companies in the city.

By analyzing other bike sharing schemes, such as Paris due to the similar scale and touristic characteristics, the Vélib system let tourists pay for daily or week tickets to use the system, and therefore the revenues are higher, since the price/day in short-term subscriptions are higher.

3. EURPOEAN PUBLIC BIKE SHARING SCHEMES

As part of the study, some European examples will be analysed, in order to study examples of successful bike sharing systems. Since the offer of bike sharing systems in Europe is large, specially will be exposed in detail schemes with a scale level similar to Bicing in Barcelona, such as Paris, Lyon or Milan.

Moreover, the level of integration of the largest European cases as well as examples of special integrated schemes will be exposed.

For each example, the following characteristics will be exposed and compared:

- **Endogenous and exogenous factors** such as city size, population, modal split and the system scale in terms of its supply
- **Subscriptions offers**, in terms of the available types of users in the system
- **Financial patterns** or business model, differing the infrastructure owner and the operator
- **Global operating costs** if available, as well as particular cost rates.
- **Integration level**, providing the physical, information and fare integration level achieved for each scheme.

3.1 VÉLIB – Paris (France)

FIGURE 3.1-1. – VÉLIB SYSTEM IN PARIS (SOURCE: VÉLIB, 2017)

Velib is a self-service bicycle hire system operating in Paris. It started in 2007 behind the idea of an intermodal transport strategy, to promote the use of bikes as an option for the daily mobility. It is considered to be one of the main examples of a large-scale bike sharing scheme.

ENDOGENEOUS FACTORS		
Station-based system **Card-based access**	**Large-scale system:** • 1.800 stations • 23.600 vélos	225 bikes / km^2 11 bikes / 1.000 hab
EXOGENOUS FACTORS		
City size: 105 km2	**Population:** 2,2 M	**Modal Split:** 5%
SUBSCRITIONS		
Long-term (1 year): Classic (29€/year), Passion (39€/year)	**Short term:** 1-day (1,7€), 7-day (8€)	30 min/trip free of usage charges 1 € for each extra 30 minutes
FINANCIAL PATTERN		
Public-private partnership **Infrastructure owner:** City Council **Operator:** JCDecaux (advertisement) – 3,4 M€/year for rights to advertising space		
INTEGRATION		
Physical integration	*Integrated information*	*Fare integration*
All main stations have at least one bike station (surroundings or inside)	Transport authorities (RATP) integrate information door-to-door. Maps.me – app provides off-line information of the system	The service is compatible with the public transport pass **Navigo.** No bonus or discounts are applied.

3.2 VÉLO'V – Lyon (France)

FIGURE 3.2-1. – VÉLO'V SYSTEM IN LYON (SOURCE: VÉLO'V, 2017)

Vélo'v is a self-service bicycle hire system operating in Lyon. It started in 2005, located all around the 9 districts of Lyon and in Villeurbanne.

ENDOGENEOUS FACTORS		
Station-based system **Card-based access**	**Large-scale system:** • 343 stations • 4.000 vélos	83 bikes / km^2 8 bike / 1.000 hab

EXOGENOUS FACTORS		
City size: 48 km2	**Population:** 500 m	**Modal Split:** 4%

SUBSCRITIONS		
Long-term (1 year): Classique (25€), 14-25 ans (15€), RESA (15€)	**Short-term:** daily (1€), 7 days)5€), Lyon city card (3€)	First 30 minutes / trip free of charges 0,75€ each extra 30 minutes

FINANCIAL PATTERN
Public-private partnership **Infrastructure owner:** City Council **Management:** Mètropole de Lyon Sytral (transport authority - TCL) **Operator:** JCDecaux (advertisement)

INTEGRATION		
Physical integration	*Integrated information*	*Fare integration*
Main hubs and stations have a closer bike station. Specially near the metro and tram halts.	In the TCL website, just general information is provided. In Metro stations, a map with the location of veló'v stations is provided.	The system allows the utilization of the TCL (transports communs Lyonnais) ticket for long-term subscriptions. Moreover, they offer an hour free of charges for every trip.

3.3 LE vélo STAR – Rennes La Rochelle (France)

FIGURE 3.3-1. – LE VÉLO STAR SYSTEM IN RENNES (SOURCE: SNCF, 2017)

The Vélo à la Carte was the first bike sharing scheme installed in France, in 1998. After 10 years, the system was completely refunded, since the first one was providing an insufficient level of service to users and its deficit was large. Nowadays LE vélo STAR is operated by a partnership between SNCF and Keolis.

ENDOGENEOUS FACTORS		
Station-based system **Card-based access**	**Short scale system:** • 25 stations • 200 vélos	7 bikes / km^2 2,5 bikes / 1.000 hab
EXOGENOUS FACTORS		
City size: 28 km2	**Population:** 8 m	**Modal Split:** 4%
SUBSCRITIONS		
Long-term (1 year) (35€)	**Short-term:** daily (1€), 7 days (5€)	30 min / trip free of charges 1€ for each extra 30 min
FINANCIAL PATTERN		
Public-private partnership **Infrastructure owner:** City Council **Operator and management:** SCNF- Keolis (National rail company)		
INTEGRATION		
Physical integration	*Integrated information*	*Fare integration*
Major stations, close to 10 main stations and bus interchanging points	Real time information in stations, apps and website provided (SNCF)	KorriGo ticketing scheme – same card for bus, metro and regional trains and LE vélo STAR. **69% of users use multimodal trip.**

3.4 Santander Cycles – London (England)

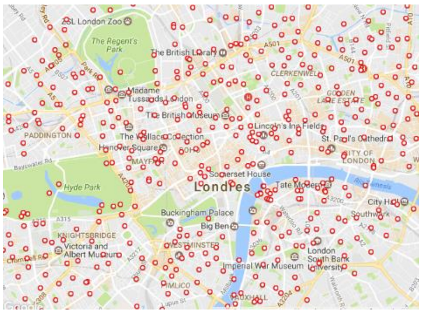


FIGURE 3.4-1. – SANTANDER CYCLING SYSTEM IN PARIS (SOURCE: SANTANDER, 2017)

Santander Cycles (previous known as Barclays Cycle Hire) is the public bike sharing system in London. It was established in the summer of 2010 as the first large-scale BSS in England. Previously, various small London boroughs were located in the city operated by OYBike. After 2010, the BSS in London promote further developments all around the United Kingdom and Europe with a similar scheme.

ENDOGENEOUS FACTORS		
Station-based system **Card-based access**	**Large-scale system:** • 750 stations • 11.500 cycles	7 bike / km^2 1,3 bike / 1.000 hab
EXOGENOUS FACTORS		
City size: 1.572 km2	**Population:** 8,6 M	**Modal Split:** 12%
SUBSCRITIONS		
Long-term (1 year) 90 pounts	**Short-term:** daily (2€)	30 minutes / trip free of usage charges 2,4€ for each extra 30 minutes
FINANCIAL PATTERN		
Public-private partnership **Infrastructure owner:** Town hall of London **Operator:** Transport for London (TfL) and Santander Bank (sponsorship)		
INTEGRATION		
Physical integration	*Integrated information*	*Fare integration*
Main metro and train stations are provided with bike dockings	Maps with metro and bike stations is provided in the Tfl-website	Not provided. The access Is not available with the Oyster-card (public transport pass)

3.5 KVB Rad – Cologne (Germany)

Figure 3.5-1. – KVB-Räd system in Cologne (Source: Nextbike, 2017)

KVB-Rad is the bike sharing system in Köln (Germany), which has been operative since early May 2015. The system implementation and its current operation belongs to the public transport authority KKVG (Kölner Verkehrsbetriebe AG).

ENDOGENEOUS FACTORS		
Station-based system **Card-based access**	**Large-scale system:** • 100 stations • 910 bikes	9 bike / km^2 3 bikes / 1.000 hab
EXOGENOUS FACTORS		
City size: 16 km2	**Population:** 128 m	**Modal Split:** 15%
SUBSCRITIONS		
Long-term (1 year) RadCard (48€), VRS-Chipkarten (Free for VRS-users)	**Short-term:** daily (9€)	30 minutes free of charges per trip. 1 € each extra 30 minutes
FINANCIAL PATTERN		
Public-private partnership **Infrastructure owner:** Public transport authority KBV (Kölner Verkehrsbetriebe) **Operator:** Netbike GmBH		
INTEGRATION		
Physical integration	*Integrated information*	*Fare integration*
System located inside the “ring” centering área.	KBV provides information of bike locations on its webside	KVB-Users have 30minutes of each trip free of charges

*No data-available

3.6 BikeMi – Milan (Italy)

FIGURE 3.6-1. – BIKEMI SYSTEM IN MILAN (SOURCE: BIKEMI, 2017)

BikeMi is the named bike sharing service in Milan, known as an easy, comfortable and ecological measure to improve the quality of the air in the city.

The idea started in December 2008, with the aim to substitute the short trips traditionally done it with the public transport metro, tram or bus for the bike mode.

ENDOGENEOUS FACTORS		
Station-based system **Card-based access**	**Large-scale system:** • 326 stations • 3.650 bikes	20 bike / km^2 3 bikes / 1.000 hab
EXOGENOUS FACTORS		
City size: 182 km2	**Population:** 1,3 M	**Modal Split:** 6%
SUBSCRITIONS		
Long-term (1 year) 36€	**Short-term:** daily (4,5€), week-ticket (9€)	30 minutes free of usages charges. 0,5 € each extra 30 minutes
FINANCIAL PATTERN		
Public-private partnership **Infrastructure owner:** Comune de Milano (City Council) **Management:** Transport authority ATM **Operator:** Clear Channel		
INTEGRATION		
Physical integration	*Integrated information*	*Fare integration*
Stations located in the ECOPASS pollution charge area and near main stations (center and suburves)	Map with all metro, tram, bus and bike stations or halts is provided in the ATM-website	ATM card not available for accessing the system. No bonus applied.

3.7 Sevici – Seville (Spain)

FIGURE 3.7-1. – SEVICI SYSTEM IN SEVILLE (SOURCE: SEVICI, 2017)

Sevici is the public bike sharing system operating in Seville since July of 2007. Its implementation was the result of an iniciative promoted through the City Council (Ayuntamiento de Sevilla) and operated and managed through JCDecaux.

ENDOGENEOUS FACTORS		
Station-based system **Card-based access**	**Large-scale system:** • 260 stations • 2.500 bikes	18 bike / km^2 4 bikes / 1.000 hab
EXOGENOUS FACTORS		
City size: 141 km2	**Population:** 690 m	**Modal Split:** 9%
SUBSCRITIONS		
Long-term (1 year) 33€	**Short-term:** week-ticket (13€)	30 minutes / trip free of usages charges 0,5 – 1€ each extra hour
FINANCIAL PATTERN		
Public-private partnership **Infrastructure owner:** Ayuntamiento de Sevilla **Operator:** JCDecaux		
INTEGRATION		
Physical integration	*Integrated information*	*Fare integration*
Most stations are locatet in the urban area of the center, close to bus halts and stations	Information about the service in many	Tarjeta el Consorcio, available for all transport modes.

3.8 BiZi – Zaragoza (Spain)

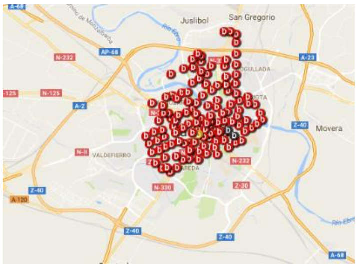


FIGURE 3.8-1. – BIZI SYSTEM IN ZARAGOZA (SOURCE: BIZI, 2017)

The named Bizi is the urban transport based in bike sharing. It is defined as an easy, practical and sustainable mode to be used in trips along the city. It started in 2008, being the second largest scheme of public bike systems in Spain, after Barcelona.

ENDOGENEOUS FACTORS		
Station-based system **Card-based access**	**Large-scale system:** • 130 stations • 1.300 bikes	1,2 bike / km^2 2 bikes / 1.000 hab
EXOGENOUS FACTORS		
City size: 1.063 km2	**Population:** 0,67 M	**Modal Split:** 1%
SUBSCRITIONS		
Long-term (1 year) 36,93€	**Short-term:** three-day ticket (5,3€)	30 minutes / trip free of charges 0,5 € each extra 30 min
FINANCIAL PATTERN		
Public-private partnership **Infrastructure owner:** City Council **Operator:** Clear Channel (advertisement)		
INTEGRATION		
Physical integration	*Integrated information*	*Fare integration*
Stations are located close to the three main train stations as well as to many bus stations	In many tram station, information about the closest station and a map is shown	Public transport card (*Tarjeta de ciutadania*) can be used for accessing the system since 2013

3.9 COMPARISON BETWEEN EUROPEAN SCHEMES

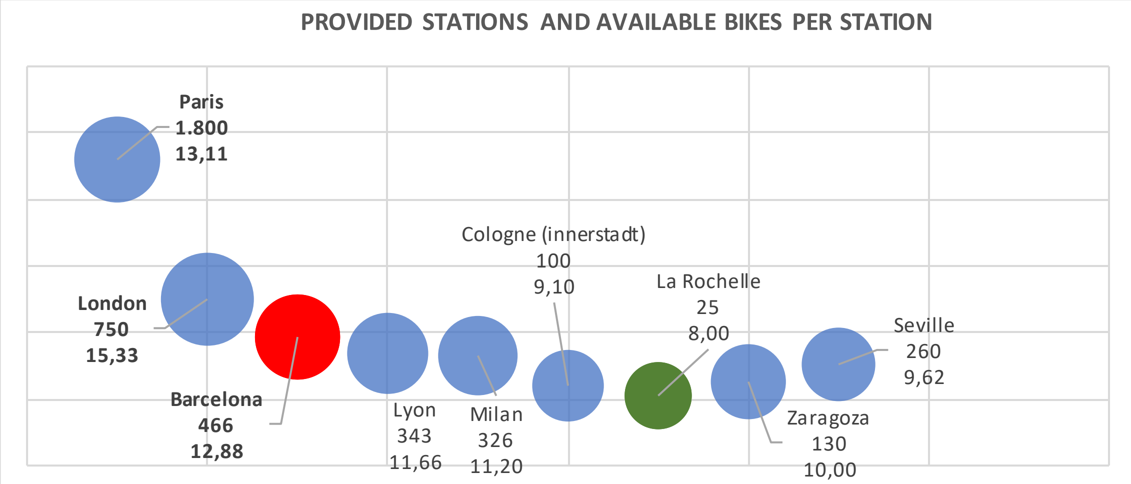
3.9.1 Scale of the system

Two different scales can be distinguished, regarding the amount of stations located in the city as well as the bike-fleet:

- **Large-scale systems:** usually linked to big urban areas such as Paris or London. Vehicle fleet exceed the 1.000 bikes and stations are above 200 units. They are sometimes grouped into clusters or crowns, since the systems are more difficult to manage and a logistic plan is needed.
- **Small scale system:** linked to small towns or systems located just in a specific area of a city.

The analysed systems are mostly large-scale, being Vélib in Paris the one with the highest amount of stations (1.800) and La Rochelle and Zaragoza the only small-scale systems, with less than 200 stations.

The figure below shows the amount of stations of each analysed system, with its radius in terms of the available bikes per station:



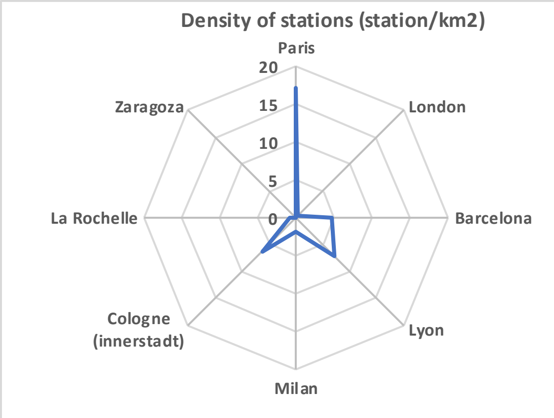
GRAPHIC 3.9 7. – PROVIDED STATIONS AND AVAILABLE BIKE PER STATION AT EACH ANALYSED SYSTEM IN EUROPE (SOURCE: OWN COSNTRUCTION)

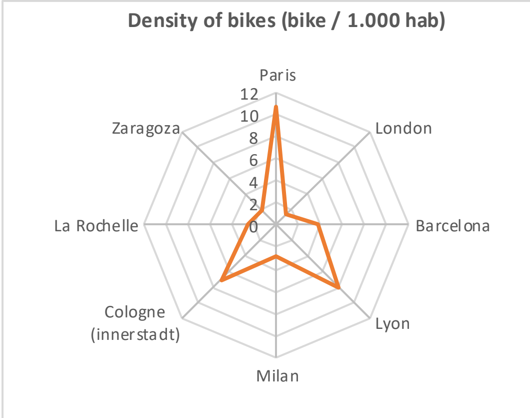
As seen, the radius of the bubbles matches with the large of the system. All rates are located between 15-8 bikes per station, being London the ones offering the highest number of available bikes per dock.

Two rates can also provide a good approach of the coverage provided: density of stations and available bikes per habitant:

TABLE 3-1– DENSITY OF BIKE SHARING SCHEMES IN EUROPE (SOURCE: OWN CONSTRUCTION)

	PARIS	LONDON	BARCELONA	LYON	MILAN	COLOGNE	ROCHELLE	ZARAGOZA
Station/km²	17,14	0,48	4,60	7,15	1,79	6,25	0,89	0,12
Bike / 1.000 hab	10,73	1,34	3,75	8,00	2,81	7,00	2,50	1,94





GRAPHIC 3.9 8. – DENSITY OF STATIONS (LEFT) AND BIKES (RIGHT) OF EACH SCHEME (SOURCE: OWN COSNTRUCTION)

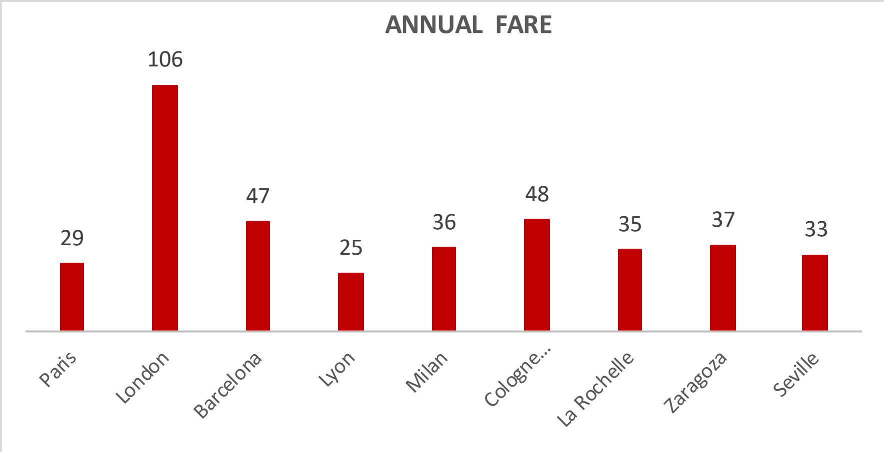
Both terms allocate Paris as the high dense system in Europe, followed by Lyon and Barcelona. As an exception, Cologne provides a high-density service, since the system is concentrated just in the inner-ring of the city, covering just the city centre.

3.9.2 Subscriptions

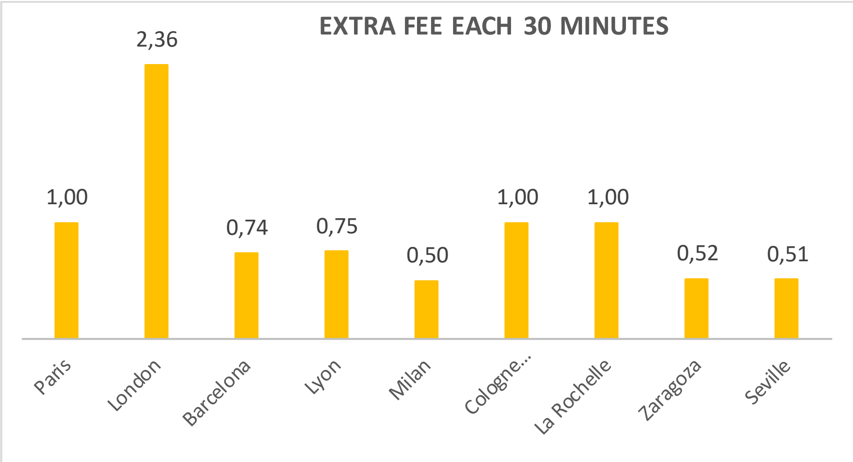
In almost all analysed systems, the subscriptions and registrations are divided into long—and short-term. Regarding long-term subscriptions, mostly systems are limited to residents, since they are high sensitive to demand changes, and *"refloating"* or collapsing problems could appear.

Some common characteristics in all systems can be found:

- Two fees are distinguished: access and usage charges.
- All systems develop a "**loyalty policy**", since long-term users are the ones which have more benefits (relative lower price and special fees). The fee-range does not exceed 50€/year, except for London (106€).
- Usage charges are understood as extra fee each 30minutes, and do not exceed 1€ except for London (2,4€/30 min)
- Most systems are card-based, since users need to use a specific magnetic card to use the bikes.
- Short-term subscriptions can be divided into daily or weekly. Bicing is the only system without short-term subscriptions.
- All annual subscriptions include 30 minutes free of usage charges.



GRAPHIC 3.9 9. – ANNUAL FARE OF EACH ANALYSED SYSTEM (SOURCE: OWN COSNTRUCTION)



GRAPHIC 3.9 10. – USAGE FEE AS €/30 MINUTES OF EACH ANALYSED SYSTEM (SOURCE: OWN COSNTRUCTION)

As mentioned before, Paris and Lyon are two of the highest dense systems in Europe. However, regarding annual price for users Vélib and Vélo'v do not correspond to the most expensive schemes. Both systems lay down low annual charges, and relative high usage fees. As a result, the applied policy in both systems is to ensure certain coverage through annual fees, and receive income peaks through sporadic usages, specially from tourists.

London is the most expensive analysed system, with an annual fee of 106€ and 2,4€/30min as usage charge.

On the other hand, Barcelona, as another large-scale system, does not allow short-term uses in the system. Its annual fare for Bicing-users is higher, to ensure certain coverage of the global operating costs.

3.9.3 Integration level

Three different level of integration between bike-sharing systems and conventional public transport are identified: physical, information and fare/access integration:

TABLE 3-2– INTEGRATION LEVEL AT EACH SCHEME (SOURCE: OWN CONSTRUCTION)

	PHYSICAL INTEGRATION	INTEGRATED INFORMATION	FARE/ACCESS INTEGRATION
Paris - Vélib	x	x	x
London – Santander cycle	x	x	o
Barcelona – Bicing	x	x	o

	PHYSICAL INTEGRATION	INTEGRATED INFORMATION	FARE/ACCESS INTEGRATION
Lyon – Vélo'v	x	x	x
Milan - BikeMi	x	x	o
Cologne – KVB Räd	x	x	x
La Rochelle – LE vélo STAR	x	x	x
Zaragoza – Bizi	x	x	x
Seville - Sevici	x	x	x

According to OBIS-Handbook (European Commission, 2011), one of the keys of success of bike sharing schemes is providing good connections and integration with the already consolidated public transport modes. Items such as a good strategy of locating stations close to main interchanging areas ore hubs, can conditionate the survival of these systems as well as consolidate them as a first/last step mode.

As shown above, all systems are properly integrated with the public transport in terms of locations of stations and provided information. All stations were located in buffers around 300m, and planned since the beginning to be close to main stations.

Another factor that conditionate the integration level of the system is its operator, being easy to provide fare and access integration the ones owned or operated by a transport authority. LE vélo STAR, is one of the greatest example of fare integration, since its operated by the national French rail company (SCNF).

Most part of the schemes allow the access to the system with transport card, such as in Paris and Lyon, where users can use the transport passes (Navigo-Paris, TCL card-Lyon).

Lyon and Cologne are the only systems with special treatment for users which come from conventional modes. Both cases give extra free minutes to users that transfer from one system to the other.

4. BICING ANALYSIS (2015)

Bicing analysis basically consists on understanding the behavior of users and the financial patterns of the system.

Due to the fact that the service is operated and managed by a private company (Clear Channel), open data was not possible to found. However, for the exercise of 2015, some patterns and aggregated data is available, and this analysis is based on this information.

4.1 DEMAND DIAGNOSIS

Demand diagnosis mainly consists on understanding demand distributions, by meanings of the mobility patterns that take place in the system as well as their characteristics:

TABLE 4-1– GLOBAL DEMAND DATA FOR THE EXERCISE OF 2015 (SOURCE: BS:M, 2016B)

	USERS	TRIPS (Millions)	VEH-KM (Millions)	TRIP / USER	VEH-KM/USER
Total	95.168	12,56	31,27	132	329

4.1.1 User's profile

From the available data provided by BS:M through internal mails (BS:M (2017)), is possible to emit an approximation of the user's profile:

TABLE 4-2– MOBILITY PATTERNS FOR USERS IN 2015 (SOURCE: BS:M, 2016A)

Mobility patterns	
Average time in the service (min)	*15*
Average travelled distance (km)	*2,5*
Morning peaking hour	*8-10h*
% of female users	*49%*
% of users between 26-35	*41%*
% of forced mobility (labour motive)	*65%*
Leisure	*16%*
Personal motive	*11%*
Trips in a working day	*38.454*
Trips in a holiday day	*22.198*

From the shown mobility patterns, it can be estimated, the annual mobility in terms of trips in a working day and in a non-working day:

TABLE 4-3– GLOBAL DEMAND DATA FOR THE EXERCISE OF 2015 (SOURCE: BS:M, 2016AB)

	Annual trips
Working day	*10.382.580*
Non-working day	*2.108.810*
Total	**12.491.390**
Error (%)	**0,12%**

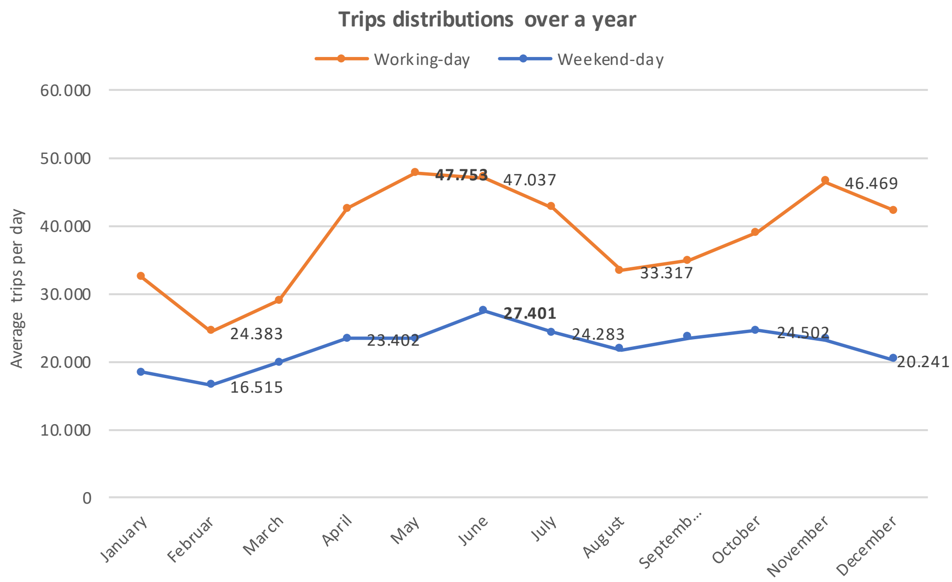
It has been estimated, that there is a total amount of 10,4 million trips / year in working day, representing the 83% of the annual mobility of the system. Considering 270 as the amount of working days in 2015, the error regarding the real registration of 12.506.620 trips lower than 1%.

4.1.2 Temporal distribution

Due to the unknown temporal distribution of subscriptions in an entire year, the hypothesis, that the number of users registered in the system is constant in the year. Since users pay an annual fee, it will be considered, that the same users do not renovate its subscription as new ones decide to pay for a year subscription. Therefore, the constant amount of 95.168 users in the system is considered.

As occurs in many European examples, the number of trips do not take place uniformly during a year. The general rule for bike sharing systems to experience a notable increase on the daily trips during the Summer season, and minimum uses during the Winter.

The following graphic shows the particularized case for Bicing system in 2015, as part of the mobility patterns of its users:



GRAPHIC 4.1 11. – EVOLUTION OF THE DEMAND IN TERMS OF USERS, TRIPS AND TRAVELLED KM (SOURCE: OWN CONSTRUCTION FROM BS:M, 2016B)

As seen above, the number of daily trips oscillate during an entire year with a maximum in May for working days and in June for non-working days. As a special fact, in August the minimum registration of daily trips take place, since is the holiday month par excellence and moreover, most residents do not stay in the city.

Considering the constant demand of 95.168 for the system, the following mobility indicator can be obtained:

TABLE 4-4– DAILY TRIP PER STATION, BIKE AND USER (SOURCE: OWN CONSTRUCTION)

	TRIP/USER-DAY
January	*0,34*
February	*0,26*
March	*0,30*
April	*0,45*
May	*0,50*
June	*0,49*
July	*0,45*
August	*0,35*
September	*0,37*
October	*0,41*
November	*0,49*
December	*0,44*
AVERAGE	***0,40***

The observed data corresponds to the working day mobility, being for all cases, the average number of trips per user less than 1. By meanings of the system management, this rate shows the *"refloating"* problems and the irregularity of its demand.

Knowing that the 65% of users use the system for moving to work, the mobility patterns should be regular, meaning that these users move from work to home twice. However, data shows that the average trip per day and user is less than 1. This fact steps up the fact that the mobility with Bicing takes place just in one direction of travel and that some users are the called "sporadic". They pay for the annual subscription, but do not use Bicing as a regular mode of travelling.

4.2 INTERMODALITY

The 40% of trips are registered as multimodal, being Bicing the mode which covers the last step of the global trip.

The following table sums up the intermodal chain taking place in the system with the other modes. Just values in % of global trips were available, and not all the chain in detail:

Mode	%
Metro	*34%*
Rodalies	*22%*
FGC	*14%*
Urban bus	*10%*
By food	*8%*
Tram	*4%*
Interurban bus	*4%*
Car	*3%*
Others	*1%*

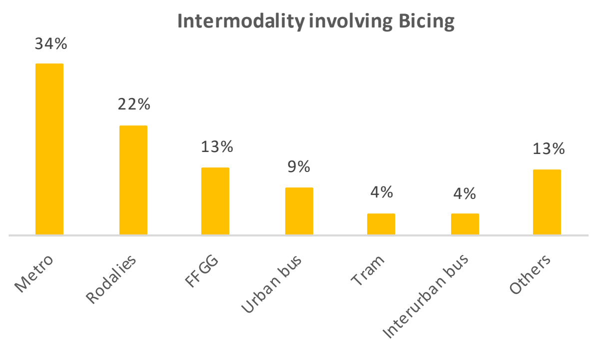


FIGURE 4.2-1. – % OF INTERMODAL TRIPS COMBINED WITH BICING BY MODE (SOURCE: BS:M, 2016A)

According to the previous table, the highest interaction corresponds to Metro service, in which almost a 34% of intermodal trips involving Bicing come from Metro. This has a direct connection with the fact that mainly, Bicing stations are located close to Metro ones. In global terms rail modes represent the 56% of the global intermodal trips. On the other hand, also the same rate (56%) represent the ones taking place at urban scale: Metro, urban bus, by food and tram.

4.3 FINANCING

The incomes of the system come basically from the annual fee revenues plus some punctual usage fees, and the sponsorship contract. Being the cost of running the system higher than the estimated incomes, the system needs subsidies, coming from the City Council -BS:M (Barcelona Serveis Municipals).

Concretely, for the exercise of 2015, the amount of incomes and the global cost of operating the system is summarized below:

TABLE 4-5– GLOBAL ANNUAL INCOMES: OWN INCOMES, SPONSORSHIP AND SUBSIDIES. TERMS IN MILLION € (SOURCE: BS:M, 2016B)

	OWN INCOMES (Million €)	SPONSORSHIP (Million €)	SUBSIDIES (Million €)	COST (Million €)
Total	*4,22±6*%*	*1,42*	*12,35*	*18,00*
% of the global cost	*23%*	*8%*	*69%*	*100%*

*As mentioned before, annual users are considered to be constant and equal to 95.168. Considering that at least all users pay for the annual subscription of 47,16€, the total incomes exceed about a 6% the published one. However, being this rate lower than 10%, it will be considered the official data (BS:M (2015)).

According to the previous annotation, the average income per user is equal to 44,4 €/user and year, since the amount of registered users and computed incomes may not correspond to the annual fixed fare of 47,2 €/year.

The service could be financed just through the sponsorship contract and own incomes if the annual fare was equal to 174,2€/subscription.

4.4 INTEGRATION

The integration with public transport modes and Bicing-service, takes place on two of the three levels.

4.4.1 Physical integration

Regarding physical integration, Bicing stations were located since its first pilot trial near main stations. Moreover, in the defined interurban hubs more than one station is located in the surroundings:

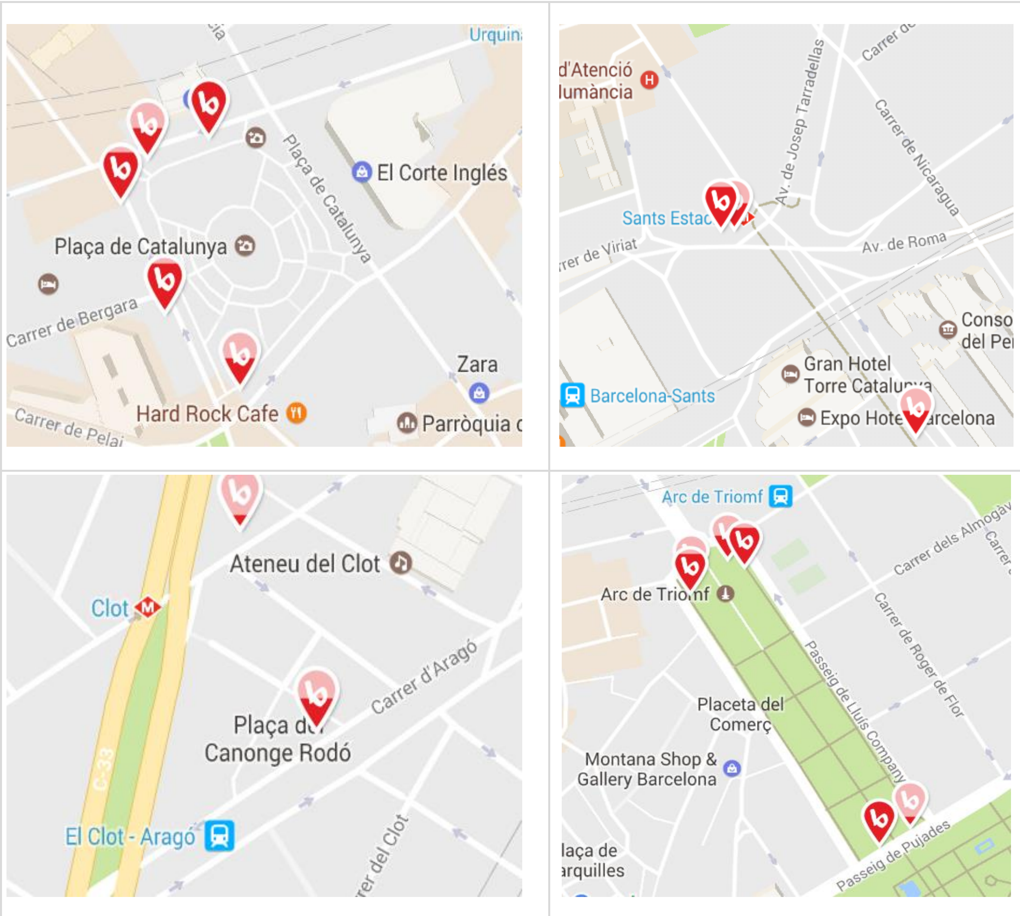


FIGURE 4.4-1. – EXAMPLES OF PHYSICAL INTEGRATION (PL- CATALUNYA, SANTS, EL CLOT STATION AND ARC DE TRIOMF) (SOURCE: BICING-APP)

4.4.2 Integration of information

The location of bike station is also combined with public transport information. Concretely, in many metro station, the logo of Bicing and an indication of the location of the closes stop can be found in many lines:

FIGURE 4.4-2. – EXAMPLES OF INTEGRATED INFORMATION (SOURCE: EUROPEAN COMMISSION, 2011)

4.4.3 Fare integration

No fare or access integration is provided in the scheme. For conventional transport modes, user use a paper-ticket, whereas Bicing software uses a magnetic card. From this point, no access or fare integration is possible between the schemes nowadays.

FIGURE 4.4-3. – EXAMPLES OF ELECTRONICAL CARD FOR BICING (LEFT) AND TRANSPORT TICKET (RIGHT) (SOURCE: GOOGLE)

4.5 MAIN INDICATORS

As a first conclusion, Bicing can be understood as an already consolidated public transport mode in terms of its supply since the offer is large in time and space. However, regarding demand, it is difficult to estimate mobility patterns of regular users.

4.5.1 Demand diagnosis

Demand presents irregularities, since the amount of trips differ between months and the rate of trips per day and user is lower than one:

- **Temporal distribution:** May is considered the month with the highest rate of average trips and August the lowest one.
- **The average number of annual trips in a working day is equal to 10,4 M uses** (38.454 daily-trips), and **2,11 for weekends** (22.198 trips/day).
- **The working demand represents the 83% of the global annual trips.** The working day demand is 1,7 times higher than in the weekends.
- **65% of the total trips are motivated for labour reasons,** and therefore this part of the demand can be understood as regular one.

The following rates show the commented demand characteristics:

Table 4-6– Average trip per user and day (Source: Own construction from BS:M, 2016b)

	Rate
Average trip/user-year	*131,4*
Average daily trips	*38.454*
Average daily trips per user	*0,4*

So, users can be divided in those which use Bicing as a daily mode and sporadic or punctual users, which pay for the annual service since its cheap, but do not correspond to regular mobility. Mostly users pay for the annual service since it has a relative low cost, but do not use Bicing as a daily mode. The average trip per day and users are lower than 0,5.

Regular mobility corresponds to the 38.454 average daily trips, which can be estimate to 19.227 daily users which use Bicing as its daily mode.

4.5.2 Intermodality

Intermodality has been estimated with a weight of the 40% of annual trips. This high rate is the result basically from the physical integration, and provides a proof that the relevance of the scheme is linked to its intermodality.

Regarding intermodal chains, some conclusions can be exposed:

- The most significant mode for transfers with Bicing scheme is the metro, with a rate of 34% of intermodal trips.
- Rail modes in the intermodal chain, represent above the 56%.
- Urban modes represent above the 56% of all intermodal trips.

In terms of annual and daily trips, the data is shown bellow:

Table 4-7. – Average annual and daily intermodal trips by mode (Source: Own construction from BS:M, 2016a)

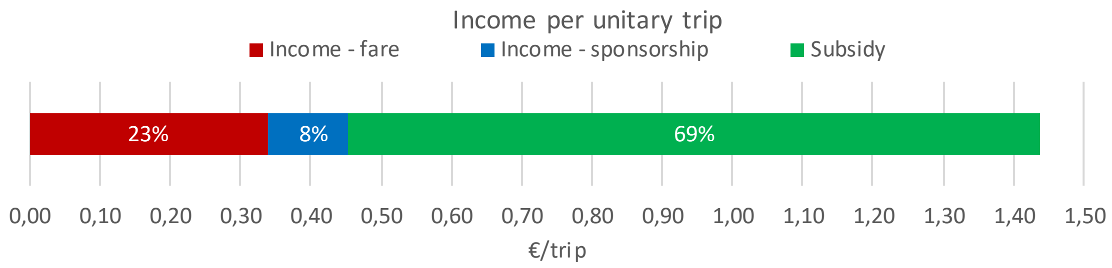
	INTERMODALITY (%)	*ANUAL TRIPS (millions)*	*DAILY TRIPS*
Metro	*34%*	*1,70*	*5.210*
Train	*22%*	*1,01*	*3.361*
FFCC	*13%*	*0,68*	*2.069*
Tram	*4%*	*0,22*	*664*
Urban Bus	*9%*	*0,48*	*1.457*
Others	*17%*	*0,86*	*2.621*
TOTAL	**100%**	**5.024.038**	**15.382**

Being Bicing a system limited to the urban area of Barcelona, the service coverage is similar to the metro or urban bus one. Due to the fact the transfers between Bicing and these two modes weight almost 50%, Bicing can be understood as a complementary urban service, which can reduce total travelled time or avoid congestion.

On the other hand, the intermodality with rail modes is equal to 56%, being this one for the Metro about the highest one, near 40%. Knowing that the commercial speed of a Metro is higher than bikes, the intermodal trips which link Metro and Bicing, can be motivated since the access time from station to origin or destination is lower in the bike sharing system.

4.5.3 Financing

As many other public transport modes, Bicing requires public subsidies to cover the annual cost of 18 million euros. However, the coverage rate for own incomes is quite low, being the average income per trip the 23% of the costs, and letting public subsidies paying the 69%. With the release of a sponsorship contract, extra incomes can help to increase the coverage rate until the 31%:



GRAPHIC 4.5 12. – INCOME PER UNITARY TRIP FROM ANNUAL FEES, SPONSORSHIP AND SUBSIDY (SOURCE: OWN CONSTRUCTION)

In monetary terms, the global incomes and costs per trip are the following one:

TABLE 4-8– INCOMES AND SUBSIDES PER TRIP FOR BICING IN 2015 (SOURCE: OWN CONSTRUCTION)

	€/trip
Income from users	*0,34*
Incomes from sponsorship contract	*0,11*
Subsidies from public sources	*0,99*
Cost	***1,44***

The rate of incomes per user was obtained with the global incomes and annual trips. However, if considering the 270 typical working days per year and a regular two trips per day with Bicing, the income per trip drops to 0,09 €/trip. This proves that the regular demand for Bicing is low, and generally users pay for long term subscription and use only the service few sporadic.

4.5.4 Integration level

Concerning integration, Bicing is known as a good example of physical and integrated information. Since its implementation as a pilot trial, the stations were located near main stations, becoming an option for daily mobility. However, no access or fare integration is included.

PART II

Public transport system in Barcelona
Role of the Metropolitan Transport Authority (ATM)

5 GENERAL OVERVIEW OF THE PUBLIC TRANSPORT SYSTEM IN BARCELONA

The strategic location of Barcelona and its large influence through the entire country, determine the mobility of its inhabitants. Mobility in the city can be understood as internal connections between urban neighbourhoods inside Barcelona and connection mobility, coming from external municipalities to the main city.

The transport system operating in Barcelona, can be divided into three categories, according to its scale:

- **Urban system**: mainly understood as a regular service provided through a metro, tram and bus scheme.
- **Interurban system:** consisting on connections between close municipalities and Barcelona. The interurban scheme is provided by a large offer of trains and buses.
- **Interregional and large distance transport:** With large national and international connections.

In order to properly understand and define the public transport operating in the city, it is necessary to consider the total influencing area of Barcelona.

5.1 MAIN JURIDIC ORGANIZATION

The global influencing area of Barcelona is composed by a total amount of three different layers, in order to define different scale of organization regarding issues such as transport, demography and environmental plans:

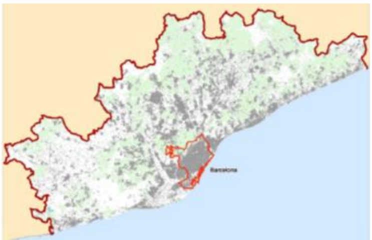


FIGURE 5.1-1. - COVERED AREA FOR THE RMB (SOURCE: ROSELLÓ X., 2006)

Metropolitan Region of Barcelona (RBM) is the region covering the total influencing area, with a total amount of 3.242 km² and 4,9 million of inhabitants (AMB 2017).

FIGURE 5.1-2. - COVERED AREA FOR THE AMB (SOURCE: AMB)

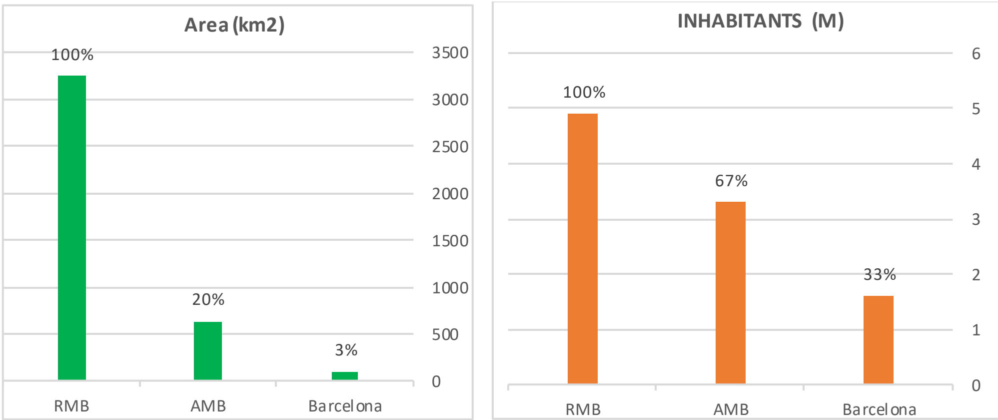
Metropolitan Area of Barcelona (AMB), consist in a global region which is hardly influenced by its main capital, Barcelona. The AMB has a total surface of 636 km² and above 3,2 million of inhabitants (AMB 2017), which makes it one of the metropolitan areas with a higher density in Spain and in the global Mediterranean Region.

FIGURE 5.1-3.- COVERED AREA FOR THE URBAN LIMITS OF BARCELONA (SOURCE: AJUNTAMENT DE BARCELONA)

Barcelona, with a total amount of 1,6 million of inhabitants in a 101,3 km²(Idescat (2016a), and being the central part of all the layers in the system. Its urban area is divided into 10 neighbourhoods. The city hall is responsible of planning and management all the issues concerning the city.

According to the size of the city, the mobility and transport plans are hardly subject to the total influencing area of Barcelona. Therefore, in order to provide global plans and policies, which; some juridical organization has to be taken into account.

The figures bellow show the different influencing zones in terms of total inhabitants and covered area, being Barcelona the lowest area but the main focus of all the organization:



GRAPHIC 5.1 13. – TOTAL AREA AND INHABITANTS COVERED BY EACH OF THE CONSIDERED ZONES (SOURCE: OWN CONSTRUCTION FROM AJUNTAMENT DE BARCELONA, 2017A AND AMB, 2017)

As shown above, Barcelona covers just the 3% of the total RMB-area, and has the 33% of the inhabitants. However, its influence is extended through the whole RMB, by meaning a total area of 3.242 km^2.

4.6 THE MAIN TRANSPORT AUTHORITY IN BARCELONA (ATM)

ATM, *Autortitat del Transport Metropolità* is the main public transport authority mainly centring its business volume in the region of Barcelona. Concretely, its activities are extended to different counties in the Barcelona region: *Alt Penedès, Baix Llobregat, Barcelonès, Garraf, Maresme, Vallès Occidental and Vallès Oriental*.

It consists on a public administration composed for a 51% of the Catalan government (Generalitat de Catalunya) and in a 49% for local administrations such as the city hall of Barcelona and the AMB, which have an important weight on its funding.

Starting in 1997, ATM was founded as a voluntary inter-administrative consortium in which all administration can join that own collective transport services individually or via groups. Its main purpose is the correct organization and cooperation between public administrations that offer collective public transport in the influence area of Barcelona. It is responsible of providing public transport service of about a 5,7 million of inhabitants. Moreover, it provides cooperation with national administration (such as state government), to ensure a proper financing of the public transportation system.

The mainly functions are summed up in three categories:

- **Planning infrastructures and services:** investment programmes, development of tools for evaluating the timescale needed for implementation of which infrastructures etc.

- **Relations with collective transport operators:** including the integrated fare system work as a cooperation between different collective transport administrations.

- **Financing the system through public administration**

- **Managing the integrated fare system** in the Metropolitan Region of Barcelona, which includes fixing per year the fare for the transport tickets and carrying on the fare-integration of the system.

In terms of integration, three levels can be clearly identified in the ATM-operating area: physical integration, integrated information, and fare integration being the last two a direct issue managed through it.

4.7 PUBLIC TRANSPORT SUPPLY

Focusing in the global Metropolitan Region of Barcelona, different public transport modes conform the global public transport supply. They can be separated into two different groups according to its basic operating structure:

- **Regular services, timetable based:** Known as the conventional modes, they are identified as public transport modes station based, which are usually operated through a public company and managed under an integrated scheme. The regular services in the RMB can be classified according to its rolling-structure:
  - **Rail supply,** divided into the ones providing urban connections like the Metro and Tram; and the ones providing a radial connection with the main city such as Rodalies-Renfe and ferrocarrils de la Generalitat (FGC).
  - **Bus supply**, also divided in the ones providing urban and interurban connections.

- **Not regular service,** usually linked to none-**traditional modes**, which are usually operated by a private company or through a private-public contract.
  - **Taxi service**, provided by different private companies
  - **Bicing bike sharing**, which will be deeply analysed in the following chapters
  - **Moto sharing** provided through two companies (Yugo and Ecoltra), both not station based.

Apart from the mentioned public transport schemes, in the city also exist intraregional and international services operated by different companies. A large example is Renfe, as the national railway authority and many private bus companies, which provide connections between different cities. However, since they are not part of the influence area of the RMB they are not explained in detail.

4.8 MAIN PUBLIC TRANSPORT OPERATORS

Regarding transport operators, the ones with the largest systems are described below:

- **Transports metropolitans de Barcelona (TMB),** who owns the right of operating the urban buses and the metro infrastructure in the city. At a second scale TMB also manages touristic buses, and old traditional tram and the funicular of Montjuic.
- **Rodalies-Renfe,** as part of the national railway company (Renfe). It owns the Rodalies railway service, which provide connections between the main stations in Barcelona and its interurban influence area.
- **FGC (Ferrocarrils de la Generalitat de Catalunya),** who owns the second largest rail supply for interurban connections.
- **TRAM,** which owns the two tram lines in the RMB-area since 2004.
- **AMB,** as the representing entity for different urban and interurban bus operators.

Apart from the mentioned main operators, above 30 other urban and interurban bus companies centre its operations in the RMB-area.

5. INTEGRATED PUBLIC TRANSPORT SYSTEM (STI)

As mentioned in the chapter before, the Metropolitan Transport Area (ATM) is in charge of managing the public transport integrated scheme.

The coverage level of the integrated public transport system can be expressed through the served population and covered surface, being these 4,7 M of inhabitants in 8.810 km^2 (ATM, 2016a).

Three levels of integration can take place in the public transport: physical integration, integration of information and fare/charges integration:

5.1 PHYSICAL INTEGRATION

Physical integration is understood as the parallel implementation of stops located in closer locations or inside the main station. This type of integration is provided in the operating area of the ATM, since for competitive reasons, many operators decided to be physically integrated since the beginning of their operations.

Different category of hubs, as main point of integrations can be identified in Barcelona, as the main centre of the integrated system:

- ***Interurban hubs;*** which basically integrate interurban und urban modes. Normally are identified as a building-station, and the interurban lines of Rodalies and FGC operate there. Moreover, the intraregional and international lines (bus and rail), mainly operate there, and all bus service have a close stop.

- ***Urban hubs;*** known as urban interchangers. Different transport modes in the city are located there, so users can easily transfer.

TABLE 5-1– HUB CATEGORY AND ITS SIGNIFICANT IN THE CITY (SOURCE: OWN CONSTRUCTION)

HUB CATEGORY	SIGNIFICANCE
INTERURBAN HUB	All types of train service mainly centre its operation. Moreover, bus stops are located in the surroundings
	Sants-station: Metro, Rodalies, International and intraregional services. Bus marquee located next to the station for interurban and urban bus stops **El Clot – station:** Metro, Rodalies, International and intraregional services. Bus marquee located next to the station **Passeig de Gràcia-exchanger:** Rodalies and metro service. Urban bus stops located next to the exchanger **Plaça Catalunya – exchanger:** Metro and Rodalies service. Interurban and urban have stops located near the square. **La Sagrera-exchanger:** Metro, Rodalies and few urban lines. Provença/Diagonal-exchanger:

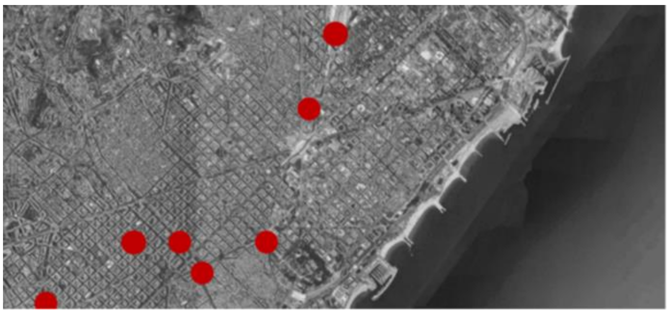


FIGURE 5.1-1.- INTERURBAN HUBS IN THE CITY (SOURCE: OWN CONSTRUCTION FROM GOOGLE MAPS)

URBAN HUB	Mainly identified as stop areas conformed by a combination of metro or/and FGC-line, with urban bus and/or tram-line which are closely located.
	Several ones can be identified in the network, such as La Sagrera, Provença/Diagonal and Maria Cristina-exchanger. Being all a point in which many lines stop regarding metro, rail and bus services.

FIGURE 5.1-2. - URBAN HUB IN THE CITY AS EXCHANGER LOCATED IN MARIA CRISTINA (BARCELONA) (SOURCE: OWN CONSTRUCTION FROM GOOGLE MAPS)

5.2 INTEGRATED INFORMATION

At information level, all urban and interurban hubs are provided with information relating the different mobility options which also operates in the proximities. They all include the timetable and line-routes that also have a stop in a close area. Moreover, the ATM provides a mobility-tool, in which users can plan a journey by knowing in detail all transport stages they can use from a specific origin to a destination

FIGURE 5.2-1. EXAMPLE OF INTEGRATED INFORMATION IN THE METRO L1 LINE. AVAILABLE TRANSFERS PER STOP WITH OTHER LINES AND MODES (SOURCE: TMB)

5.3 FARE INTEGATION SYSTEM (STI)

The integrated fare system, named as "*Sistema de tarifes integrat*" embraces a total amount of **346 municipalities** along 8 regions in the influence area of Barcelona, allowing users using with the same ticket all public transport supply in the zone.

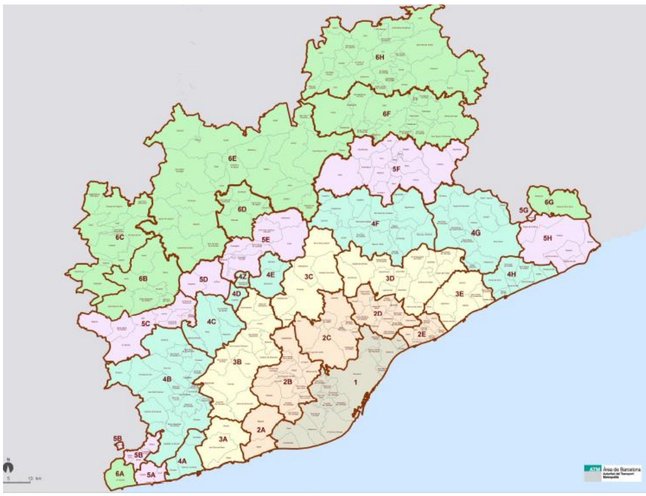


FIGURE 5.3-1. - ATM COVERED AREA (SOURCE: ATM, 2017A)

It started in 2001 under the management of the ATM, whose main issue is to provide a good connection between the different transport modes and ensure its correct finance. Moreover, is in charge of providing the correct sale of integrated tickets and decide how the incomes are divided between the involved transport actors.

The main urban and interurban transport modes mentioned before (Chapter 4.7) are included as part of this integrated system:

- **Metro and urban bus lines**, operated by Transport Metropolità de Barcelona (TMB)
- **Railway supply**, operated by Ferrocarrils de la Generalitat de Catalunya 8FGC)
- **Interurban train lines**, who act as interurban lines in the area and are known as Rodalies and are operated through the national railway company Renfe-Rodalies.
- **Tram**, whose operator is the public company TRAM and started to offer this service in 2004.
- **Interurban buses**, whose operators cooperate together through the management of Metropolitan Area of Barcelona (AMB)
- Many other bus lines that provide urban and interurban services and managed through the Catalan government (DGTM)

5.3.1 STI - Zoning

The fare system is length-based, since the covering area is divided into 6 main crowns located concentric around Barcelona, named as the 1-zone. The system also provides a subdivision inside each of the crowns.

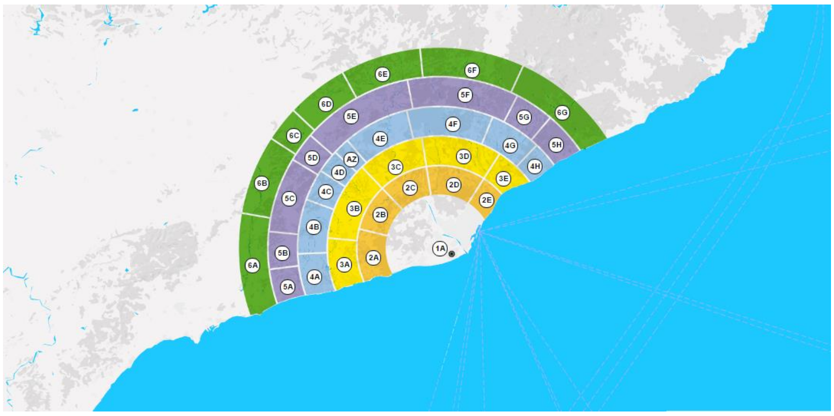


FIGURE 5.3-2. - ZONING OF THE FARE-INTEGRATED DISCRETIZED INTO CROWNS (SOURCE: TRAM)

As a result, the region is configurated starting from a central compact city, with a total amount of 1,6 million inhabitants, and a large number of intermediate cities whose large oscillate between the 0,1 and 0,2 million inhabitants.

The total served population of 4,7 millions is divided into 346 municipalities and a total area of 8.810 km^2.

According to this structure, users have access to the entire transport public offer, but tickets are divided according to the number of zones they use during a trip.

5.3.2 BACKGORUNDS

Before 2001, different transport-operators consolidated its pricing structures according to different standards, fixed by three public organisms. As a result, there were none homogenous criteria to fix the fare Euros/pax-km, and neither a homogeneous physical support to provide transport tickets.

There was a total amount of 41 transport operators (3 responsible of rails and 38 bus -operators), and a total amount of 5 fare-models in the named Metropolitan Region of Barcelona (RMB):

- Flat rate in the central zone
- Kilometre-fare for the FGC-supply
- Kilometre-fare for the interurban buses, which where managed through concessions from the DG de Ports I Transports
- Kilometer-fare from the Transport Metropolitant entity (TME)
- Crown system from Rodalies-Renfe for the trains

5.3.3 MAIN BASIS

The main basis to consolidate the system as the current integrated fare-system managed by the ATM were the ones shown below:

- All transport titles (tickets) belong to the system, and ATM on its own is the main organ which is in charge of fixing the total fare imports as long as its distributions for users.
- User pays in a discretized way according to the travelled distance, based on the concentric crown system.
- The system needs to be easy to understand and reed by the user
- Transfers do not imply an extra cost for users in monetarized terms. The tickets allow users to transfer between modes during a specific interval of time, which depends on the ticket.
- Implementation of a user-loyalty policy: The relative price per trip is reduced in function of its number of uses.
- Financial coverage so that the public transport deficit does not extremely increase.

5.3.4 UNIMODAL-TICKETS

Each company operating one of the integrated public transport modes also offers unimodal tickets, as isolated trips in which user is not allow to transfer. They are only available on the mode for which the user has paid, and are normally linked to a single trip:

TABLE 5-2– UNIMODAL TICKETS BY MAIN OPERATOR (SOURCE: OWN CONSTRUCTION FROM FGC, RODALIES, TMB)

Single ticket (€)	FGC	Rodalies	TMB
1 ZONA	2,15	2,15	2,15
2 ZONES	3,00	2,50	-
3 ZONES	4,00	3,40	-
4 ZONES	5,10	4,10	-
5 ZONES	6,50	4,90	-
6 ZONES	7,60	6,15	-

However, also offers monomodal-ticket discounts that include more than one trip, but user cannot use any of the other modes. They do normally correspond to social tickets or special tickets for going to the airport.

FIGURE 5.3-3. - UNIMODAL TICKETS BY MAIN OPERATOR: TARGETA DE PENSIONISTA (LEFT), BONOTREN (MIDDLE) AND BITLLET AEROPORT (RIGHT) (SOURCE: FGC, RODALIES, TMB)

5.3.5 MULTIMODAL-TICKETS

The implementation of the integrated fare system also led to the definition of new integrated tickets, coexisting with the singles ones from each operator. The prices of these are agreed and reviewed annually between the main entities which conform the STI and the ATM itself.

The policy of "Retain the user" served as basis to fix prices and tickets. The STI establish a pricing policy for tickets in which the unitary price of a trip was lower according to the frequency of use and the distance of travel. The policy aims to reduce too much the price of tickets without causing extra costs to operators and maintaining good coverage coefficients from incomes.

There is a wide range of integrated tickets as well as integrated tickets with special bonifications (such as for unemployers, retireds etc.), each one with a different unit price per trip. The main principle for fixing the range of prices and tickets is providing multizonal tickets depending on the origin-destination of the trip.

The main used tickets are described below:

- **T-10 – ticket:** Allows users to make 10 integrated trips while combining in each of them until 4 different transport modes.
- **T-50/30:** As a unipersonal and monthly transport ticket. It allows one single user to do 50 integrated trips in any mode during 30 days.
- **T-70/30:** Allows multiple users do 70 integrated trips in different modes in a month (30 days).
- **T-Mes:** Unipersonal ticket with an unlimited number of available trips during a month. The user is allowed to use all transport modes in the same fare zone.
- **T-Trimestre:** Unipersonal ticket which allows an unlimited number of trips in all kind of modes operating in the city during 90days, starting the first validation day.

- **T-Jove:** Unipersonal transport ticket, available for the ones under 25 years old. It allows users to use an unlimited number of trips during 90 days (3 months), starting the day of the first trip.

Tickets also differ regarding prices depending on the number of zones:

TABLE 5-3– PRICE FOR EACH TICKET AND ZONE IN THE STI (SOURCE: OWN CONSTRUCTIONS FROM DATA OF ATM, 2017B)

TÍTOL	T-10	T-50/30	T-70/30	T-Mes	T-Trimestre	T-Jove
1ZONA	9,95	42,50	59,50	52,75	142,00	105,00
2ZONES	19,60	71,00	86,05	77,45	211,00	155,00
3ZONES	26,75	99,60	118,00	105,00	290,00	210,00
4ZONES	34,45	122,00	144,50	124,50	342,50	249,00
5ZONES	39,55	140,00	165,50	143,00	390,00	285,50
6ZONES	42,05	150,00	179,50	153,00	406,00	305,50
						

With this policy, users need to pay a single fee for each trip, regardless the number of stages and modes using the same.

It is needed to property differentiate the concept of trip and stage, being the first concept understood as the result of a single journey made by the user from an origin to a destination. On the other hand, is defined as a stage, all used modes for the same trip. Therefore, the displacement is directly involved with the charge, while the stage is linked to a validation.

FIGURE 5.3-4. - EXAMPLE OF THE INFORMATION CONTAINED IN A SINGLE INTEGRATED T-10 TICKET (SOURCE: ROSELLÓ X., 2006)

5.4 T-MOBILITAT

Recently, ATM has planned to implement a new ticketing system based in a contactless magnetic card in which users will be able to integrate all their transport bonds T-Mobilitat is planned to be implemented in stages starting in 2017 and finalizing in 2019. The solution will lead the authority to better manage the global behavior of users and built a significant database to better analyze the provided service. It will substitute the current 80 existing transport tickets and change the pricing policies, since users will pay according to its mobility patterns and usage of the scheme.

SocMobilitat is the company which awarded the T-Mobility project. The company is carrying out the implementation process which will include 14.000 terminals in access controls, new vending machines in stations, buses, trams etc. The transport authority ATM is the owner and keeps the control of the system.

5.5 FARE-INTEGRATION PERFORMANCE

The fare-integration performance is based on information. Some integrated transport tickets include a bit tracking, so it can be check with enough reliability the itinerary carried on by the ticket during a trip. For example, regarding T-10 ticket, the 10% of them incorporate the bit tracking. In basis of this information, ATM then distributes the single income of a trip between the different involved agents.

According to this basis, ATM builds a data base in basis of general mobility statistics and basic queries. As a result, the company build its own management system of the fare-integration for the system:

- **Distribution and compensation politics of the total incomes coming from the sales** between the main transport stakeholders (operator, financing entities etc)
- Sales and validation treatment
- Basis for fixing the tickets and fare prices
- Distribution of tickets and transport titles

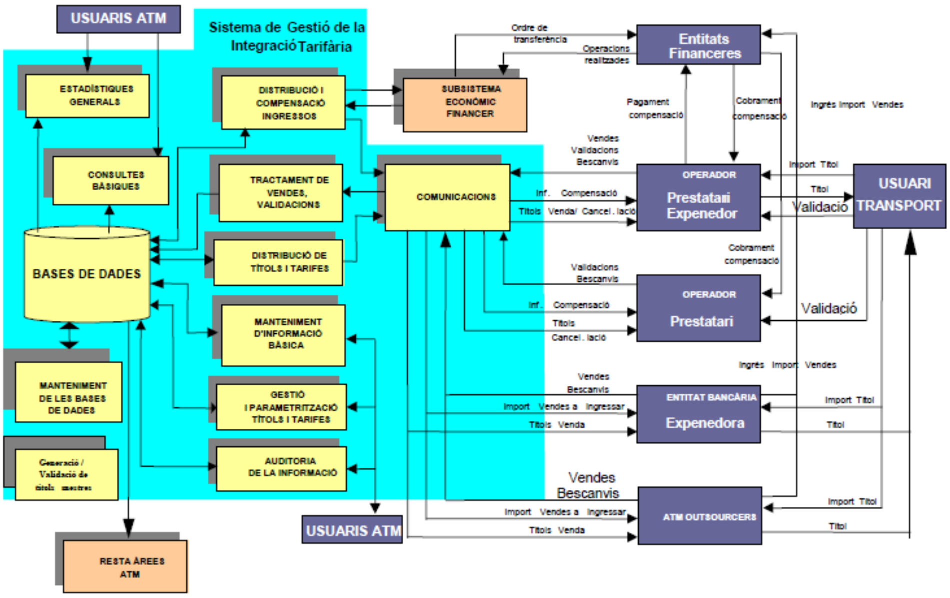


FIGURE 5.5-1. - FARE INTEGRATION PERFORMANCE. (SOURCE: ROSELLÓ X., 2006)

5.5.1 Distribution and compensation policy

The explained data base and tickets allows the transport authority estimate the number of stages carried out and with which operator they were realized.

As mentioned before, user pays only one single fare, regardless the number of validations in different modes of transport he does, since the main basis of the STI is the free-charges for transfers. With this structure, when changing mode, user does not pay twice and therefore, the operators receive a lower import for each validation, since they have to divide the total incomes of the total integrated trip.

The ATM founded some rules to distribute all incomes coming from integrated tickets as well as compensate the possible losses of money the integration could cause to them. From the bit tracking installed in some tickets, the authority can estimate the stages of each trip and built an algorithm taking into account the net fare and the modal chain realized on a trip.

Rules for distibution

Distribution is understood as the charge to operators from the total incomes coming from the integrated weighted average fare named "A". The rules for distribution takes into account the collected net fare and the modal chain of each trip, obtained through an algorithm called intermodality-rate.

The bit tracking allows reconstructing stages of each trip and estimate the intermodality rate in order to decide the rules for distributing the total incomes managed by the ATM.

The are some general rules for distributing the incomes of a trip between the involved operators:

1-Single stage	$R = T$	*Eq.1*
2-stages, one urban zone + one interurban zone	$U = {}^{1}/_{2} * A$ $I = T - U$	*Eq.2*
3-stages, one urban zone + interurban zone + interurban zone	$U = 0{,}45 * A$ $I_1 = (T - U) * Z_1/Z$ $I_2 = (T - U) * Z_2/Z$	*Eq. 3*
4-stages, one urban zone and the rest interurban zones	$U = 0{,}43 * A$ $I_1 = (T - U) * Z_1/Z$ $I_2 = (T - U) * Z_2/Z$ $I_3 = (T - U) * Z_3/Z$	*Eq.4*

Where:

$T := Fare\ income$

$R := Income\ of\ the\ generic\ operator$

$U := Urban\ operator\ income$

$I_k := k - interurban\ operator\ income$

$\boldsymbol{A := Average\ integrated\ fare\ regarding\ in\ the\ 1 - zone}$

$Z_k := Number\ of\ travelled\ zones\ with\ the\ k - operator$

$Z := Total\ number\ of\ travelled\ zones$

Similar formulas are used in all possible stage-combinations.

Rules for compensation

Compensations is understood as the charge to operators due to the different between the A after and before integration. The aim is to compensate the number of trips before integration, and operators do not experience any loss of incomes or users in their service.

With the introduction of integrated modes, operators may lose money, since they become a lower income for trip since they have to divide the total import of an integrated trip:

$$Unitary\ integrated\ fare < \sum_{i=1}^{n} Unitary\ fare_i \qquad Eq.5$$

Being the variable *i* the used mode.

5.5.2 Average integrated fare "A"

As explained before, the main basis of the integrated fare system performance regarding incomes, is the term named as *Average integrated fare regarding the 1-zone*. In basis of it, the incomes are divided through the different operators.

This fare-term was first stablished in 2001, when consolidating the STI system of the ATM. IT was estimated as the average fare payed per unit of trip and user in the current named 1-zone. From 2001 until now, this term was actualized in basis of IPC (*índice de precios de consumo)*, which is defined as an economic indicator in which are valuated a predetermined set of goods and services (popular known as familiar basket).

For 2015 this fare was stablished in $\boldsymbol{A = 0,69}$ €$/\boldsymbol{trip}$ (ATM, 2017c)

5.5.3 Subsidies policy

Financing is one of the main challenges for the Transport authority, since one of its main goals is providing a good sustainable mobility which can offer a good alternative to private transport in daily displacements for citizens.

It is well known, that the public transport is a society good, and its profitability is also worthy in social terms: social equality, pollution reduce etc. However, these terms cannot be taken into account in user's incomes, and therefore operators do not cover its costs through the sold tickets. As a result, subsidies coming from public administrations are needed.

The obtained database also is useful to estimate the global cost of the integrated system. According to demand estimations and expected incomes, the ATM can also estimate the required public subsidies to cover the total cost of the STI by mode.

5.6 PRINCIPAL RESULTS

The implementation of the STI in the metropolitan region of Barcelona had qualitative and quantitively benefits, which were evaluated after a year of its implementation. On the one hand, the perception of the public transport for residents considerable improve. On the other hand, a centralized management of the public transport enabled to better establish budgets and estimations.

In facts, the amount of trips growth about a 7% in 2001 respect to 2000, with the implementation of the STI. No compensation was needed for any of the involved operators. The percentage of integrated tickets was about the 60%, being the T-10 ticket the most used one and its income represented over the half of the global public transport system. Moreover, the intermodality rate growth from a 8,3% in 2000 to 18,7 in 2001 (Roselló, X., 2006).

6. PUBLIC TRANSPORT ANALYSIS

In this chapter, a brief view of the global public transport turnover will be analysed and particularized for the integrated system of the ATM. According to the last available data, the performance of the service in 2015 will be the main focus, specially the significance of the STI and the intermodality between integrated modes.

In order to do so, it is necessary to focus firstly on the global volumes of the system, and then analyse them in detail for each of the different operators. The main indicators of the public transport turnover are incomes, subsidies and the operating costs:

- **Fare incomes**, defined as the reuptake from users according to the sold tickets in economical units. Its total amount can increase by increasing prices or its demand. They can be divided into the ones coming from the not integrated (unimodal) tickets, and the integrated ones.

- **Subsidies,** defined as administrative economical participations. It normally involves public administrations at national, regional and urban scale such as the Catalan government (*Generalitat de Catalunya)* and the city hall (Ajuntament de Barcelona).

- **Operating costs,** defined as the cost that involves operating the system. Its value is estimated through the public transport authorities in order to predict the incomes and subsidies they will need to cover the taxes.

6.1 GLOBAL PUBLIC TRANSPORT

A global public transport analysis allows to understand the mobility characteristics by transport mode in the area of influence in Barcelona.

The three main indicators for the system in 2015 are summed up in the following table:

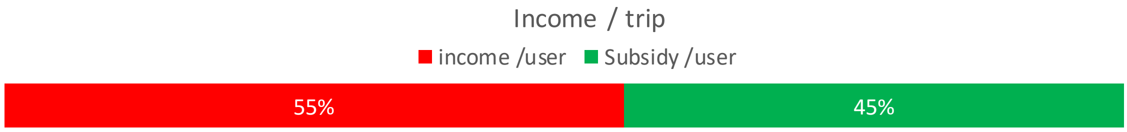
TABLE 6-1– MAIN INDICATORS OF THE GLOBAL PUBLIC TRANSPORT FINANCIATION (SOURCE: ATM, 2015B)

	INCOMES (M€)	SUBSIDIES (M€)	COST (M€)
Total	**768,9**	**621,6**	**1.390,4**

The administrative participation in terms of economical subsidies, allows the system to cover the entire annual cost. The coverage rate is the proportion of the annual cost which can be covered through the incomes coming from users:

$$Coverage\ rate = \frac{Incomes}{Annual\ costs} \qquad Eq.\ 6$$

In an ideal scenario, this rate would be 100% or above, allowing public transport being a profit business. However, this rarely occurs, being for the public transport in Barcelona about the 55%:



GRAPHIC 6.1 14. – AVERAGE INCOME PER UNITARY TRIP (SOURCE: OWN CONSTRUCTION)

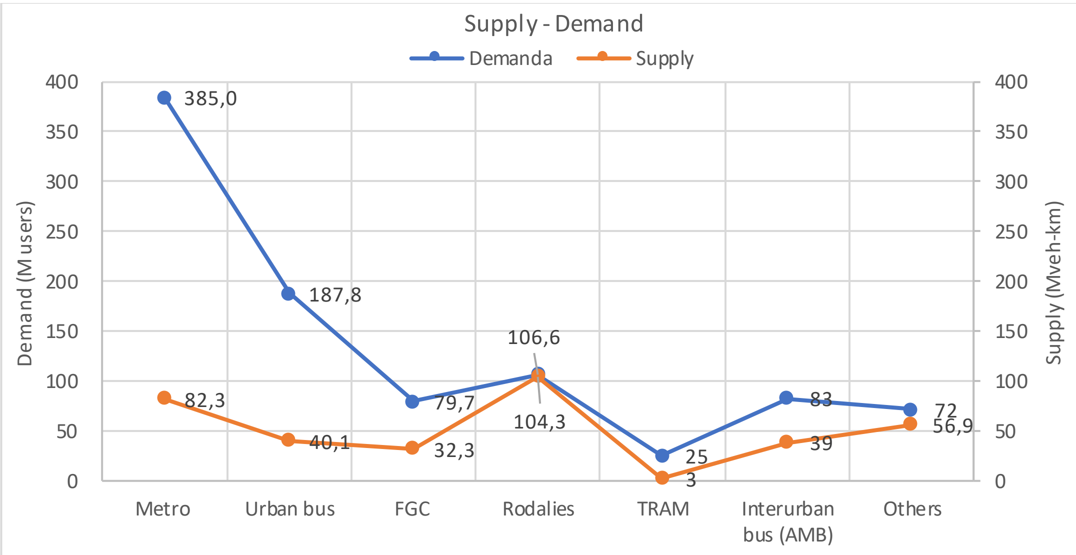
6.1.1 Supply-Demand analysis

The supply and demand analysis can be analysed through the main transport modes in the city: Metro, urban buses (owned by TMB); FGC, Rodalies, Interurban buses and Tram service.

With the available data, the total transport operating scheme in the RMB can be summarized in the following table:

TABLE 6-2– MAIN INDICATORS OF PUBLIC TRANSPORT IN TERMS OF SUPPLY AND DEMAND IN 2015 (SOURCE: ATM(2015A)

	LINES	LENGHT (KM)	VEHICLES-KM (MILLIONS)	DEMAND (MILLIONS)
Metro (TMB)	7	103	82,3	385,0
Urban bus (TMB)	100	873	40,1	187,8
FGC	2	147	32,3	79,7
Rodalies (Renfe)	7	516	104,3	106,6
TRAM	6	29	2,5	25
Interurban bus (AMB)	130	2.245	39	83
Others	541	13.400	56,9	72
Total	769	16.380	355,5	939



GRAPHIC 6.1 15. – SUPPLY AND DEMAND OF THE GLOBAL PUBLIC TRANSPORT IN TERMS OF MILLIONS OF USERS AND VEH-KM IN 2015 (SOURCE: OWN CONSTRUCTION FROM ATM, 2016A)

There is usually a decoupling between the demand, measured through the millions of trips taking place in the system; and the offered supply, measured through the millions of veh-km. The reason is the demand's behaviour, since the offer has not a significant elasticity in terms of generating demand. Specially for the metro service, which is the one covering more trips, with a low supply-performance.

The graphic above shows the significant of the rail mode in the global mobility of the city, representing the 64% of the trips; whereas the bus-modes just represent the 36%.

Concretely, the Metro serves the 41% of the total demand in the entire system, whereas it just owns 21% of the total length of the system. As it occurs in all main European cities, the Metro is understood as the fastest and most popular transport system inside urban areas, so it's the highest mobility focus.

6.1.2 Economic analysis

From the provided data in 2015, its global incomes and subsidies can be known separated according to the different transport modes.

TABLE 6-3– TOTAL INCOMES, AND SUBSIDIES BY OPERATOR IN 2015 (SOURCE: OWN CONSTRUCTION FROM ATM, 2016B).

	Incomes		Subsidies	
	Total (Million €)	%	Total (Million€)	%
Metro	254,6	33%	172,3	28%
Urban bus (TMB)	136,7	18%	159,1	26%
FGC	72,8	10%	46,3	7%
Rodalies (Renfe)	140,8	18%	3,9	1%
TRAM	13,4	2%	95,5	15%
Interurban buses (AMB)	86,9	11%	109,1	18%
Others	63,8	8%	35,6	6%
Total	768,9	100%	621,6	100,0%

Being again the metro the transport mode with the highest value for incomes, with a total 254,60 million euros coming from direct from users and representing a 33% of the global incomes. On the other hand, the lowest income come from the TRAM, according to the fact that its system has just 2 global lines divided into 6 different itineraries.

6.2 FARE INTEGATED SYSTEM (STI)

The STI turnover results are part of the global public transport results, considering just the users using the integrated tickets and modes in the system:

TABLE 6-4– INCOMES AND DEMAND OF THE GLOBAL TRANSPORT SYSTEM AND THE STI (2015). (SOURCE: OWN CONSTRUCTION)

	INCOMES (Million €)	DEMAND (Milion trips)
Total PT	*768,9*	*938,9*
Total STI	*491,2*	*677,9*
% STI	**64%**	**72%**

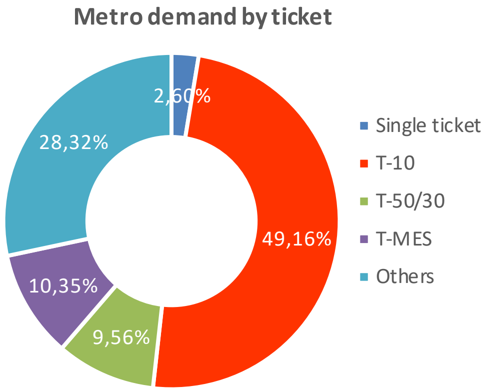
According to the table, the significant of the STI volumes inside the global public transport can be seen; representing a 64% of the global incomes, and above the 70% of the annual trips taking place in the city.

From the global incomes and demand of the STI service, it can be estimate that in average, users pay an amount of **0,724 €/integrated trip**.

Particularizing for the Metro case, above the 70% of the demand correspond to STI users. Specially the T-10 ticket, which represents almost the half of the global demand for 2015:

TABLE 6-5– DEMAND BY TRANSPORT TICKET IN THE METRO (SOURCE: IERMB, 2016A)

	Single ticket	T-10	T-50/30	T-MES	Others	Total
Demand (M users)	10,0	189,3	36,8	39,9	109,0	**385**
% demand	2,6%	49,2%	9,6%	10,4%	28,3%	**100%**



GRAPHIC 6.2 16. – WEIGHT OF EACH TRANSPORT TICKET IN METRO (SOURCE: OWN CONSTRUCTION FROM IERMB, 2016A)

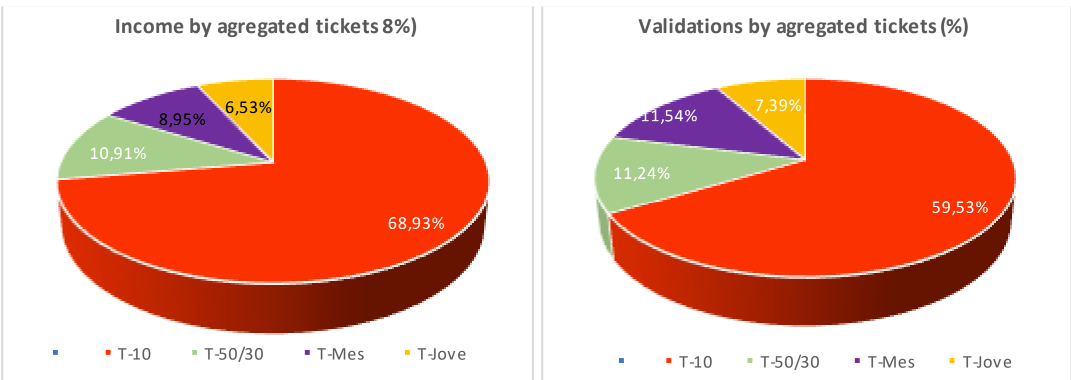
6.2.1 Weight of integrated transport tickets

With the provided data, is possible to know the total incomes and registered stages performed during the year 2015, since the open-data tool of ATM enables all users to obtain certain information of the system.

The following table shows the incomes and stages by aggregated ticket, proving that the T-10 transport ticket plays an important role, since represents about a 69% of the total incomes and a 60% of the total ticket's validations registered in the system for this year (ATM, 2016e):

TABLE 6-6– INCOMES, STAGES, SALES AND INTERMODALITY BY TICKET FROM STI (2015)
(SOURCE: OWN CONSTRUCTION FROM ATM, 2016C)

	INCOMES		VALIDATIONS		SALES		INTERMODALITY
	Million €	%	Millions	%	Millions	%	%
T-10	338,54	69%	403,5	62%	32,9	93%	**21%**
T-50/30	53,6	11%	76,2	12%	1,2	3%	**28%**
T-70/30	2,8	1%	3,6	1%	0,04	0%	**23%**
T-Mes	43,9	9%	78,2	12%	0,8	2%	**28%**
T-Trimestre	5,1	1%	17,2	3%	0,04	0%	**28%**
T-Jove	32,1	7%	50	8%	0,3	1%	**27%**
T-FM/FN	11,7	2%	25	4%	0,2	1%	**21%**
Others	3,4	1%	24,2	4%	0,3	1%	**15%**
Total	**487,7**	**100%**	**653,8**	**100%**	**35,5**	**100%**	**24,5%**



GRAPHIC 6.2 17. – INCOMES AND VALIDATIONS BY AGGREGATED TICKETS (SOURCE: OWN CONSTRUCTION FROM ATM, 2016C)

6.2.2 Fidelizing users-policy

The fidelizing users-policy corresponds to the pricing policy stablished for the STI in which the trip price was fixed according the frequency of use and the travelled distance.

Considering the amount of validated stages and sales, the average number of trips per ticket can be estimated. From there, knowing the structure of current prices, the discounts between them and the single ticket 2,15€ for each case can be computed.

TABLE 6-7– INCOMES, STAGES, SALES AND INTERMODALITY BY INTEGRATED TICKET OF STI (2015) (SOURCE: OWN COSNTRUCTION)

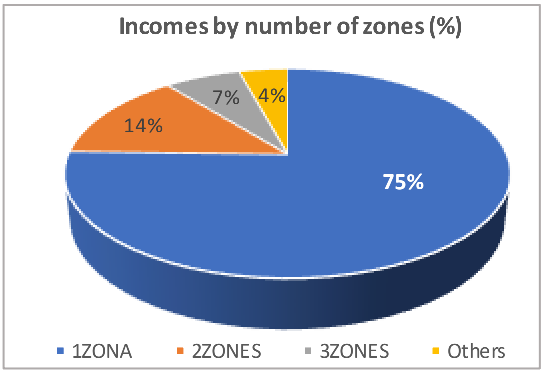
	Average amount of trips/ticket	Price/trip	% Discount
T-10	12	0,81	**62%**
T-50/30	63	0,68	**69%**
T-70/30	85	0,70	**68%**
T-Mes	95	0,55	**74%**
T-Trimestre	453	0,31	**85%**
T-Jove	188	0,56	**74%**

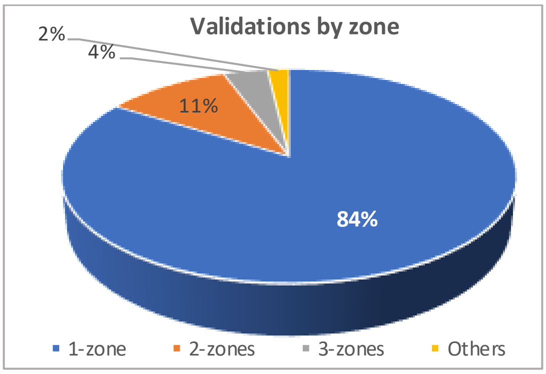
6.2.3 Weights of zones

The same table is shown in terms of the total incomes and stages by crown considered, showing the huge impact of the first crown, which corresponds to the 75% of the total incomes and 84% of the total registries in the system:

TABLE 6-8– INCOMES AND STAGES OF STI BY ZONES (SOURCE: OWN CONSTRUCTION FROM ATM, 2016C)

	INCOMES		VALIDATIONS	
	Incomes (Million €)	%	Stages (Millions)	%
1 ZONE	370,6	75,5%	568,6	84,7%
2 ZONES	67,5	13,8%	71,4	10,5%
3 ZONES	32,2	6,6%	25,4	3,7%
4 ZONES	10,4	2,1%	6,8	1,0%
5 ZONES	3,0	0,6%	1,6	0,2%
6 ZONES	7,5	1,5%	4,3	0,6%
Total	**491,2**	**100,00%**	**678**	**100,00%**





GRAPHIC 6.2 18. – INCOMES AND VALIDATIONS BY ZONES (SOURCE: OWN CONSTRUCTION FROM ATM, 2016C)

6.3 INTERMODALITY

Intermodality is understood as changes in the transport mode or line inside the STI-system. The transfers between modes is known through the tracking chip installed in some tickets managed by the ATM, since is the basis for the distribution of incomes between modes.

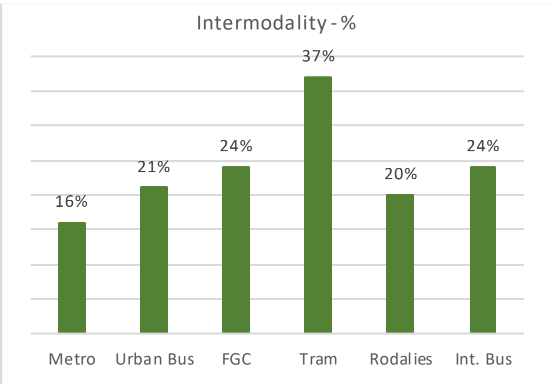
The following table shows the intermodality trips and % by the principal modes operating in Barcelona (ATM, 2017c):

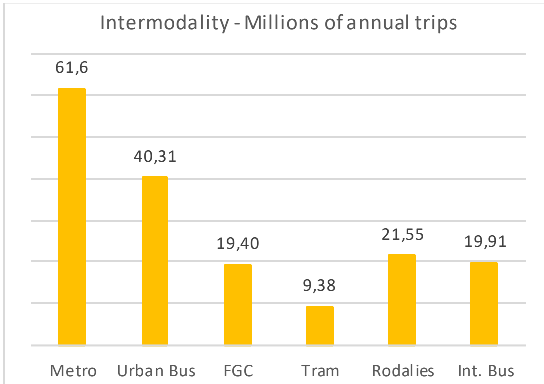
TABLE 6-9– INTERMODAL TRIPS IN 2015 AND % PER MODE (SOURCE: ATM, 2017C)

	MONOMODALITY		INTERMODALITY	
	Total (M)	%	Total (M)	%
Metro	323,4	84%	61,6	**16%**
Urban Bus	147,5	79%	40,31	**21%**
FGC	60,3	76%	19,40	**24%**
Tram	16,0	63%	9,38	**37%**
Rodalies	85,1	80%	21,55	**20%**
Interurban bus	63,1	76%	19,91	**24%**
Total	**695,34**	-	**172,19**	-

Being the lowest rate of intermodality for Metro users. However, it is needed to comment that the data is estimated from validations of tickets. Since for changing from one line to another for Metro is integrated in the same underground terminal, there is no need to validate again the ticket. Therefore, the estimation of its intermodality loses all users that transfer without registering the ticket, and the approximation may not be showing the real transfer between metro lines.

As check in the following graphics, regarding annual trips, the highest significance falls on Metro while in %, the highest intermodality-rate corresponds to Tram.





GRAPHIC 6.3 19. – INTERMODALITY RATE IN %(LEFT) AND MILLIONS OF ANNUAL TRIPS (RIGHT) (SOURCE: OWN CONSTRUCTION FROM ATM, 2017C)

Apart from global data, the bimodal chains can be represented in matrix terms, involving the main modes:

TABLE 6-10– BIMODAL CHAINS IN 2015 PER O-D MODE. TERMS IN MILLION OF ANNUAL TRIPS (SOURCE: OWN CONSTRUCTION)

Users (M)	Metro	Urban Bus	FGC	Tram	Rodalies	Int. Bus
Metro	11,6	13,2	13,5	4,6	12,2	6,6
Urban Bus	13,2	18,8	2,4	1,1	2,1	2,7
FGC	13,5	2,4	0,8	0,3	1,0	1,4
Tram	4,6	1,1	0,3	0,8	2,1	0,5
Rodalies	12,2	2,1	1,0	2,1	1,1	3,0
Interurban Bus	6,6	2,7	1,4	0,5	3,0	5,7

The data was obtained from internal mails with the responsible organ of the integrated fare system of ATM (STI). Notice that the matrix is symmetric, and represents annual trips in each mode. The global bimodal chain represents the 18% of the total trips taking place in the system.

The most significant chains in the system are the ones that follow, with its weight in the global intermodal trips:

TABLE 6-11– MOST SIGNIFICANT BIMODAL CHAINS IN 2015 AND % PER O-D MODE (SOURCE: OWN CONSTRUCTION)

USERS (M)	MILLION TRIPS / YEAR	%
Urban bus – Urban bus	18,8	11%
Urban bus - Metro	13,2	8%
FGC – Metro	13,5	8%
Rodalies – Metro	12,2	7%
Metro - Metro	11,6	7%
GLOBAL	**69,3**	**41%**

The highest rate is transfer between urban buses, which responds to its grid structure. Apart from these intern transfers, metro mode involves about the 60% of intermodal trips.

PART III

Integration of the Bicing scheme into the STI

Estimation of the impacts

7. FARE INTEGATION OF BICING INTO THE STI

Bike sharing schemes such as Bicing, appear as an alternative way of moving through cities avoiding congestion and covering the named as "last mile" of an intermodal chain. In previous part I, the main principles of European bike sharing schemes were compared and particularized for the Bicing case.

Bicing is a service working through a low annual subscription of 47,2 €/year. Users pay for the annual service but do not use it as a regular mode but for punctual trips in which intermodality has significance. Integration is therefore, one of the keys of success in Bicing:

- Physical integration, which responds to allocation of stations near each other to make easier transfers.
- Integrated information
- Fare integration, referred to provide a global fare system for different modes and no access-barriers.

Both physical and integrated information appear already in bike sharing schemes since its implementation. However, fare integration is a more complex issue.

On the other hand, the performance of the global public transport system in Barcelona was exposed. The significance of the STI lies in the establishment of an integrated and intermodal readable system. In general terms, the sold tickets after the implementation in 2001 increase about a 7% and the intermodality-rate achieve the 21% value. Today, in demand terms the STI perceived the 72% of the total demand and about the 64% of the total public transport incomes (Chapter 6.2). As seen, integration is also one of the key of success and growth of public transportation in Barcelona.

Based on the significance of integration for Bicing and the STI system for the global public transport, the possibility of its fare integration into the STI as any another mode will be analysed.

The integration could absorb part of intermodal demand coming from other modes in some specific cases, in which user could avoid congestion or obtain a better door-to-door coverage. According to the principles of the STI, users will no pay an extra fee for changing the mode, so they will not percept any change if transferring to Metro or urban bus or Bicing. On the other hand, Bicing will get into the distribution and compensatory policy of the ATM as any other mode, without changing the pricing policy of the STI.

Two barriers are identified as "obstacles" to be taken into account: <u>access barrier and pricing per trip-barrier.</u>

7.1 Access - barrier

Today, Bicing members have to receive specialized magnetic card as keys to unlock bikes within the city system, and the subscription is limited to an annual fare and for residents. In the future, the sharing-scheme could operate seamlessly with the new transit system card named as T-Mobilitat.

T-Mobilitat is planned to be a contactless card in which users can charge different transport titles. Registration of users will be needed as it occurs with current system of tickets, just for nominal tickets such as T-Jove, T-Trim etc. This support would lead also Bicing-users to register in the data base and allow the service to charge extra fees in case of damage or incidents.

As seen, T-Mobilitat will delete any access-barrier between public transportation and Bicing-scheme.

7.2 Pricing – barrier

According to the analysed bike sharing schemes, there is no experience in pricing per trip, but diary or weekly tickets. The perception of flexible transport system such as bike sharing is a low-cost way of travel which offers a flat rate (normally of 30 minutes) and whose demand needs to be limited, since its capacity is low in comparison to traditional modes. The pricing structure is fixed for extra minutes of riding, not for trips.

Evaluating the possibility of paying per trip per Bicing means comparing the price users are willing to pay for it with the price of other public transport tickets. Currently, users pay a fixed annual fare and can use the scheme unlimitedly being the price per trip cheaper the more they use the service. According to global incomes and the usage rate per user and day (Chapter 4.5), users pay and 0,34 €/trip in average. However, if considering regular demand which use the scheme 270 days/year the average income drops to 0,09 €/trip meaning 3 times lower than the average payed.

According to the distribution rules (Chapter 5.5), in average one-trip of an integrated ticket corresponds to A= 0,69 €/trip which is 2 times the average income per user in Bicing and 13 times higher the one regular users pay. If proposing a fare integration for Bicing inside the STI, the structure of pricing per trip implemented in other traditional modes would not possible, since no user would be willing to change from annual subscription to pay per trip. Therefore, the annual subscription for residents will be kept as part of the scenario of fare integration, and the scheme will be open to the rest of the STI.

However, for intermodal trips pricing per trip has some potential for Bicing scheme. Distribution rules show that for bimodal chain, urban mode receives $U = {}^{1}/_{2} * A$, which means about 0,35 €/trip. The rate is similar to the one perceived nowadays for Bicing scheme. Users would no perceive any extra fee since one of the main basis of the STI is "free of charges transfers", and the total system would no perceive economical losses.

The main steps to provide a scenario of integration focusing on intermodality are the ones that follow:

- Comparison between Bicing and the other implemented modes in the city in order to diagnose with which modes the scheme is better integrate and can compete.
- Study the competitive-range of Bicing for changing the mobility patterns of some intermodal trips. In basis of the comparison, the candidate mode will be selected and invested time for users that transfer on it will be analysed.
- Demand viability, as the intermodal potential demand that could transfer to Bicing mode.
- Estimate some of the impacts that the fare integration could have in terms of demand and finance.

8. COMPARISON BETWEEN MODES

The comparison aims to better analyse the role of Bicing mode inside the city and its direct competitors, by focusing on the coverage of each of them towards Bicing. Moreover, the objective is to identify the interaction between the sharing scheme and the other modes.

Considering the entire Metropolitan Region of Barcelona (RMB), the public transport consists in an extensive system that allow users get anywhere within the region, and specially provides good connections with the city.

The comparison will be limited to the services operating inside Barcelona, and in the first crown to also consider some interurban modes:

FIGURE 7.2-1. - ATM FIRST CROWN (SOURCE: AMB)

Since the main issue is to identify the main competitors and the modes which better interact with Bicing, the weight of the intermodality with different modes is needed to be taken into account:

TABLE 8-1– INTERMODAL MODES WEIGHT INVOLVING BICING-MODE (SOURCE: OWN CONSTRUCTION)

Intermodal modes	%
Metro	34%
Rodalies	22%
FGC	14%
Urban bus	10%
By food	8%
Tram	4%
Interurban bus	4%
Car	3%
Others	1%

As seen, the principal rail services and urban bus have the highest significance in the intermodal trips, representing the 83% of the total intermodal chain involving Bicing-mode.

All data used in the following chapters was obtained through Manamgent Reports of the Transport Authority ATM, from particular reports of each single transport company (TMB, TRAM, Rodalies and FGC) and either from the city council (Ajuntament de Barcelona) for demographic and territorial data. For all of them, 2015 was analysed, in order to use data consistent with those used in other chapters

8.1 TERRITORIAL COVERAGE

The coverage of a service refers to two main factors: the served area and population. Therefore, its influence over the territory is understood as the area of the municipalities they serve, and the population of these municipalities.

Bicing is understood as an urban transport mode, which operates inside the city. However, its service is only extended to 47 of the total 73 neighbourhoods of the city, which means that the 36% of the neighbourhoods do not have any station inside its limits.

The coverage of the service is resumed bellow, being the location of stations directly linked to the presence of the service on a specific area:

TABLE 8-2– COVERAGE OF BICING (SOURCE: OWN CONSTRUCTION)

Neighbourhoods	*47*
Covered area	*55,2 km^2*
% of covered area respect to Barcelona	*55%*
Covered population	*1,32 Mhab*
% of served population respect to Barcelona	*82%*

Details of the coverage analysis appear in Annex I

Considering the entire population of Barcelona (1,6 M inhabitants) and its limits, which correspond to a total area of 101,3 km^2.

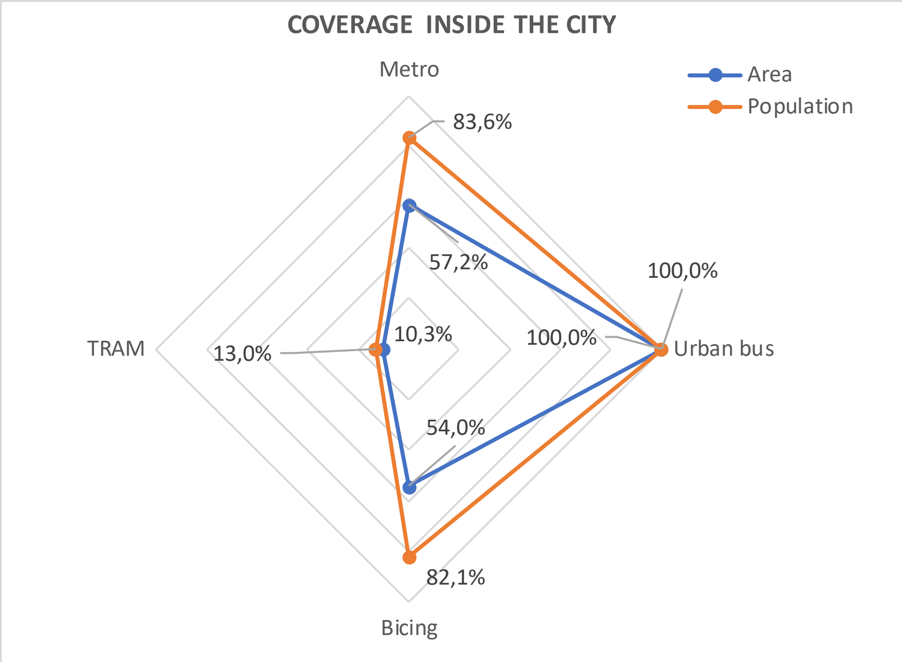
As seen, the service provides a good coverage in terms of served population, since its mainly centred on the densest areas of the city. The service is focus on the city centre and areas with low slope, and its presence decreases while getting close to the high parts of the city, which are the less dense ones.

The following table sums up the coverage in terms of served population and covered area limited to urban modes and considering that urban buses cover the entire city:

TABLE 8-3– AREA OF INFLUENCE AND POPULATION OF THE MAIN MODES AND NEIGHBOURHOODS (SOURCE: OWN CONSTRUCTION)

	AREA OF INFLUENCE (KM^2)	AREA OF INFLUENCE (%)	POPULATION (HAB)	POPULATION (%)
Metro	58,4	57%	1,3	84%
Urban Bus	102,2	100%	1,6	100%
TRAM	10,5	10%	0,2	13%
Bicing	**55,2**	**54%**	**1,3**	**82%**
BARCELONA	**100,3**	**100%**	**1.604.556**	**100%**

As checked, the closest modes are Metro and Bicing, with above the 50% of the city area covered and the 80% of the population served.



GRAPHIC 8.1 20. – COVERAGE IN TERMS OF SERVED POPULATION AND AREA BY URBAN MODES (SOURCE: OWN CONSTRUCTION)

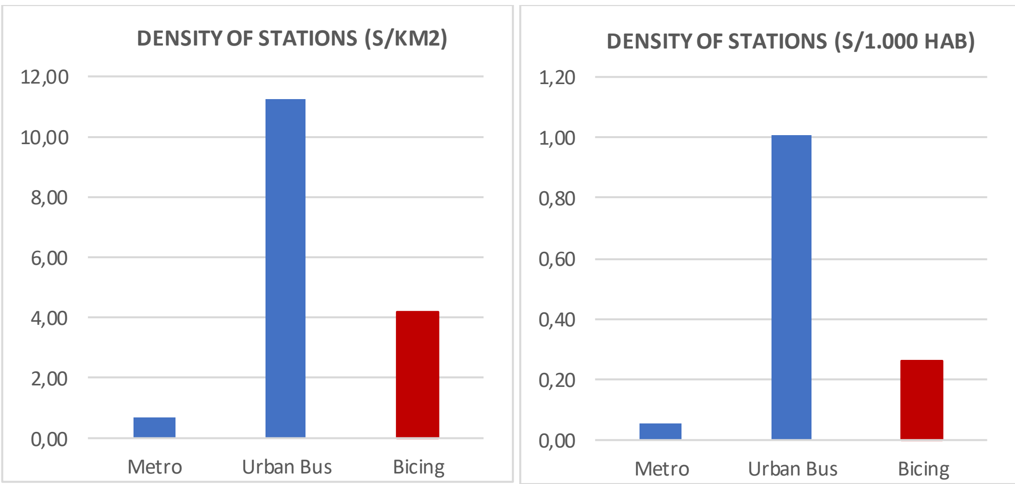
8.2 DENSITY

A usual indicator for density is the rate of stations in relation with covered area and its inhabitants. In this case the considered scale is municipalities by assuming that Metro is extended to Barcelona and 8 municipalities whereas Bicing is restricted for residents. TMB- urban bus have presence in 10 municipalities apart from Barcelona.

For both terms, the amount of stations located in the considered area and its population is considered:

TABLE 8-4– STATIONS AND DENSITY OF STATIONS OF EACH MODE (SOURCE: OWN CONSTRUCTION)

	METRO	*URBAN BUS*	*BICING*
Stations	*141*	*2.529*	*420*
S/ km²	*0,67*	*11,27*	*7,61*
S/1.000 hab	*0,06*	*1,01*	*0,32*



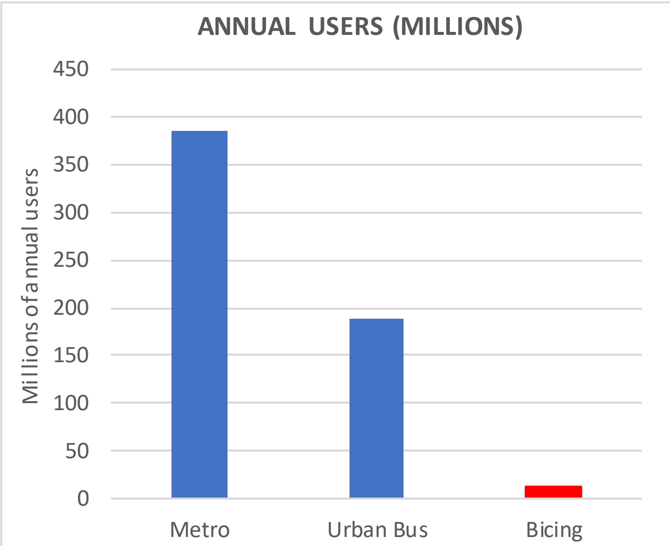
GRAPHIC 8.2 21. –DENSITY OF STATIONS PER KM2 COVERED AND 1.000 HABITANTS FOR EACH MODE (SOURCE: OWN CONSTRUCTION)

As observed, both terms maintain in general case the same order between modes, being the urban bus service the densest mode with an average of 11,3 stations per km^2, and above 1 stations each 1.000 habitant.

Bicing service is located between the urban bus and the metro mode, with a rate of almost 8 stations per km^2 of the urban limits of Barcelona. On the other hand, 0,32 stations are available for each 1.000 habitants.

8.3 DEMAND

The annual demand of each is registered as validations of each mode for the exercise of 2015 inside the first crown. The following figure shows the annual users for the analysed modes, being the metro and the urban bus service the highest demanded modes:



GRAPHIC 8.3 22. –ANNUAL USERS PER CONSIDERED MODE. TERMS IN MILLION USERS PER YEAR (SOURCE: OWN CONSTRUCTION FROM ATM, 2016A AND BS:M, 2016B)

Both Metro and Urban bus system are the dominant modes in terms of annual demand, since its weight inside the city is large and consolidated. As expected, the Bicing service is the system with the lowest demand, about a 12,5 million of uses per year beings 31 and 15 times lower than the metro and urban bus service respectively.

The differences in terms of average occupancy per veh-km are not that large as in demand terms, being Metro and urban bus just 5 times greater than the Bicing:

TABLE 8-5– AVERAGE OCCUPANCY, BY RATE OF PAX/VEH-KM (SOURCE: TMB,2015)

	RATE OF PAX / VEH-KM
Metro	4,68
Urban Bus	4,68
Bicing	1

8.4 SERVICE CHARACTERISTICS

A profile of provided service for each mode can be built, by knowing the typical distance and time in the system, as well as the average access time they need to access the system.

TABLE 8-6– SERVICE CHARACTERISTICS BY MODE (SOURCE: OWN CONSTRUCTION FROM TMB, 2015 AND BICING, 2015)

	METRO	URBAN BUS	BICING
Average travelled distance (km)	5,1	2,8	2,5
Average travelled time (min)	11,5	13,9	15,0

	METRO	URBAN BUS	BICING
Spacing between stations (m)	700	300	300
Average access time (min)	6	3,6	3,6
Commercial speed (km/h)	26,7	12,1	12
Headway (min)	3,5	5	-
Length (km)	101,3	873,18	120
Corridors	-	163,6	120

All terms excepting the average access time were obtained directly from sources of each mode. For the access time, an average walking speed of 5km/h was used.

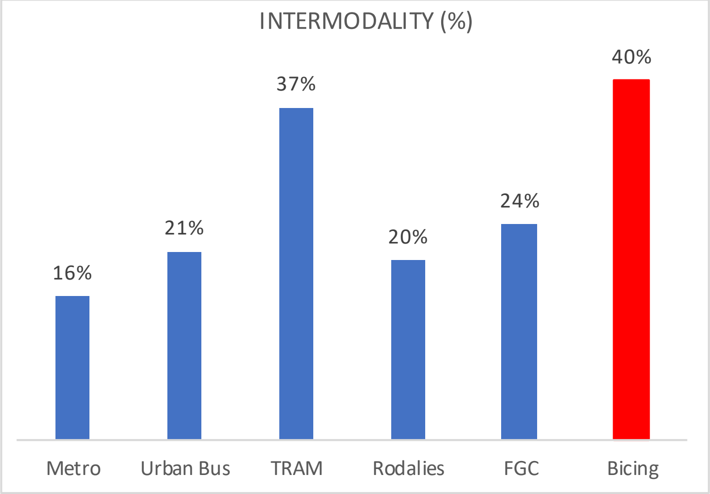
Traditional modes provide more competitive terms in almost all considered rates, since the commercial speed is higher. However, Bicing has some potential for access, since the spacing of its stations are smaller than the Metro ones and equal to the urban bus. Moreover, Bicing provides a flexible transit, letting users moving from many to many points in the city. Therefore, users do not need to transfer and the commercial speed in both is similar.

8.5 INTERMODALITY

The intermodality is considered in percentage in the entire metropolitan region of Barcelona, since concretely data for the first crown was not available.

The rate intermodal-monomodal trips may reflect the good integration between modes as well as the territorial coverage of it. In other words, intermodal trips in a mode which has a low territorial coverage, can reflect its lack of presence in the territory. On the other hand, a high rate in urban modes considering the intermodality in the entire region (RMB) show the importance of integration between interurban and urban modes.

The following figure represents the intermodal trips in % respect the total trips per mode in a year (2015), being Bicing the one with the highest rate:



GRAPHIC 8.5 23. –INTERMODALITY IN % OF INTERMODAL TRIPS RESPECT OF THE TOTAL TRIPS (SOURCE: OWN CONSTRUCTION)

As seen Bicing service is the one with the highest rate of intermodality. This responds to already mentioned fact that bike sharing is understood as a "last-mile" mode. Bicing role inside the public transport network is understood as a complementary service to cover the last (or first) part of a trip.

In % of intermodal trip, the second largest value corresponds to the Tram. However, the reason does not correspond on its role inside daily mobility but to its supply. Just two lines are implemented in the region, so they cover local trips and are use as part of the intermodal chain specially linked to Metro.

8.6 FUNDING CHARACTERISTICS

The main urban modes (Metro, Urban Bus) and Bicing differ in terms of its funding characteristics. Both traditional ones are financiered through their own incomes from tickets and public subsidies which are managed and fixed by the main authority ATM. On the other hand, Bicing is financed from own incomes, public subsidies fixed by the city hall and a sponsorship contract.

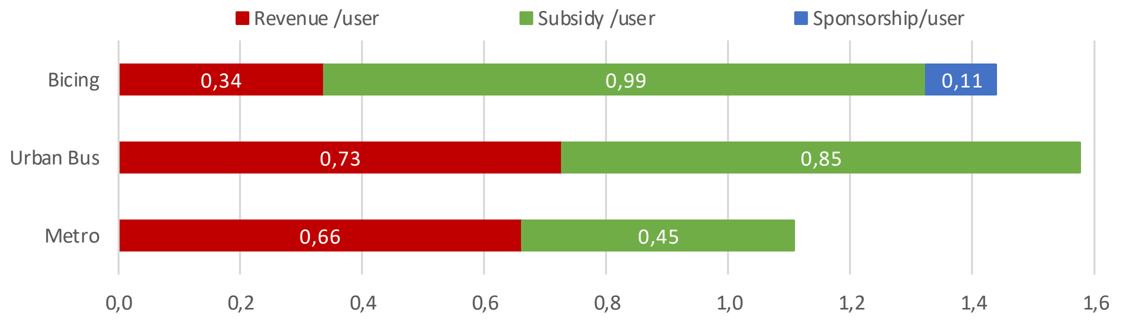
The global revenue, considering all terms involving the financing(revenues from tickets, sponsorship and subsidies) are summed up in the following table:

Table 8-7– Unitary incomes by trip and veh-km in 2015 (Source: Own construction).

	INCOME/ TRIP	INCOME/ VEH-KM
Metro	1,11	5,19
Urban bus (TMB)	1,57	7,37
Bicing	1,44	0,58

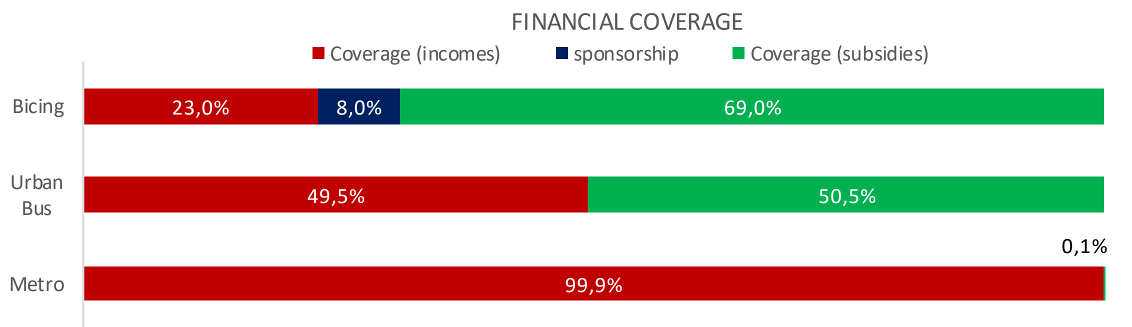
Comparing the global incomes in terms of veh-km allocates Bicing in an extremely low position in comparison with the other modes. While Bus and Metro increase the rate if considering the revenues per veh-km, Bicing rate is lower. The main reason is the fact that traditional modes, such as Metro and Bus are motor based, while Bicing is a mechanical service.

The global unitary revenues in user terms are close, being Bicing-rate between the other two. However, if separating in incomes and subsidies, the rates differ, being the Metro the only mode with a higher rate for incomes than subsidies:



Graphic 8.6 24. –Global incomes per trip in terms of own incomes, sponsorship and subsidies per trip (Source: Own construction)

As seen above, the global revenues per trip do not differ as much as the structure of them. Starting from the structure of the total revenues, the coverage of each mode can be disaggregated:



GRAPHIC 8.6 25. - COVERAGE BY MODE IN TERMS OF INCOMES, SPONSORSHIP AND SUBSIDIES (SOURCE: OWN CONSTRUCTION)

8.7 CONCLUSIONS

Flexible service and traditional modes may differ from its basic organization. Traditional modes inside a city are usually linked to timetable based systems, composed by a set of lines and stops which are organized either as a hub and spoke system, grid or a hybrid. On the other hand, flexible modes such as Bicing provide a many to many service, leaving users move free from one station to the other.

After doing the comparison between the main modes operating in Barcelona some similarities can be taken, as well as points in which the Bicing can compete.

8.7.1 Territorial Coverage

Due to the limits of extension of the Bicing service, the mode can only compete and be complementary to the Metro and urban bus modes. Specially in the neighbourhoods located in the low zones, where the slope is not excessive.

In terms of coverage, limiting the analysis to the city, Metro and Bicing have a similar coverage inside the city, **around 55% of the territory an 80% of the total population**. Metro has at least one station in 54 of the 73 neighbourhoods, and Bicing in 47. If analysing deeply the services, they almost have presence in the same neighbourhoods and districts, being the coverage in Sants and the upper parts poorly covered.

A total amount of 38 districts, which represent the 52% of the total districts are covered for both Metro and Bicing. On the other hand, just a 14% of them (10) do not have any of the two services.

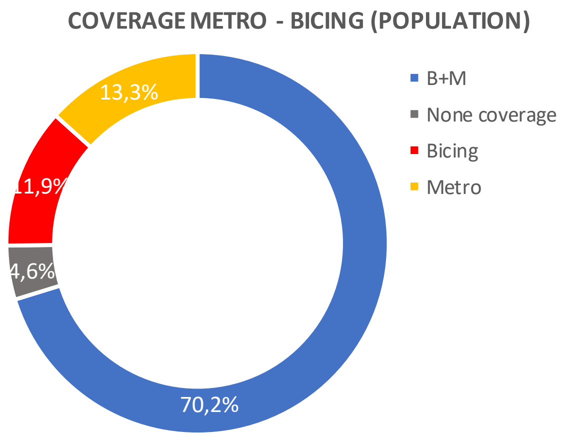
The following table shows the % of area and population which is cover either for Metro and Bicing and the % of which does not have any of these services:

TABLE 8-8– COVERAGE IN AREA AND POPULATION TERMS OF METRO AND BICING (SOURCE: OWN CONSTRUCTION)

	AREA OF INFLUENCE (KM²)	AREA OF INFLUENCE (%)	POPULATION (HAB)	POPULATION (%)
Metro and Bicing	43,8	42,9%	1.127.079	70,2%
No Metro or Bicing	32,3	31,7%	73.332	4,6%
Just Bicing	11,4	11,2%	190.157	11,9%
Just Metro	14,6	14,3%	213.988	13,3%
BARCELONA	**100,3**	**100%**	**1.604.556**	**100%**

Since both services are located in the most densed areas, the 70% of the population is covered for them and just the 50% in terms of area.

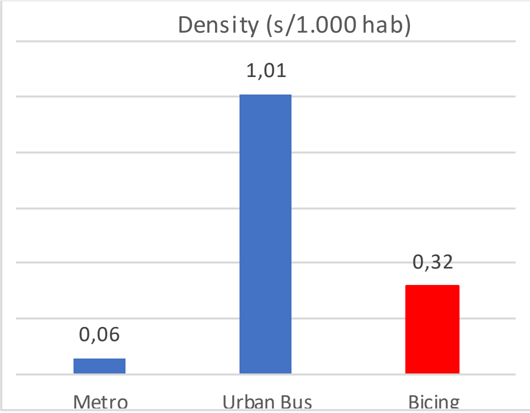
Just the 25,2% is covered only by Bicing of Metro, which means that the physical integration between both is achieved. This reaffirms the fact that Bicing service was implemented in order to cover the "last-mile" of an intermodal chain with Metro.



GRAPHIC 8.7 26. – COVERAGE IN TERMS OF SERVED POPULATION BY BICING AND METRO (SOURCE: OWN CONSTRUCTION)

8.7.2 Service characteristics

Bicing presents a high density regarding the station per covered area. This responds to the fact that the service main focus in covering the densest part of the city, which concentrate in a small portion of its entire limits.



GRAPHIC 8.7 27.- DENSITY OF STATIONS PER COVERED POPULATION OF URBAN MODES (SOURCE: OWN CONSTRUCTION)

Waiting time and access are the two factors that can penalized the total invested time for users using Metro and Urban modes, if they need to cover small distances. Specially for the Metro, due to the high spacing between stations. Therefore, Bicing has some potential, in substituting short trips.

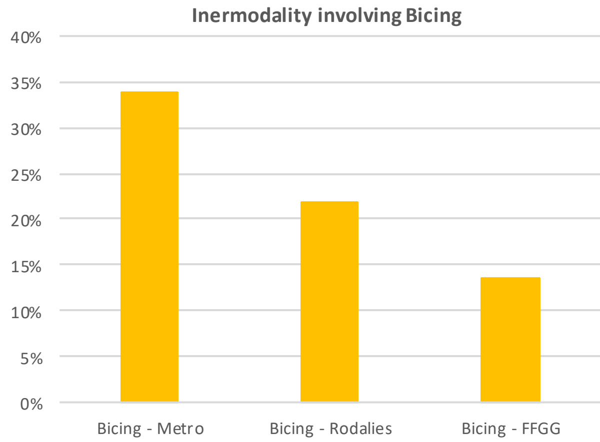
TABLE 8-9– SERVICE CHARACTERISTICS (SOURCE: OWN CONSTRUCTION FROM TMB, 2015 AND BICING, 2015)

	METRO	URBAN BUS	BICING
Spacing between stations (m)	700	300	300
Average access time (min)	6	3,6	3,6
Headway (min)	3,5	5	-

8.7.3 Intermodality

The rate of intermodal trips involving Bicing represent the 40% of the total one taking place in the system. This value responds to the fact that Bicing is a complementary service to interurban modes and in the other hand is used to cover the "last-mile" inside urban areas.

As seen, the highest rates of intermodality correspond to the chain Metro-Bicing, Rodalies-Bicing and FGC-Bicing, being 34%, 22% and 14% respectively. Therefore, the physical integration between Metro and the main stations allows transfers from one service to Bicing.



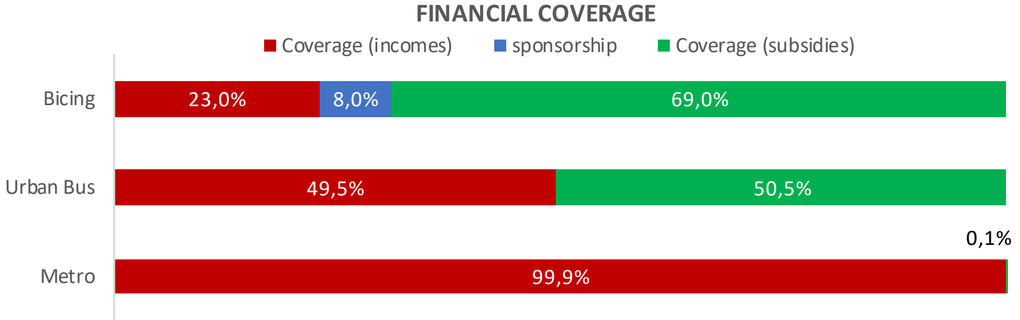
GRAPHIC 8.7 28.- DENSITY OF STATIONS PER COVERED POPULATION OF URBAN MODES (SOURCE: OWN CONSTRUCTION FROM BS:M, 2016A)

8.7.4 Funding characteristics

Comparing Bicing in incomes per veh-km allocates the service in an extremely low position in comparison with other modes. The main reason is the fact that traditional modes, such as Metro and Bus are motor based, while Bicing is a mechanical service.

On the other hand, comparing the total incomes per trip Bicing is located between their two main competitors inside the city. The bus service is the one with the highest cost per trip, equal to 1,58 €/trip, while for Bicing is 1,44 (considering the sponsorship).

In coverage terms, Bicing has the lowest rate of covering the global cost through the own incomes, being this about a 23%. The main difference in the funding characteristics is the sponsorship contract with Vodafone, which represent the 8% of the global incomes.



GRAPHIC 8.7 29. - COVERAGE BY MODE IN TERMS OF INCOMES, SPONSORSHIP AND SUBSIDIES (SOURCE: OWN CONSTRUCTION)

9. TRANSFER TIME ANALYSIS

According to previous chapter, Metro is the service that better competes in coverage terms with Bicing, but according to the service characteristics and user-profile they differ widely (Chapter 8.4).

TABLE 9-1– SERVICE CHARACTERISTICS (SOURCE: OWN CONSTRUCTION FROM TMB, 2015 AND BICING, 2015)

	METRO	BICING
Average travelled distance (km)	5,1	2,5
Average travelled time (min)	11,5	15,0
Spacing between stations (m)	700	300
Average access time (min)	6	3,6
Commercial speed (km/h)	26,7	12
Headway (min)	3,5	-

The chapter aims to analyse the difference between the invested time in a door-to-door analysis using each mode. the next step is to analyse the door to door time in both modes. Since the fare integration would catch intermodal demand, the invested time in transfers involving Metro inside this mode and the one if using Bicing service will be compared. The idea behind is to find the interval of distance or time in which each mode is more competitive and to determine if Bicing has potential in catching demand coming from its competitor.

In general terms, important user metrics are: Access (A), Waiting (W), In-vehicle time (IVTT) and Transfers, all expressed in time units:

$$TT = AT_o + WT + IVTT + AT_f \qquad Eq.\ 7$$

These user metrics depend on the chosen mode and route. Just user-costs in terms of time will be considered, since according to the fare integration principles, no extra monetary cost results from transfers.

9.1 Transfers involving Metro

Under the previous considerations, the metro model for a general case of transfers is defined with the following mathematical expression:

$$TT_{Metro} = AT_o + WT + IVTT + AT_f \qquad Eq.\ 7$$

Where:

$AT_{o/f} :=$ *Access time in origin/destination*

$WT :=$ *Waiting time subject to a schedule*

$IVTT :=$ *Inside vehicle travell time*

Each term is specified as it follows:

$$AT_o = \frac{\delta_{trans}}{v_w} \qquad Eq.\ 8$$

$$WT = \bar{H} \qquad Eq.\ 9$$

$$IVTT = \frac{\bar{l}_{i-m}}{v_m} + \frac{\bar{l}_{i-m}}{\bar{s}_m} \cdot \tau + \frac{\bar{l}_{i-m}}{\bar{s}_m} \cdot \tau' \qquad Eq.\ 10$$

$$AT_f = \frac{\bar{s}_m}{2 \cdot v_w} \qquad Eq.\ 11$$

$$TT_m = \frac{\delta_{trans}}{v_w} + \frac{\bar{H}}{2} + \frac{\bar{l}_{i-m}}{v_m} + \frac{\bar{l}_{i-m}}{\bar{s}_m} \cdot \tau + \frac{\bar{l}_{i-m}}{\bar{s}_m} \cdot \tau' + \frac{\bar{s}_m}{2 \cdot v_w} \qquad \text{Eq. 12}$$

Being:

$\delta_{trans} \coloneqq tipicall\ travelled\ distance\ for\ transfer - access\ (km)$

$v_w \coloneqq walking\ speed\ for\ access\ (km/h)$

$\bar{H} \coloneqq average\ waiting\ time\ due\ to\ transfer\ and\ at\ the\ end\ of\ travel\ (min)$

$\bar{l}_{i-m} \coloneqq average\ in - vehicle - length\ from\ i\ mode\ to\ metro$

$v_m \coloneqq Metro\ maximum\ speed\ (km/h)$

$\bar{s}_m \coloneqq average\ spacing\ between\ metro\ stations\ (km)$

$\tau \coloneqq lost\ time\ due\ to\ acceleration\ and\ deacceleration$ (s)

$\tau' \coloneqq\ lost\ time\ due\ to\ boarding\ and\ alighting\ per\ station\ (s)$

The following data was obtained from Daganzo (Daganzo, 2010, for a particular case study in the city of Barcelona:

TABLE 9-2– USED VALUES FOR TRANSPORT MODEL (SOURCE: OWN CONSTRUCTION FROM DAGANZO, 2010))

PARAMETER	VALUE
δ_{trans}	200 m
v_w	5 km/h
v_m	60 km/h
τ	45s
τ'	5s

For the other parameters, and average was used from the data provided by the Annual Report of TMB 2015 (TMB (2015)), considering the selected Metro lines (L1,L3,L5) and the typical values during the peak hour:

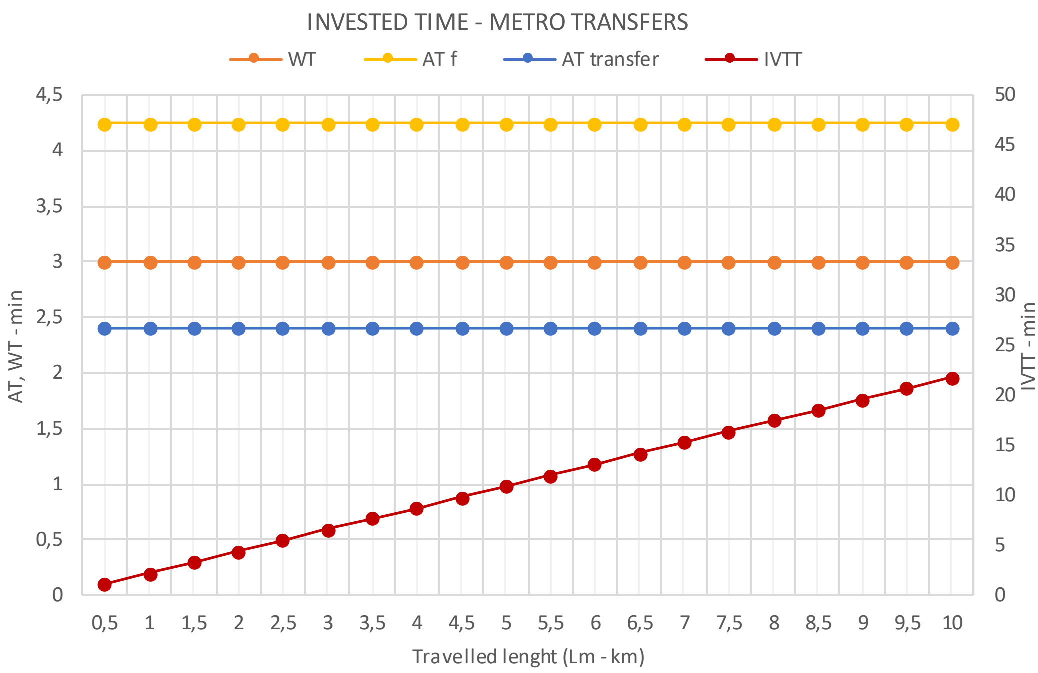
TABLE 9-3– USED VALUES FOR TRANSPORT MODEL (SOURCE: OWN CONSTRUCTION FROM TMB, 2015)

PARAMETER	VALUE
$\bar{H}$	3 min
$\bar{s}_m$	707,8 m

Being the $\bar{l}_{i-m}$ the parameter to be particularized.

The Value of time to estimate the invests in monetary terms for users is considered to be 10 €/h while users move and 15€/h for waiting time, according to Daganzo, 2010.

Considering different typicall values for $\bar{l}_{i-m}$, the total invested time disaggregated in AT, IVTT WT can be represented:



GRAPHIC 9.1 30. – INVESTED TIME IN TRANSFERS INVOLVING METRO (SOURCE: OWN CONSTRUCTION)

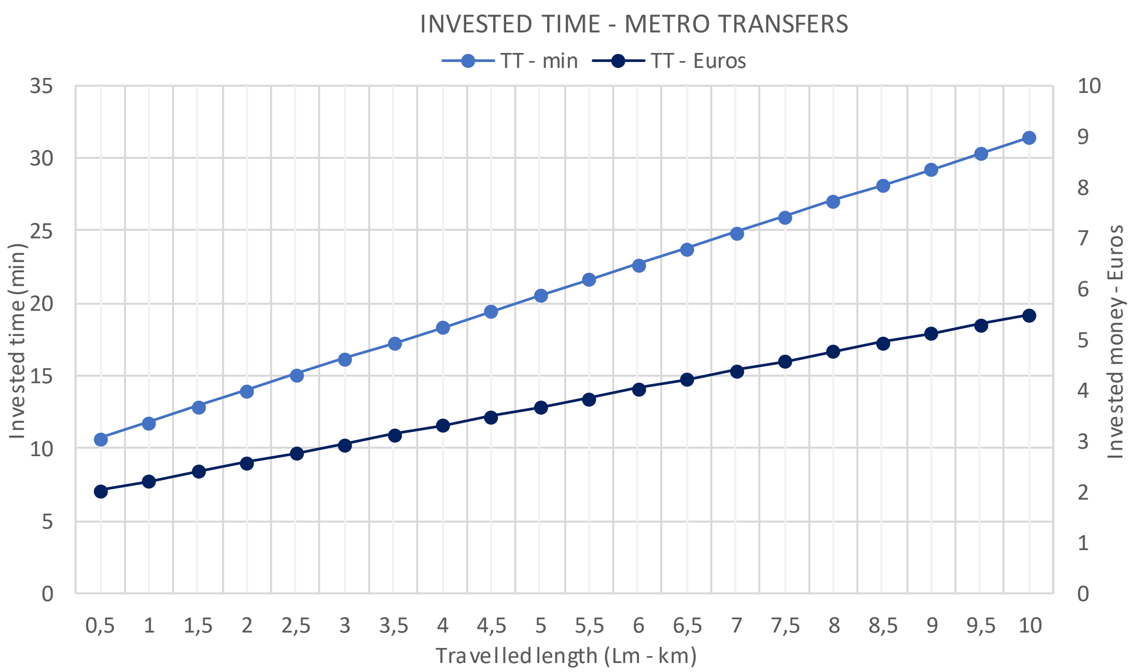
Where the waiting and access invested time are fixed terms since they do not depend on the travelled distance and the invested time inside the vehicle is linear with l, according to the previous formulation.

The invested time can be re-written as it follows

$$TT_m\ (min) = 9{,}7 + 2{,}18 * l_i \qquad \textit{Eq. 13}$$

$$TT_m\ (€) = 1{,}9 + 0{,}36 * l_i \qquad \textit{Eq. 14}$$

With an average commercial speed of 27,6 km/h.



GRAPHIC 9.1 31. – TRANSPORT MODEL FOR TRANSFERS INVOLVING METRO IN TIME AND MONETARY TERMS FOR DIFFERENT TRAVELLED LENGTHS (SOURCE: OWN CONSTRUCTION)

9.2 Transfers involving Bicing

Similar model is used for transfers involving Bicing mode:

$$TT_{Bicing} = AT_o + IVTT + AT_f + WT \qquad Eq.\ 15$$

Each term is specified as it follows:

$$AT_o = \frac{\delta'_{trans-b}}{v_w} \qquad Eq.\ 16$$

$$WT = 0 \qquad Eq.\ 17$$

$$IVTT = \frac{\bar{l}_{i-b}}{v_b} \qquad Eq.\ 18$$

$$AT_f = \frac{\bar{s}_b}{2 \cdot v_w} \qquad Eq.\ 19$$

$$TT_b = \frac{\delta_{trans-b}}{v_w} + \frac{\bar{l}_{i-b}}{v_b} + \frac{\bar{s}_b}{2 \cdot v_w} \qquad Eq.\ 20$$

Being:

$\delta_{trans-b} :=$ *tipicall travelled distance for transfer − access (km)*

$v_w :=$ *walking speed for access (km/h)*

$\bar{l}_{i-b} :=$ *average in − vehicle − length from i mode to metro*

$v_b :=$ *Bicing maximum speed (km/h), considering accelerations and deacelerations*

$\bar{s}_b :=$ *average spacing between metro stations (km)*

The source for estimating the principal parameters was the collected data from Bicing (2015) and maintaining the one mentioned from Draganzo (2010):

TABLE 9-4– USED VALUES FOR TRANSPORT MODEL (SOURCE: OWN CONSTRUCTION)

PARAMETER	VALUE	SOURCE
v_w	5 km/h	Daganzo, 2011)
v_b	13 km/h	Estimated*
$\bar{s}_b$	300 m	Bicing, 2015a
$\bar{H}$	3 min	Estimated
$\delta_{trans-b}$	50 m	Estimated

*Estimated from average travel time and distance: 2,5km; 11,5 min (BS:M, 2016a)

Where the $\delta_{trans-b}$ is introduced as a penalization for users that need to mode from the first mode to Bicing. In general, the original station is located underground and users need to walk to the closest Bicing station located on floor level. Therefore, a quart part of the used distance for transfers with Metro was considered.

The chosen speed is considered to be 13km/h. In many consulted bibliographies appears the range between 12-15 km/h for maximum speed in urban areas for bikes. Since the assumption that the probability of finding a bike at each station is neglected, the lower bound of the speed is considered in order to be on the security side.

Since the Bicing model was built in order to compare the invested time for a same travelled length as in case of transferring to Metro, the $\bar{l}_{i-b}$ term can be expressed in terms of the $\bar{l}_{i-m}$:

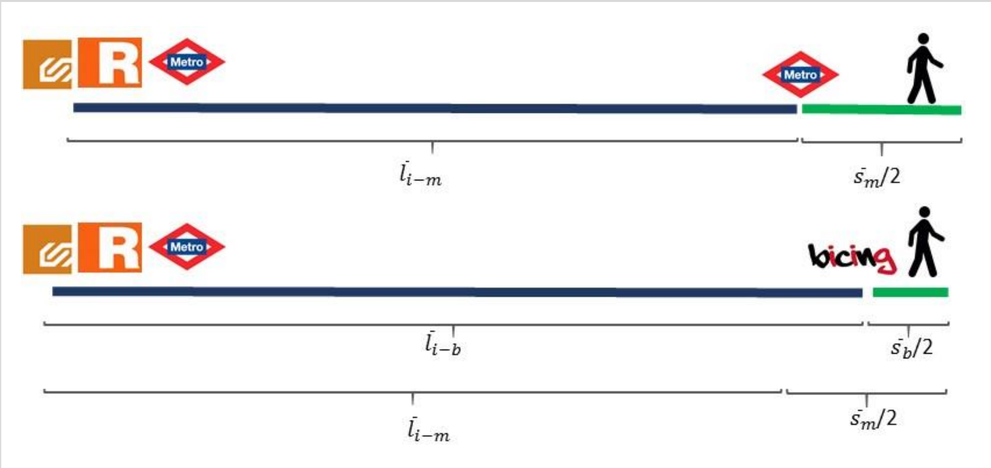
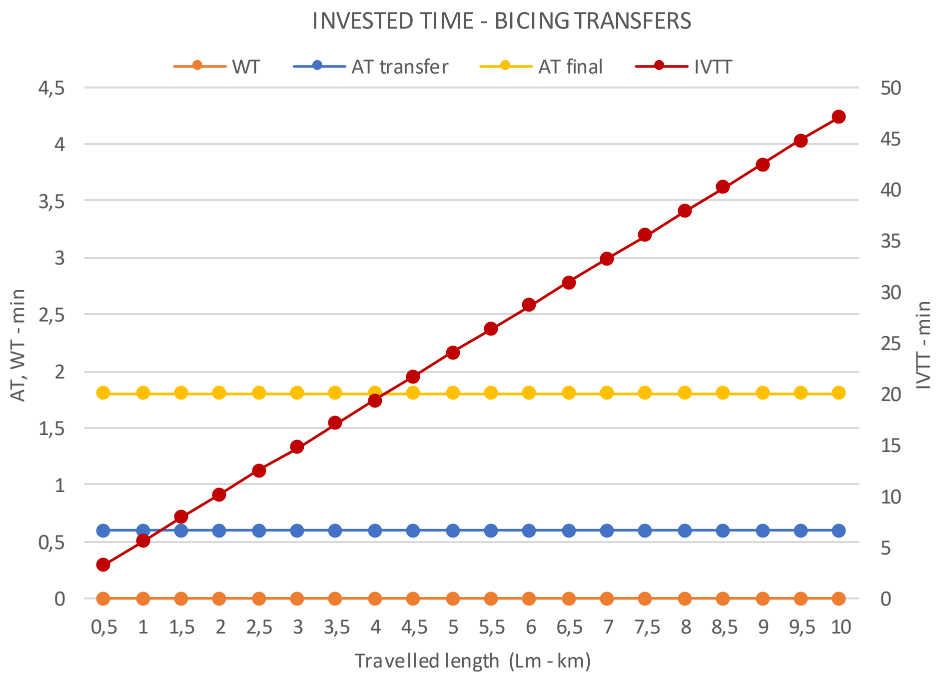


FIGURE 0-1. - DIAGRAM OF THE TOTAL TRAVELLED LENGTH OF TRANSFERS WITH METRO AND BICING MODE (SOURCE: OWN CONSTRUCTION)

According to the previous diagram, the average travelled distance inside Bicing can be obtained considering the spacing of the two modes and the same term if using Metro:

$$\bar{l}_{i-b} = \bar{l}_{i-m} + (\bar{s}_m - \bar{s}_b)/2 \qquad \textit{Eq. 21}$$

With the previous expression, the total invested time changing Metro for Bicing in transfers can be represented for different values of $\bar{l}_{i-m}$ and disaggregated in their terms:



GRAPHIC 0 32. – INVESTED TIME IN TRANSFERS INVOLVING BICING (SOURCE: OWN CONSTRUCTION)

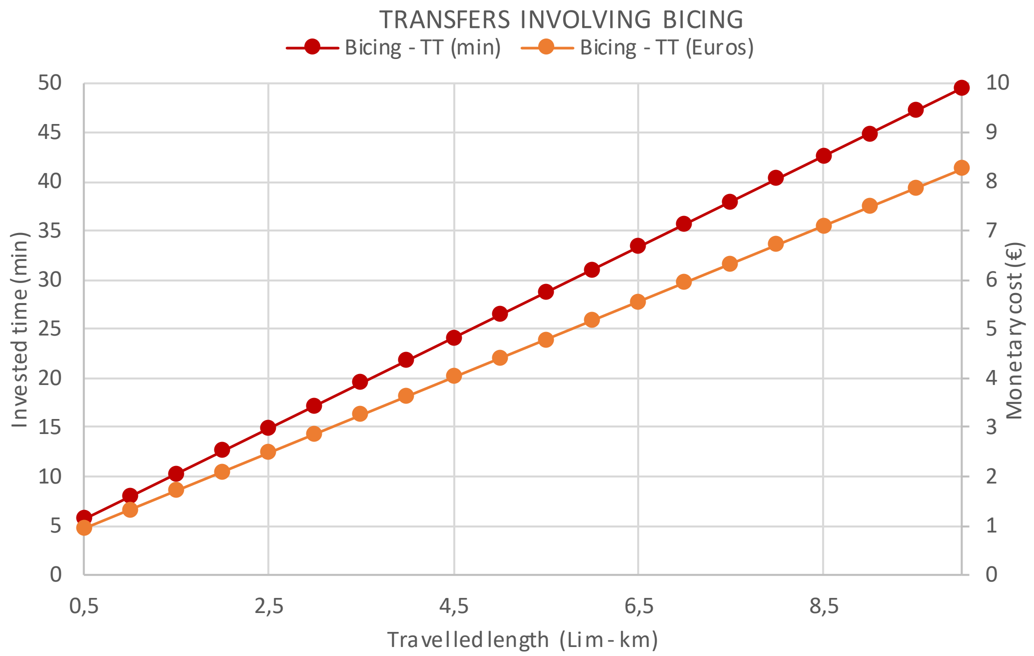
As for the Metro case, some terms are independent of the travelled length, such as the access and transfer time. In this case, the assumption that there is no waiting time is taken.

The invested time can be re-written as it follows in terms of the travelled length inside Bicing system:

$$TT_m\ (min) = 4{,}3 + 4{,}6 * (l_i - 0{,}2) \qquad \textit{Eq. 22}$$

$$TT_m\ (€) = 0{,}7 + 0{,}8 * (l_i - 0{,}2) \qquad \textit{Eq. 23}$$

With an average commercial speed of 13km/h.



GRAPHIC 0 33. – INVESTED TIME(RED) AND MONEY (ORANGE) IN TRANSFERS INVOLVING BICING FOR DIFFERENT TRAVELLED LENGTHS (SOURCE: OWN CONSTRUCTION)

9.3 COMPARISON BETWEEN THE TWO MODES

From previous analysis, it has been shown that both invested times in transfers involve Access and inside vehicle travel time. The main difference explained above is the fact that for Bicing, it has been assumed that no waiting time is required in the general case.

9.3.1 Invested time

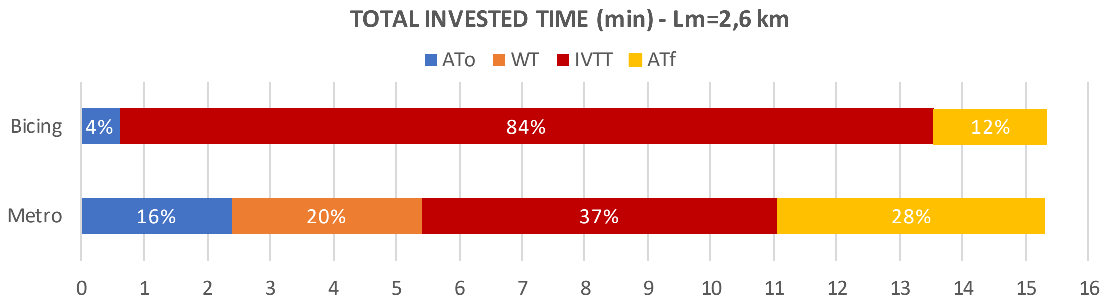
In both cases, the curve of the total invested time is linear in terms of the travelled length, chosen as the independent variable:

TABLE 9-5– LINEAL EXPRESSION OF TOTAL INVESTED TIME FOR METRO AND BICING (SOURCE: OWN CONSTRUCTION)

Mode	Lineal expression	Slope (min /km)	Commercial speed (km/h)
Metro	$y = 2{,}18x + 9{,}65$	2,18	27,5
Bicing	$y = 4{,}6x + 3{,}3$	4,6	13

Where the slope represents the inverse of the global commercial speed for each mode in min/km.

The intersection between both curves takes place in a length of 2,6km, which corresponds to an equal amount of 15,5 min for both modes. However, the weights of each part of the total time differs, due to the structure of each mode. Metro mode requires more access and waiting time, whereas a high % of the total time in Bicing corresponds to the riding time:



GRAPHIC 9.3 34. – TOTAL INVESTED TIME IN MINUTES FOR A TRAVELLED LENGTH OF LM=2,6KM

As seen, the global invested time in both corresponds to a total amount of 15,3 minutes, being the weight of each part completely different. On the one hand, users need to invest the 63% of the total time in waiting and access if they decide to take the Metro whereas for Bicing it just involve the 16%. On the other hand, the 84% of the total time corresponds to riding the bike while just the 37% of the invested time in Metro is the one inside the vehicle.

9.3.2 Invested money

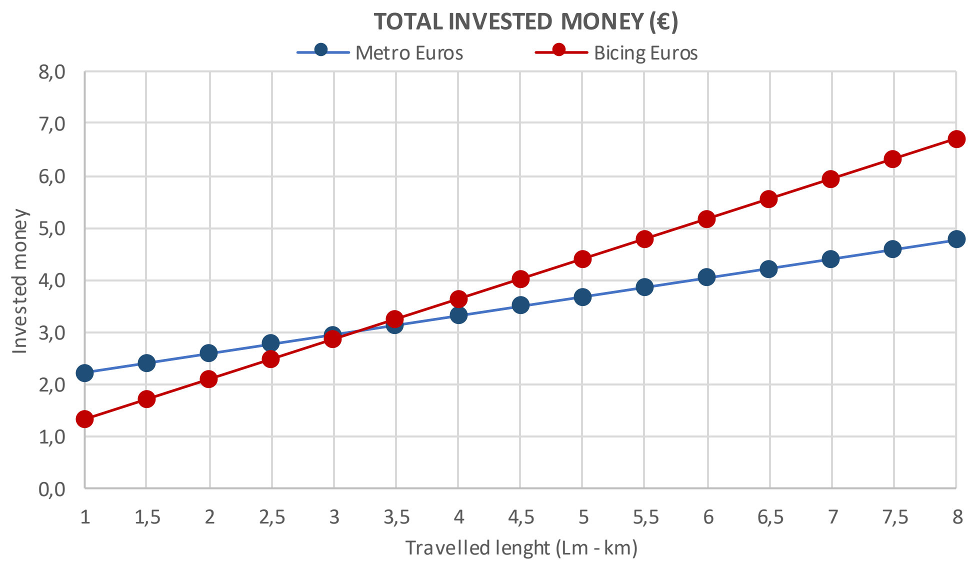
High access and waiting time are usually linked to a bad perception of the service for users. Therefore, with monetary terms in which waiting is penalized, the interval in which Bicing is theoretically more competitive than Metro is larger:

TABLE 9-6– LINEAL EXPRESSION OF TOTAL INVESTED MONEY FOR METRO AND BICING (SOURCE: OWN CONSTRUCTION)

Mode	Lineal expression	Slope (€ /km)
Metro	$y = 0,36x + 1,86$	0,36
Bicing	$y = 0,77x + 0,56$	0,77

Where the slope represents the global value of time for each mode in €/km, and the independent term the fixed charge for access and waiting.

The intersection between both curves takes place with a length of **3,2 km**, which corresponds to an equal amount of 3,0 € for both modes.

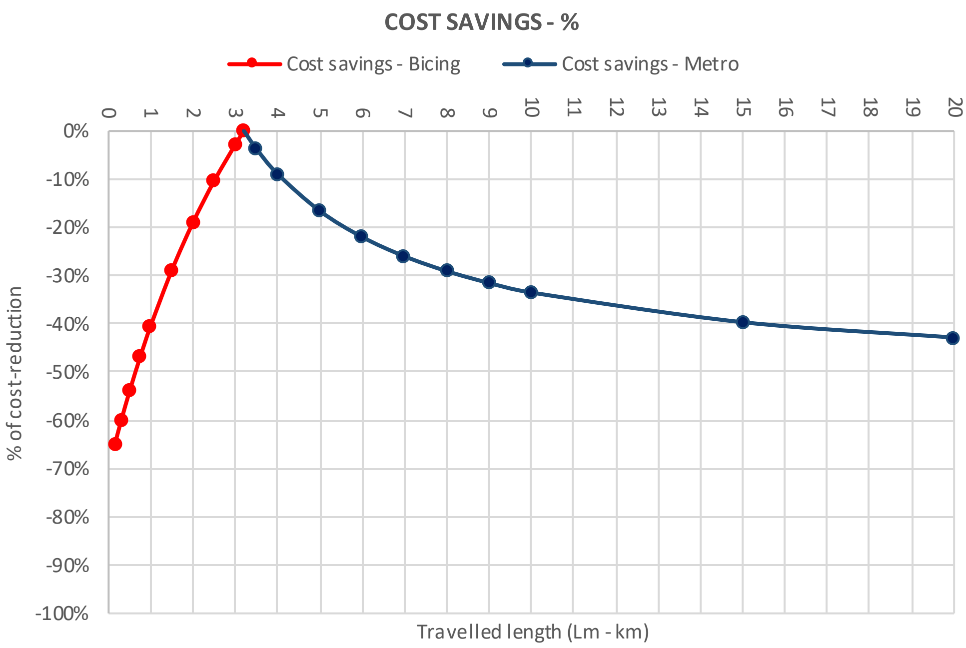


GRAPHIC 9.3 35. – TOTAL INVESTED MONEY IN TERMS OF THE TRAVELLED LENGTH FOR BICING (RED) AND METRO (BLUE) MODE (SOURCE: OWN CONSTRUCTION)

For users who need to cover a shorter distance than 3,2 km, Bicing results a more profitable mode than Metro. Therefore, the flexible mode has some potential on replacing transfers that cover distances <3,2 km and the integration could absorb part of the Metro demand of transfers.

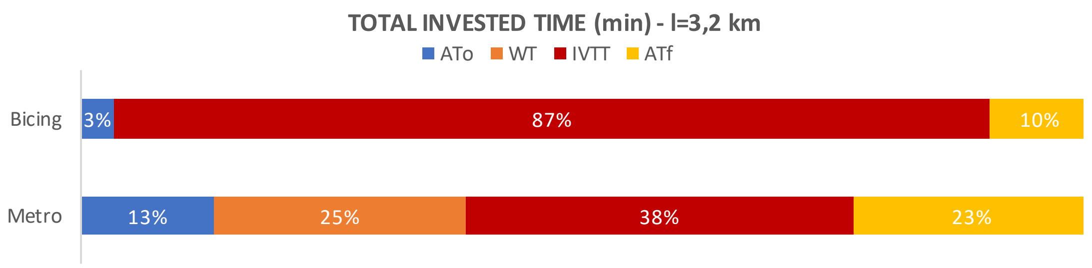
9.3.3 Cost savings

Cost savings in choosing the more competitive mode in terms of the travelled length can be seen in the Graphic bellow:



GRAPHIC 9.3 36. – COST SAVINGS IF CHOOSING THE MOST COMPETITIVE MODE ACCORDING TO THE TRAVELLED LENGTH. IN RED COST SAVINGS IF CHOOSING BICING. IN BLUE IF CHOOSING METRO (SOURCE: OWN CONSTRUCTION)

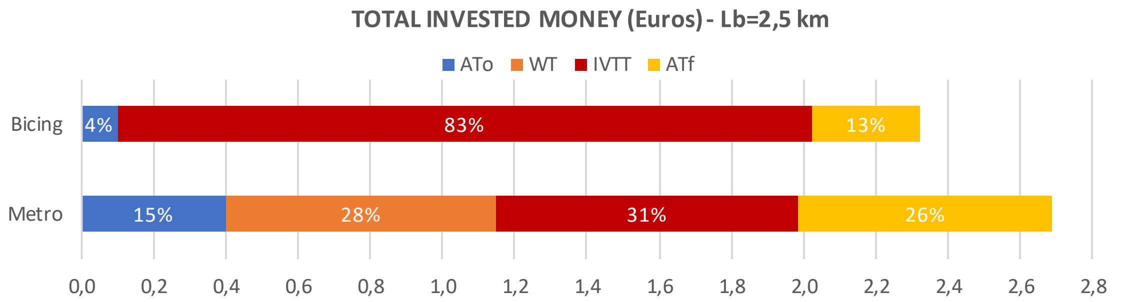
In red, the interval of L (inside Metro mode), in which choosing Bicing has benefits and in blue, the interval of L (inside Metro mode) in which choosing Metro mode results more profitable. The range of values for the travelled length goes from 150m to 20km, being the first one the half of the spacing between Bicing stations and the second one the length of the largest metro line (L1). Cost savings were computed as the difference in invested money between both modes, separating values lower and higher than 3,2km.



GRAPHIC 9.3 37. – TOTAL INVESTED TIME IN € AND % FOR A L=3,2KM (SOURCE: OWN CONSTRUCTION)

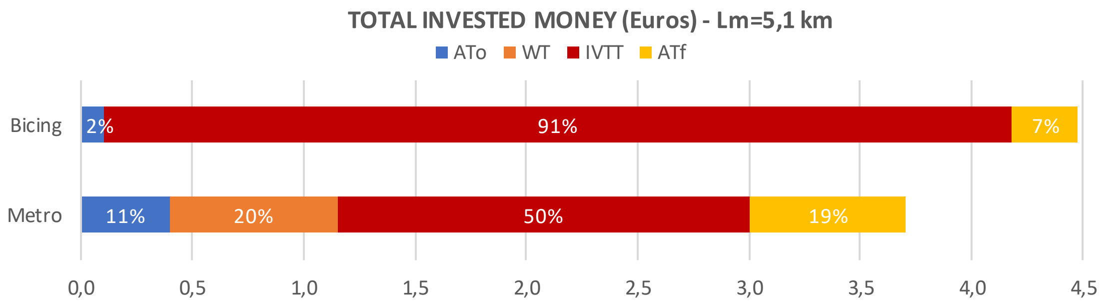
9.3.4 Typical values of L for Bicing and Metro

As seen, both curves decrease as a second-degree polynomial when getting closer to the value of L=3,2km. On the one hand, Bicing saving costs (in red) go fast from 65% if travelling 150km respect to Metro to 0% if the travelled distance is equal to 3,2km. Specifically, for the typically travelled distance of 2,5 (Chapter 8.4) the invested money is 2,3€ with a save of a 14% respect to Metro, where the travelled length is 2,3km:



GRAPHIC 9.3 38. – TOTAL INVESTED TIME IN € AND % FOR A LB=2,5KM (SOURCE: OWN CONSTRUCTION)

On the other, the saving costs if choosing Metro can grow just until 40%. This fact reflects the limits of the analysis, since the model was built by focusing in short distances and penalizing the perception of waiting and transfers. For the typical travelled length of 5,11km, the total invested cost is 4,5€, with a save of 17% respect choosing Bicing mode:



GRAPHIC 9.3 39. – TOTAL INVESTED TIME IN € AND % FOR A L=5,1KM (SOURCE: OWN CONSTRUCTION)

As seen, Bicing becomes more competitive, the highest is the % of the invested money for access and waiting in the Metro. Bellow a travel distance of 3,2km, Bicing has some potential in offering better connections for transfers while the opposite occurs if the distance is above 3,2km. When global costs of access and walking represent above the 62%, Bicing start to have profits.

10. POTENTIAL INTERMODAL DEMAND

The chapter aims to determine which intermodal chains involving Metro could be transferred to Bicing if the fare integration took place.

According to coverage reasons (Chapter 8), Bicing and Metro have the closer coverage inside the city, serving the 70% of the residents. On the other hand, Bicing has some potential in intermodal trips coming from Metro, since congestion, access and waiting time can be reduced for users if using bikes. As seen in Chapter 9, Bicing has some potential in short trips of a travelled length inside vehicle of less than 3,6km, in which access and waiting due to transfer is penalized.

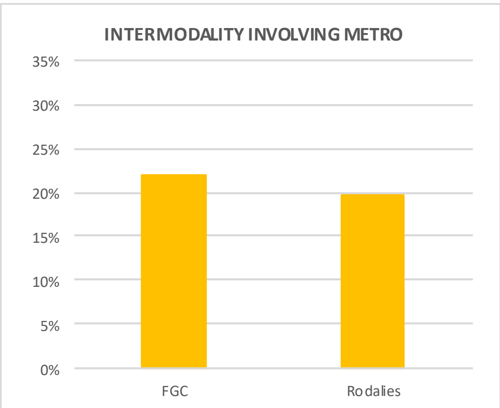
10.1 Previous considerations

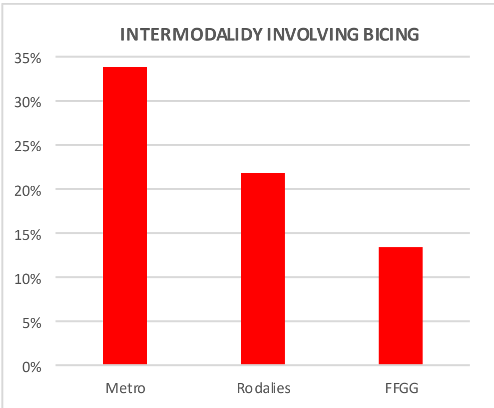
In order to simplify the estimation, some hypothesis and simplifications need to be done:

- Bicing stations are located near Metro stops, so the physical integration is solved. Moreover, by using the Metro as the potential mode to be substituted, in most cases the origins and destinations can also be covered by Bicing, due to the similarity of coverage they provide inside the city.

- Urban bus is discarded as a potential mode to be substitute for Bicing. They don't have the same coverage across the city and user patterns. Moreover, the highest intermodal chains correspond to the urban bus itself and transfers with metro. Both urban modes which could have already been redirected to Bicing. Knowing that annual fees of Bicing are low (47 €/year), these transfers have no potential, since users will not change their behaviour.

- Specifically, the chains considered are Rodalies – Metro, FGC-Metro as potential induced demand due to its significance inside the intermodality of the STI system and in the intermodal-demand of Bicing.





GRAPHIC 10.1 40. – INTERMODALITY INVOLVING METRO. WEIGHT OF FGC AND RODALIES (SOURCE: OWN CONSTRUCTION FROM ATM, 2017E AND BS:M, 2016A)

10.2 Hypothesis

The typical value to be estimated are the travelled length for an average user transferring from one of the selected modes (Rodalies, FGC or Metro) to Metro.

The following hypothesis are used to simplify the computing part:

- In order to simplify computations, just Lines L1, L3 and L5 will be considered.

TABLE 10-1– WEIGHT OF L1,L3,L5 INSIDE METRO (SOURCE: OWN CONSTRUCTION FROM ATM, 2016A)

	Global L1,L3,L5
% of the Total Metro length	*61%*
% of the total Metro stations	*63%*
% of the total Metro users	*62%*
% of the total veh-km	*74%*

- For all cases, average values will be considered, due to available data.
- Given a particular bimodal chain between lines, users are equally distributed at each possible station in which transfers are possible.
- At one transfer-station, the 50% of users travel in each direction inside Metro line.
- In transfers, users travel an average length of 1/4 of the Metro resting-length from the station by direction or ½ if the station is the last one of the line.

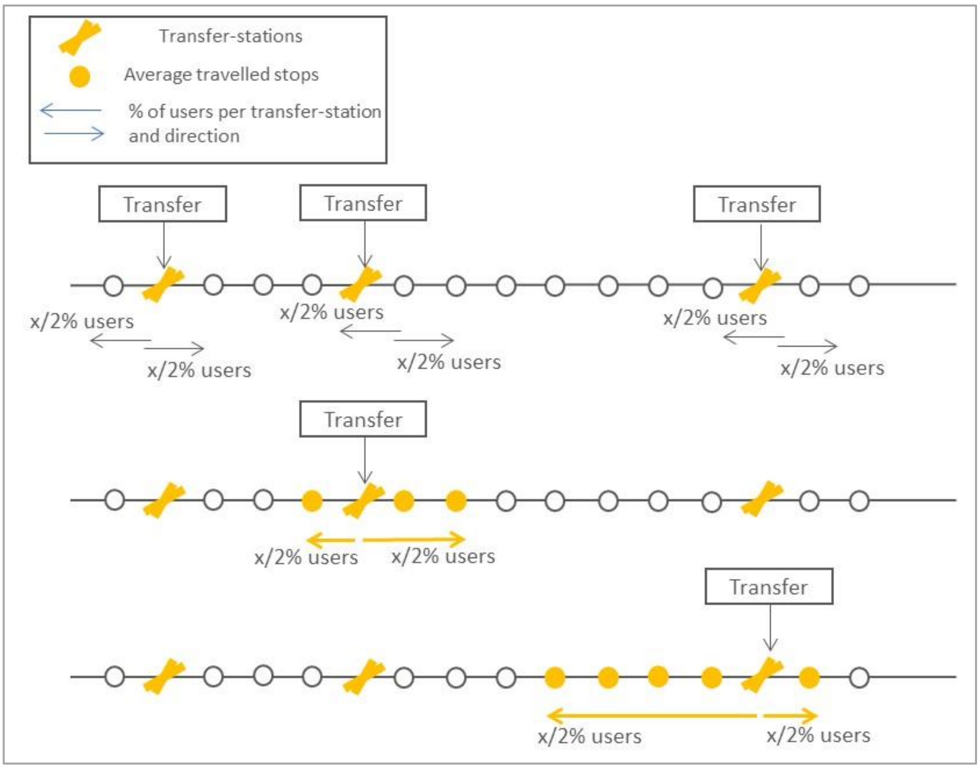


FIGURE 10.2-1. - SCHEME OF THE CONSIDERED HYPOTHESIS (SOURCE: OWN CONSTRUCTION)

10.3 Methodology

Under the previous hypothesis and for a specific pair of origin mode and Metro destination line (O-D lines), the general methodology used is the one it follows:

- Considering a specific line of the first mode, the Metro lines (L1, L3,L5) in which transfers are possible have to be identified.
- As a result of the first two step, each bimodal chain can be weighted:

$$O_i \quad \rightarrow \quad L_j := \%_{ij}$$

Being i the line of the first mode and j each metro line as the second mode (1,3 or 5).

- According to the hypothesis, users are equally divided in all possible stations. Therefore, the % of users is known by station, metro line and direction.

- The last step is to estimate (for each station, direction of travel and metro line) the average travelled stations, as the ¼ of the partial Metro line or ½ in chase of final station.
- Changing amount of travelled stations to typical length is possible, since for each line and mode the average spacing between metro stations is known:

$$spacing_j = L_j/\#of\ stations_j$$

All steps are done for each pair O-D lines of the different considered modes: Rodalies-Metro, Metro-Metro and FGC-Metro.

As a result, for each O-D pair of lines (second one involving Metro), the travelled length is weighted in terms of the dispersion of Metro demand into its lines.

The last step is to estimate the global averaged length for each mode. In order to do so, each O-D line pair is weighted according to the weight of the O-line demand inside the total demand of the considered origin mode.

10.4 Metro metrics

The used metrics are restrained to the L1, L3 and L5 lines:

TABLE 10-2– WEIGHT OF L1,L3,L5 INSIDE METRO (SOURCE: OWN CONSTRUCTION FROM ATM, 2016A)

METRO LINES	LENGTH	STOPS	DEMAND (Million users)	% OF DEMAND	SPACING
L1	20,72	30	105,6	38%	691 m
L3	18,41	26	83,81	30%	706 m
L5	18,92	26	89,96	32%	728 m

FIGURE 10.4-1. – L1, L3 AND L5 METRO LINES (SOURCE: TMB(2017))

Detailed steps of the computations are explained in Annex II of this document.

10.5 Analysed transfer-chains

10.5.1 Rodalies – Metro

Metro and Bicing service have a similar coverage. Moreover, Rodalies is always integrated with Metro scheme, since their stops in the city are always located in the main intermodal hubs, in which Metro has a large presence. The principal stations are Sants-station, Pl. Catalunya, Arc de Triomf and El Clot-station. Bicing stations have also a large presence in these hubs. Therefore Rodalies- Metro is one of the main potential demand to be taken into account.

For the bimodal chain Rodalies-Metro, fourth lines are considered, since are the ones crossing the city: R1, R2, R3 and R4. The following table sums up the weights of each bimodal change between Rodalies and the three Metro lines:

TABLE 10-3– WEIGHT OF EACH O-D LINE INVOLVING RODALIES (SOURCE: OWN CONSTRUCTION)

MODE	O – D PAIR LINES		O -D WEIGHT
R1	R1 – L1		38%
	R1 – L3		30%
	R1 – L5		32%
R2	R2 – L1		38%
	R2 – L3		30%
	R2 – L5		32%
R3	R3 – L1		38%
	R3 – L3		30%
	R3 – L5		32%
R4	R4 – L1		38%
	R4 – L3		30%
	R4 – L5		32%

Once the weight of both O and D mode per line has been identified, the average length is identified by following the procedure is the one explained in Chapter 10.3.

R1 – Rodalies line

R1 line represent the 31% of the total demand involving Rodalies mode. Transfers are allowed in 5 stations located inside the Bicing-covering-area, corresponding to different Metro stations:

TABLE 10-4– AVAILABLE TRANSFER-STATIONS BETWEEN R1 AND L1,L3,L5 METRO (SOURCE: OWN CONSTRUCTION)

	L1	L3	L5
Hospitalet Carrilet	x	o	o
Sants	o	x	x
Pl. Catalunya	x	x	o
Arc de Triomf	x	o	o
Clot	x	o	o

Where x represents the stations in which transfers are possible with the specific Metro line.

Once identified at which stations transfers can take place, the average number of stations in each direction are computed, by assuming that users will travel in average ¼ or ½ of the resting-line number of stations from the considered station:

TABLE 10-5– AVERAGE NUMBER OF METRO STATIONS AT EACH TRANSFER-STATION FOR R1 (SOURCE: OWN CONSTRUCTION)

	DIRECTION	L1	L3	L5
Hospitalet Carrilet	s1	3	o	o
	s2	12	o	o
Sants	s1	o	5	9
	s2	o	7	16
Pl. Catalunya	s1	12	7	o
	s2	2	13	o
Arc de Triomf	s1	2	o	o
	s2	3	o	o
Clot	s1	3	o	o
	s2	7	o	o

Considering the particular spacing of each of the metro lines, the average length in each case is obtained, considering ¼ of the length if more than one transfer-station is located of ½ if not:

TABLE 10-6– AVERAGE TRAVELLED LENGTH FROM EACH TRANSFER-STATION FOR R1 (SOURCE: OWN CONSTRUCTION)

	DIRECTION	L1	L2	L3
Hospitalet Carrilet	s1	1,0	o	o
	s2	2,1	o	o
Sants	s1	o	1,8	3,3
	s2	o	1,2	5,8
Pl. Catalunya	s1	2,1	1,2	o
	s2	0,3	4,6	o
Arc de Triomf	s1	0,3	o	o
	s2	0,5	o	o
Clot	s1	0,5	o	o
	s2	2,4	o	o

Considering the weight of each R1 – Li pair, the obtained average length for users that transfer from R1 to a Metro line is $L_{R1} = 2{,}6\ km$

R2 – Rodalies line

Same procedure is used for R2-line, from Maçanet-Massanes to St. Vicenç de Calders. The line is divided into three sublines and represents about the 33% of the total Rodalies demand.

TABLE 10-7– AVAILABLE TRANSFER-STATIONS BETWEEN R2 AND L1,L3,L5 METRO (SOURCE: OWN CONSTRUCTION)

	L1	L3	L5
Sants	o	x	x
Passeig de Gràcia	o	x	o
Estació de França	o	o	o
Clot	x	o	o
St Andreu Comtal	x	o	o

TABLE 10-8– AVERAGE TRAVELLED LENGTH FROM EACH TRANSFER-STATION FOR R2 (SOURCE: OWN CONSTRUCTION)

	DIRECTION	L1	L2	L3
Sants	s1	o	1,8	o
	s2	o	1,2	o
Passeig de Gràcia	s1	o	1,2	3,3
	s2	o	4,6	5,8
Estació de França	s1	o	o	o
	s2	o	o	o
Clot	s1	6,9	o	o
	s2	3,1	o	o
St Andreu Comtal	s1	o	o	o
	s2	o	o	o

Considering the weight of each R2 – Li pair, the obtained average length for users that transfer from R1 to a Metro line is $L_{R2} = 3{,}1\ km$.

R3 and R4 – Rodalies line

R3 and R4 have a similar structure regarding transfers and transfer-stations inside the limits of Barcelona. On the one hand, R3 line represent just the 5,4% of the total demand involving Rodalies, while R4 has a weight of the 31%. However, R3 line has been taken into account since it has transfers in many stations and for all considered metro lines.

TABLE 10-9– AVAILABLE TRANSFER-STATIONS BETWEEN R3 OR R4 AND L1,L3,L5 METRO (SOURCE: OWN CONSTRUCTION)

	L1	L3	L5
Hospitalet	x	o	o
Sants	o	x	x
Pl. Catalunya	x	x	o
Arc de Triomf	x	o	o
Sagrera	x	o	x
Sant Andreu Arenal	x	o	o

TABLE 10-10– AVERAGE TRAVELLED LENGTH FROM EACH TRANSFER-STATION FOR R3 (SOURCE: OWN CONSTRUCTION)

	DIRECTION	L1	L2	L3
Hospitalet	s1	1,0	o	o
	s2	2,1	o	o
Sants	s1	o	1,8	3,3
	s2	o	1,2	1,5
Pl. Catalunya	s1	2,1	1,2	o
	s2	0,3	4,3	o
Arc de Triomf	s1	0,3	o	o
	s2	0,9	o	o
Sagrera	s1	0,9	o	1,5
	s2	0,2	o	2,9
St Andreu *Arenal	s1	0,2	o	o
	s2	2,1	o	o

As a result of following the procedure, the obtained travelled length is equal to $L_{R3} = 1{,}77\ km$

Global results

From previous precedures, the obtained average travelled length for each Rodalies-line was obtained:

TABLE 10-11– AVERAGE TRAVELLED LENGTH FOR EACH R-LINE (SOURCE: OWN CONSTRUCTION)

DIRECTION	% OF DEMAND	L_{Ri}
R1	31,2%	2,6
R2	32,7%	3,1
R3	5,4%	1,8
R4	30,7%	1,8

Weighting the %of the demand they represent and the obtained length, a global result for transfers between Rodalies and Metro mode is obtained:

$$L_R = 2,46\ km$$

10.5.2 FGC – Metro

For the bimodal chain FGC-Metro, two lines are considered F1: Vallès and F2: Llobregat. Both represent the 22% of the intermodal demand involving Metro. They have 5 stations located inside the city in which transferring to Metro mode is available: *Hospitalet-Carrilet, Pl. Espanya, Pl. Catalunya, and Provença (Diagonal).*

The following table sums up the weights of each bimodal change between them and the three Metro lines:

TABLE 10-12– WEIGHT OF EACH O-D LINE INVOLVING FGC (SOURCE: OWN CONSTRUCTION)

MODE	O – D PAIR LINES		O -D WEIGHT
F1	F1 – L1	X	38%
	F1 – L3	X	30%
	F1 – L5	X	32%
F2	F2 – L1	X	56%
	F2 – L3	X	44%
	F2 – L5	X	0%
			100%

Vallès – FGC line

Vallès line represent the 43% of the total demand involving FGC mode and is the one covering the north line of FGC service. Transfers are allowed in 3 of the 5 stations located inside the Bicing-covering-area, corresponding to different Metro stations:

TABLE 10-13– AVAILABLE TRANSFER-STATIONS BETWEEN FGC-VALLÈS AND L1,L3,L5 METRO (SOURCE: OWN CONSTRUCTION)

	L1	L3	L5
Hospitalet Carrilet	o	o	o
Espanya	o	o	o
Pl. Catalunya	x	o	o
Provença (Diagonal)	o	x	x

Once identified at which stations transfers can take place, the average number of stations in each direction are computed, by assuming that users will travel in average ¼ or ½ of the resting-line number of stations from the considered station:

TABLE 10-14– AVERAGE NUMBER OF METRO STATIONS AT EACH TRANSFER-STATION FOR FGC-VALLÈS (SOURCE: OWN CONSTRUCTION)

	DIRECTION	L1	L3	L5
Pl. Catalunya	s1	15	12	o
	s2	14	2	o
Provença (Diagonal)	s1	o	2	12
	s2	o	11	13

Considering the particular spacing of each of the metro lines, the average length in each case is obtained, considering ¼ of the length if more than one transfer-station is located of ½ if not:

TABLE 10-15– AVERAGE TRAVELLED LENGTH FROM EACH TRANSFER-STATION FOR FGC-VALLÈS (SOURCE: OWN CONSTRUCTION)

	DIRECTION	L1	L3	L5
Pl. Catalunya	s1	5,2	4,2	o
	s2	4,8	0,4	o
Provença (Diagonal)	s1	o	0,4	4,4
	s2	o	3,9	4,7

Considering the weight of each FGC– Li pair, the obtained average length for users that transfer from R1 to a Metro line is $L_{R1} = 6{,}3\ km$

Llobregat – FGC line

FGC-Llobregat has a total amount of 8 different lines, which represent the 57% of the FGC-demand. Transfers to Metro mode are possible just with L1 and L3 in two stations: *Hospitalet and Pl. Espanya.*

Same procedure was used to obtain results.

TABLE 10-16– AVAILABLE TRANSFER-STATIONS BETWEEN FGC-LLOBREGAT AND L1,L3,L5 METRO (SOURCE: OWN CONSTRUCTION)

	L1	L3	L5
Hospitalet Carrilet	x	x	o
Espanya	x	x	o
Pl. Catalunya	o	o	o
Provença (Diagonal)	o	o	o

TABLE 10-17– AVERAGE TRAVELLED LENGTH FROM EACH TRANSFER-STATION FOR FGC-LLOBREGAT (SOURCE: OWN CONSTRUCTION)

	DIRECTION	L1	L3	L5
Hospitalet	s1	0,7	o	o
	s2	1,6	o	o
Pl. Espanya	s1	1,6	2,5	3,3
	s2	6,2	6,4	1,5

As a result of following the procedure, the obtained travelled length is equal to $L_{R3} = 2{,}3\ km$

Global results

From previous procedures, the obtained average travelled length for each FGC-line was obtained:

TABLE 10-18– AVERAGE TRAVELLED LENGTH FOR EACH FGC-LINE (SOURCE: OWN CONSTRUCTION)

FGC-LINE	% OF DEMAND	L_{Ri}
Vallès	42,8%	6,3
Llobregat	57,2%	2,3

Weighting the %of the demand they represent and the obtained length, a global result for transfers between FGC and Metro mode is obtained:

$$L_R = 4,0\ km$$

10.6 CONCLUSIONS

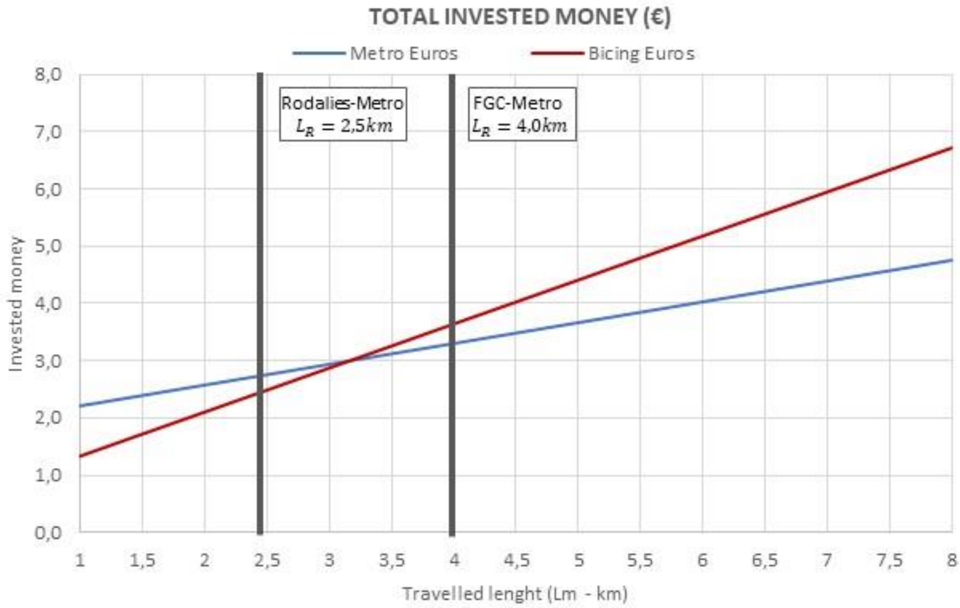
As seen, some of the selected lines have some potential, since the average travelled length inside Metro mode while transferring is less than 3,2km:

TABLE 10-19– AVERAGE TRAVELLED LENGTH FOR EACH INTERMODAL TRANSFER LINE (SOURCE: OWN CONSTRUCTION)

DIRECTION	% OF DEMAND	L_i (km)
R1	31,2%	2,6
R2	32,7%	3,1
R3	5,4%	1,8
R4	30,7%	1,8
Vallès	42,8%	6,3
Llobregat	57,2%	2,3

Where the average travelled length inside Metro mode for users coming from a Rodalies line is equal to 2,5km and to 4km if coming from a FGC-line.

The graphic bellow shows the invested money according to the hypothesis of Chapter 9, and the potential of the Rodalies-Metro mode to be partially absorbed for a Rodalies-Bicing intermodal chain:



Graphic 10.6 41. – Total invested money for Bicing (red) and Metro (blue) mode and the estimated L for Rodalies and FGC (grey). (Source: Own construction)

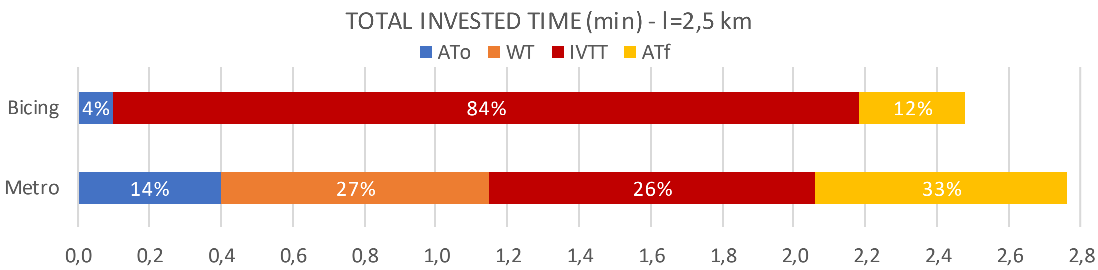
10.6.1 Rodalies transfers

The global travelled length for Rodalies-Metro transfers was averaged in 2,5km. Considering the expression of the invested time in monetary terms developed in Chapter 9, the invested time for transfers can be compared in both systems:

Table 10-20– Invested money for Metro and Bicing for a L=2,5 km (Source: Own construction)

	METRO		BICING	
	Invested €	%	Invested €	%
Ato	0,4	14%	0,1	4%
WT	0,8	27%	0,0	0%
IVTT	0,9	33%	2,1	84%
ATf	0,7	26%	0,3	12%
TOTAL	**2,8**	**100%**	**2,5**	**100%**

As seen, the economy of invested money is about a 10% if users choose Bicing instead of Metro.



Graphic 10.6 42. – Total invested money for Bicing and Metro for L=2,5km (Source: Own construction)

Apart from the explained mathematical background that shows Rodalies-Metro demand is a good candidate to be taken into consider and which could partially be induced to Bicing mode, some physical facts also support the idea. Mainly, current intermodal chains with Bicing are linked to Metro (34%) and in a second grade to Rodalies (22%). Since the ser1vice is limited to residents, the rate of Rodalies-Bicing is considered to be high. This responds to the achieved level of physical integration between both modes.

The biggest stations are located near Rodalies stations such as Arc de Triomf and Plaça Catalunya, which have 8 and 7 stations respectively. Considering the average number of bikes per stations, both reach the amount of 100 bikes in a buffer of <5 min by walking (400m).

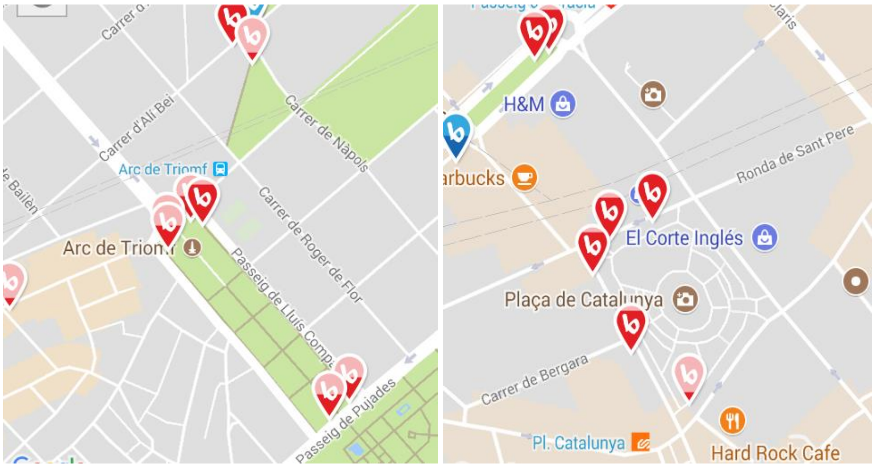


FIGURE 10.6-1. – BICING-STATIONS IN ARC DE TRIOMF (LEFT) AND PLAÇA CATALUNYA (RIGHT) (SOURCE: BICING-APP)

10.6.2 FGC transfers

In the case of FGC-Metro transfers, two lines were analysed: the one called Vallès which covers the north part of the city and Llobregat, which covers the west bound. Just Llobregat line has some potential in changing its patterns and be part of the induced intermodal of Bicing, since the average length in-vehicle is 2,3<3,2km. Specially in Pl. Espanya-stop, since 5 bike stations (70 bikes) are located in a buffer of 200m.

FIGURE 10.6-2. – BICING-STATIONS IN PLAÇA ESPANYA (SOURCE: BICING-APP)

On the other hand, integration between FGC-Vallès and Bicing results more complex. Mathematically, the travelled length for Metro transfers is high, which corresponds to a non-profit range of values if taking Bicing. Moreover, the line covers mainly the part of the city with slope.

11. IMPACT

The chapter aims to define and estimate some of the impacts fare integration would have for Bicing and for the fare integrated system (STI). As a first approach, the fare integration would mean the inclusion of Bicing-mode inside the STI system, which mean that its demand and income-manage would be manage through the ATM.

For the moment, Bicing is owned by the City Councill and operated through a concession. The service is limited to residents and just an annual subscription is available. In the present, the hypothesis that the entire ATM-users could use the scheme will be taken and therefore changes in demand and financing of it and all operators will be taken into consider.

11.1.1 Previous considerations

As known, the annual fare of Bicing is equal to 47,2 €/year. With the subscription, they can do unlimited trips with just the time restriction of 30 minutes. A regular user who makes an average of 540 trips per year (2 per working day), pays 9 cents the trip. This price is considerable lower to the unit prices fixed by the ATM, which ranges from 0,31 to 0,81 (Chapter 6.2.1). The low rate of this income in comparison to the fixed in the STI-intermodal ticket (Chapter5.3.5) suggest that if the integration took place, residents would not change its behaviour.

Moreover, according to the previous assumption and since no European bike sharing scheme has experience in pricing the trips instead of an annual subscription, pricing structure will not be changed. Annual subscription for residents is kept and the Bicing-operator would be able to offer it as its “own monomodal-ticket” just as other operators do.

According to the previous arguments, it will be assumed that fare integration would mean no motivation for residents to change their mobility patterns. Therefore, the annual demand would suffer no changes, by meaning that subscriptions would not drop out:

TABLE 11-1– CURRENT ANNUAL DEMAND OF BICING. ANNUAL TRIPS AND USERS (SOURCE: OWN CONSTRUCTION FROM B:SM,2016 AND AJUNTAMENT DE BARCELONA, 2015)

	ANNUAL TRIPS (millions)	USERS
Monomodal	7,5	57.101
Intermodal-PT*	4,4	33.115
Intermodal -PC**	6,5	4.953
TOTAL	**12,5**	**95.168**

*PT: public transport, **PC: Private car

11.2 Demand impact

Demand changes in Bicing are motivated through the hypothesis that fare integration would induce changes in the intermodal demand involving Metro. Specifically, and according to what has been analysed, allowing all users of the entire ATM-system using the scheme would catch some intermodal trips coming from Rodalies and FGC lines (Chapter XXX).

In order to build a scenario and estimate the transferred demand, it will be considered the rate of intermodality Rodalies-Bicing of the 5% and FGC-Bicing rate of 3%:

TABLE 11-2– INTERMODAL DEMAND IN % FOR RODALIES AND FGC 2015 (SOURCE: OWN CONSTRUCTION)

Users (M)	Metro	Urban Bus	FGC	Tram	Rodalies	Int. Bus	Bicing
FGC	67%	12%	4%	1%	5%	7%	**3%**
Rodalies	54%	9%	5%	9%	5%	13%	**5%**

Under these considerations and taking into account that just the FGC-Llobregat line can be included as part of the potential demand, the scenario of induced demand from Metro to Bicing mode can be built, in terms of annual millions of trips:

TABLE 11-3– TOTAL, POTENTIAL AND INDUCED DEMAND TO BICING. MILLION ANNUAL TRIPS (SOURCE: OWN CONSTRUCTION)

	TOTAL DEMAND	POTENCIAL DEMAND	INDUCED TO BICING
Rodalies - Metro	12,2	12,2	0,6
FGC - Metro	13,5	4,6*	0,2
TOTAL	**25,73**	**16,79**	**0,8**

*It has been assumed that the 34,7% of the FGC-Metro corresponds to the FGC-Llobregat line, according to its rate in terms of global demand.

Knowing that the rate between annual and daily trips in Metro is equal to 350 (384 annual Musers, 1,1 daily (ATM, 2016d), the average amount of trips in a typical working day achieves the rate of 2.222.

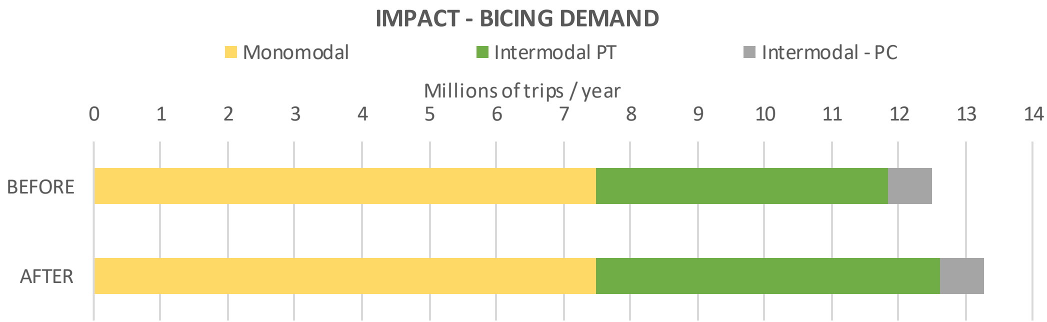
11.2.1 Impact on Bicing demand

According to the hypothesis, Bicing global demand increases about a 6%, becoming the total annual trips of 13,3 million:

TABLE 11-4– IMPACT ON BICING ANNUAL DEMAND. TERMS IN MILLIONS OF ANNUAL TRIPS (SOURCE: OWN CONSTRUCTION)

	BEFORE INTEGRATION	AFTER INTEGRATION	INCREASE (%)
Monomodal	7,5	7,5	*0%*
Intermodal-PT	4,4	5,1	*17%*
Intermodal -PC	0,7	0,7	*0%*
TOTAL	**12,5**	**13,3**	***6%***

No changes in the monomodal demand or intermodal with private or no motorized modes are considered to happen due to the fare integration. It was assumed that residents would no change its behaviour, and according to the European experience, Bicing would not catch trips from private modes.

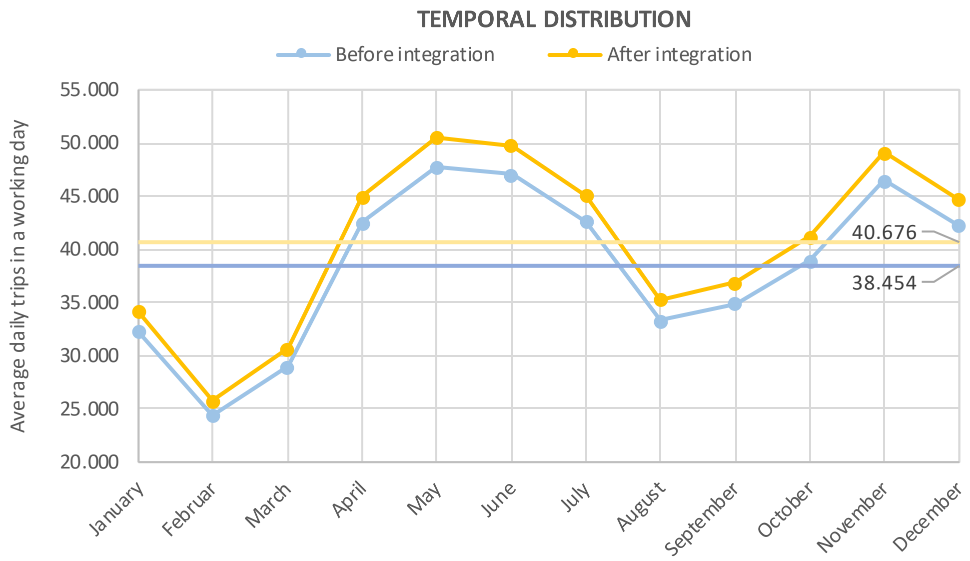


GRAPHIC 11.2 43. – IMPACT ON BICING ANNUAL DEMAND (MILLIONS OF ANNUAL TRIPS) (SOURCE: OWN CONSTRUCTION)

Assuming that no changes in the behaviour of the current demand takes place and the induced one due to fare integration does an average amount of 0,4 trips per day (same as current Bicing-users), the annual users increase a 6%. The total amount of subscriptions is rated in 101.087 annual users and 13,3 million trips.

Temporal distribution

Under the consideration that temporal dispersion of the demand is maintained in terms of average daily trips in each month (BSM, 2016), the new average amount of daily trip increases a 6,3%, achieving the 40.676 trips/day:



GRAPHIC 11.2 44. – IMPACT ON TEMPORAL DISTRIBUTION OF BICING-ANNUAL DEMAND (MILLIONS OF ANNUAL TRIPS) (SOURCE: OWN CONSTRUCTION)

As seen, the maximum value reaches the amount of 50.513 daily trips in May, which means a deviation above the +24% the middle value while the minimum in February means a negative deviation of the -37%.

Intermodal chain

Discretizing into the intermodal chain between Bicing and other modes, fare integration could increase the Rodalies-Bicing and FGC-Bicing annual users in a 54% and 23% respectively, being the global increase of intermodal demand about a 15%:

TABLE 11-5– IMPACT ON BICING INTERMODAL CHAIN. TERMS IN MILLIONS OF ANNUAL USERS (SOURCE: OWN CONSTRUCTION)

	BEFORE INTEGRATION	AFTER INTEGRATION	INCREASE (%)
Metro	1,7	1,7	***0%***
Rodalies	1,1	1,7	***54%***
FGC	0,7	0,8	***23%***
Urban bus	0,5	0,5	***0%***
Tram	0,2	0,2	***0%***
Interurban bus	0,2	0,2	***0%***
By Food	0,4	0,4	***0%***
Car	0,2	0,2	***0%***
TOTAL	**5,0**	**5,8**	***15%***

11.2.2 Impact on Metro demand

The impact means a double change in the demand of Metro mode. The global annual trips of 385 millions (ATM, 2016d) are currently divided into monomodal (84%) and intermodal (16%), and would experience two changes:

- On the one hand, part of the considered “monomodal” trips would change into intermodal, since the chain Metro-Bicing would now be included as part of bimodal demand. So, the 1,7 millions of annual trips involving Metro-Bicing change from monomodal to intermodal demand of Metro.

- On the other hand, the capitation of users coming from Rodalies (5%) and FGC (3%) which change Metro for Bicing would mean a decrease in 0,78 millions of annual trips.

The net value of the changes in the global Metro - demand would be estimated in a decrease of a 0,2%, as seen in the table below:

TABLE 11-6– IMPACT ON METRO INTERMODAL CHAIN. TERMS IN MILLIONS OF ANNUAL USERS (SOURCE: OWN CONSTRUCTION)

	BEFORE INTEGRATION	AFTER INTEGRATION	INCREASE (%)
Monomodal	323,4	321,7	***-0,5%***
Intermodal	61,6	62,6	***1,5%***
TOTAL	**385,0**	**384,2**	***-0,2%***

As seen, the decrease in global terms is not significant, since the global demand decreases a 0,2%, and the intermodality of Metro (becoming Bicing-Metro to be managed together), would keep the value of 16%.

11.2.3 Impact on intermodal chain of the STI

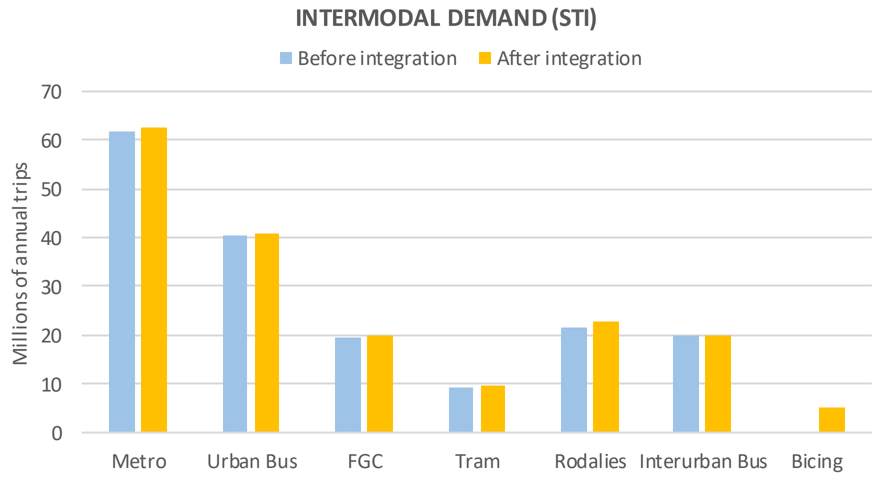
As seen, the principal consequence resulting from the fare integration would be the inclusion of the intermodal Bicing demand inside the STI, since the assumption that users could still pay the annual fare if they do not transfer to other public modes is kept. The total demand of STI (939 million of annual trips), would be the same since no new trips would be resulting from the integration.

The global intermodal demand in the STI would increase in a 5,1% due to the inclusion of intermodal Bicing demand, from 172,2 (ATM, 2017e) to 180,9 million of annual users:

TABLE 11-7– IMPACT ON STI -INTERMODAL DEMAND. VALUES IN MILLIONS OF ANNUAL TRIPS AND % (SOURCE: OWN CONSTRUCTION)

	BEFORE INTEGRATION		AFTER INTEGRATION		Δ
	ANNUAL TRIPS	%	ANNUAL TRIPS	%	%
Metro	61,6	36%	62,6	35%	**1,5%**
Urban Bus	40,3	23%	40,8	23%	**1,2%**
FGC	19,4	11%	20,1	11%	**3,5%**
Tram	9,4	5%	9,6	5%	**2,3%**
Rodalies	21,5	13%	22,6	13%	**5,1%**
Int. Bus	19,9	12%	20,1	11%	**1,0%**
Bicing	-	-	5,1	3%	-
TOTAL	**172,2**	**100%**	**180,9**	**100%**	**5,1%**

As seen, the weight of each mode changes as a result of integration and especially for rail modes (Metro, FGC and Rodalies), which are the principal intermodal chains which currently involve Bicing.



GRAPHIC 11.2 45. – IMPACT ON THE INTERMODAL DEMAND OF THE STI (MILLIONS OF ANNUAL TRIPS) (SOURCE: OWN CONSTRUCTION)

Moreover, a "reallocation" inside the bimodal-chain would take place, affecting the chains involving Metro and Rodalies or FGC (in blue):

TABLE 11-8– BIMODAL CHAINS PER O-D MODE AFTER THE FARE INTEGRATION OF BICING-SCHEME. MILLIONS OF INTERMODAL ANNUAL TRIPS IN THE STI. CHANGES IN BLUE. BICING INTERMODAL DEMAND IN RED. (SOURCE: OWN CONSTRUCTION)

Users (M)	Metro	Urban Bus	FGC	Tram	Rodalies	Int. Bus	Bicing
Metro	11,6	13,1	**13,4**	4,6	**11,6**	6,6	1,7
Urban Bus	13,1	18,8	2,4	1,1	2,1	2,7	0,5
FGC	**13,4**	2,4	0,8	0,3	1,0	1,4	**0,8**
Tram	4,6	1,1	0,3	0,8	2,1	0,5	0,2
Rodalies	**11,6**	2,1	1,0	2,1	1,1	3,0	**1,7**
Interurban Bus	6,6	2,7	1,4	0,5	3,0	5,6	0,2
Bicing	1,7	0,5	**0,8**	0,2	**1,7**	0,2	0,0

In all cases, the contribution of each chain involving Bicing represents less than the 1%, which means that the weight of both Metro-Rodalies and Metro-FGC experiences a decrease lower than 5%.

11.3 Service impact

According to the assumptions, the rates of average trip per user and day would remain constant and equal to 0,4. Same occurs with the average trips per user and year, estimated in 131 equivalent trips. However, the amount of trips per day and during the peak hour would increase in a 6%, according to demand estimations. As a result, the service-offer may decrease in terms of the rate of available bikes or stations per trip, if assuming the bike fleet remains constant:

TABLE 11-9– SERVICE INDICATORS. IMPACT ON THE DENSITY OF BIKES AND STATIONS. (SOURCE: OWN CONSTRUCTION)

	BEFORE INTEGRATION	AFTER INTEGRATION	INCREASE (%)
Bike fleet	6.000	6.000	-
Stations	420	420	-
Bike / station	14,29	14,29	-
Daily trips	38.454	*40.676*	*+6%*
Trips / peak hour (*)	3.854	4.676	*+6%*
Bikes / trip (peak hour)	1,56	1,48	*-5%*
Bike / 1.000 user	63,05	59,35	*-6%*

(*) It has been assumed a peak-factor of 10%

In order to maintain the service characteristics by meanings of the rate of 1,56 available bikes per trip during the peak hour, an increase in the bike-fleet would be required. If the operator would like to maintain the exact rate of 1,56 available bikes per trip during the peak hour almost an extra bike for each 6 new generated trips would be required, achieving the total amount of 347 new bikes.

However, the exact number is not possible to estimate. From the service evolution between 2007-2015 it can be seen that the behaviour of the demand does not have a direct relation to the rate of available bikes (Chapter XXXX). Since 2008 the bike fleet was consolidated and kept in 6.000 bikes while the demand has oscillated during the same period.

11.4 Incomes impact

In financial terms, Bicing's fare integration within the STI would have a direct impact on its funding principles, since pricing has a completely different structure if compared with other modes integrated inside the STI.

As discussed at the beginning of this chapter, no Bicing user would be willing to pay a fixed price per route and therefore, the pricing structure of annual subscriptions for residents is kept. However, revenues from intermodal demand or punctual trips would be subject to the management of STI.

According to the distribution and compensation policy (Chapter 5.5.1), ATM founded some distribution rules in order to divide all incomes coming from integrated tickets and a compensation policy in case of possible monetary losses due to integration. Same rules would be used and the assumption that in case of a bimodal chain involving two urban or interurban modes the fare income is equally divided is taken:

1-Single stage	$R = T$	*Eq.1*
2-stages, one urban zone + one interurban zone	$U = {}^{1}/_{2} * A$ $I = T - U$	*Eq.2*

Where:

$T := Fare\ income$ equal to 0,72 €/trip (Chapter 6.2)

$R := Income\ of\ the\ generic\ operator$

$U := Urban\ operator\ income$

11.4.1 Global considerations

Changes in financial terms related to incomes can be separated between three general items that will result from the fare integration:

- **<u>Incomes coming from annual subscriptions</u>:** Current intermodal demand of the Bicing service would no more pay the annual fare of 47,2 €. As a result, part of the its annual incomes would decrease.

- **<u>Incomes coming from current intermodal demand:</u>** Current intermodal demand of Bicing, would start to use the STI-tickets to access the service. ATM would then distribute the total income of the transport tickets including Bicing as part of the STI-chain. As a result, all operators would notice changes, since they current do not divide the income of a intermodal trip involving Bicing.

- **<u>Re-distribution due to demand changes</u>**: Some intermodal trips involving Metro would transfer to Bicing as seen in previous chapters. As a result, ATM will need to transfer the total incomes Metro was receiving for these trips to Bicing service.

As seen, all operators would experience monetary losses and Bicing would be the one winning incomes, since new trips would take place on the service. On the other hand, ATM will no experience monetary loses, since just a different performance of the distribution would take place, but no changes in global terms would be noticed.

11.4.2 Impacts on Bicing incomes

As explained above, changes on global incomes would result from a decrease in the incomes coming from annual subscriptions and incomes coming from intermodal demand, whose pricing structure would be for individual trip.

<u>Incomes coming from annual subscriptions</u>

An average rate of 131,2 trips per year and user, the ones which make intermodal trips with public transport can be estimated:

TABLE 11-10– CURRENT ANNUAL USERS AND INCOMES OF BICING (2015). (SOURCE: OWN CONSTRUCTION)

	ANNUAL USERS (subscriptions)	ANNUAL INCOMES (Million €/year)
Monomodal	57.101	2,53
Intermodal-TP	33.115	1,47
Intermodal -VP	4.953	0,22
TOTAL	95.168	4,22

The annual income payed for the service is equal to 47,2€. However, due to the annual number of users may oscillate during the annual year (since the subscription is annual), the average registered annual income per user is equal to 44,4 €.

Incomes coming from current intermodal demand

Incomes coming from intermodal demand can be divided into the ones resulting from current demand, and new incomes due to the "catched" trips from Metro-mode

On the one hand, same intermodal users would use STI-integrated tickets. Based on the 2-stages distribution rules, the punctual incomes per intermodal trip are estimated in the table bellows according to the distribution rules: $U = {}^{1}/_{2} * A = 0{,}35\ €/trip$ (blue) in case of interurban-urban chain and $T/2 =$ 0,36 in case of urban-urban chain (grey). So, Bicing would now receive part of the total import coming from integrated tickets and according to its current demand:

TABLE 11-11– CURRENT INTERMODAL DEMAND AND NEW INCOMES OF BICING AFTER THE FARE INTEGRATION (2015). SOURCE: OWN CONSTRUCTION)

	INTERMODAL DEMAND (Million trips)	INCOMES (Million €)
Metro	1,69	0,61
Urban Bus	0,47	0,17
FGC	0,67	0,23
Tram	0,22	0,07
Rodalies	1,09	0,38
Interurban Bus	0,20	0,07
TOTAL	4,35	1,54

As seen, the incomes coming from current intermodal demand are estimated in 1,54 million euros, which mean an increase of the 2% respect the 1,47 M€ currently collected for these trips.

Incomes coming from new demand

On the other hand, 0,8 million trips coming from Rodalies and FGC service would change the Metro for using Bicing mode. Using the 2-stages distribution rule for urban mode Bicing would enter a total amount of 268.348 € ($U = {}^{1}/_{2} * A = 0{,}345\ €/trip$).

Global result

The ATM would be in charge of receiving the incomes coming from the sale of transport-tickets and would return it to Bicing according to the distribution rules.

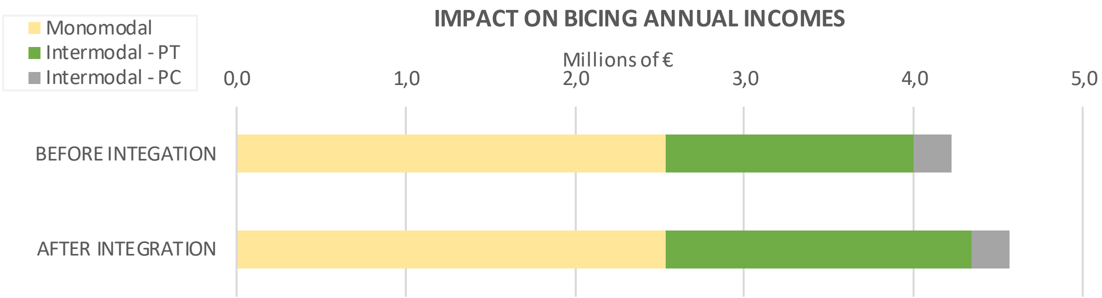
Sum it up, fare integration could increase in 0,34 million of € the incomes coming from intermodal trips. In %, it could mean the increase of about an 8%:

TABLE 11-12– GLOBAL ANNUAL INCOMES BEFORE AND AFTER THE INTEGRATION. TERMS IN MILLION € (SOURCE: OWN CONSTRUCTION)

	BEFORE INTEGRATION	AFTER INTEGRATION	INCREASE (%)
Monomodal	2,53	2,53	*0%*
Intermodal-TP	1,47	1,81	*23%*

Intermodal -VP	0,22	0,22	*0%*
TOTAL	**4,22**	**4,56**	***8%***

The global result is positive for Bicing, since the global incomes for the current demand will increase in 0,34 million €, which means a 8%:



GRAPHIC 11.4 46. – IMPACT ON TEMPORAL DISTRIBUTION OF BICING-ANNUAL DEMAND. TERMS IN MILLIONS OF ANNUAL TRIPS (SOURCE: OWN CONSTRUCTION)

In average, for new intermodal demand and current one Bicing could enter about 0,35 €/trip according to the distribution rules. Monomodal demand would keep implying an average income of 0,34 €/trip, assuming users would pay for the annual service and use it just 0,40 times/day (Chapter 8.6).

11.4.3 Changes in other modes incomes

Changes in other modes would be linked directly to the inclusion of intermodal demand coming from Bicing inside the STI. Currently, both demands are managed separately, by meaning that users pay Bicing-service as well as the public transport tickets. Resulting from this integration, users would pay a unique ticket and ATM would be the authority in charge of distributing the global income.

So, the impact for other operators in terms of own revenues would result from the fact that previous considered monomodal trips would now be part of the intermodal demand and therefore, the global income of the trips would need to be divided between Bicing and the other modes. As seen in the following table, the monetary lost in terms of millions of € for each mode corresponds to the same amount estimated for Bicing new incomes (Table 11-11):

TABLE 11-13– IMPACT IN TERMS OF CHANGES IN THE MONOMODAL DEMAND AND INCOMES OF EACH MODE. (SOURCE: OWN CONSTRUCTION)

	MONOMODAL DEMAND (Million trips)	INCOMES (Milllion €)
Metro	-1,69	-0,61
Urban Bus	-0,47	-0,17
FGC	-0,67	-0,23
Tram	-0,22	-0,07
Rodalies	-1,09	-0,38
Interurban Bus	-0,20	-0,07
TOTAL	**-4,35**	**-1,54**

Moreover, Metro would lose the amount of 0,78 millions of annual intermodal trips according to the demand previsions. These would be reflected in a loss of 268.348 €/year.

The following table reflects the global changes in the incomes per mode before and after the integration due to monomodal demand changes in millions of annual €:

TABLE 11-14– IMPACT IN TERMS OF CHANGES IN OWN INCOMES PER INTEGRATED MODE. TERMS IN MILLION €. (SOURCE: OWN CONSTRUCTION)

	BEFORE INTEGRATION	AFTER INTEGRATION	INCREASE (Million trips)	INCREASE (%)
Metro	254,6	253,7	-0,9	-0,3%
Urban Bus	136,7	136,5	-0,2	-0,1%
FGC	72,8	72,6	-0,2	-0,3%
Tram	13,4	13,3	-0,1	-0,6%
Rodalies	140,8	140,4	-0,4	-0,3%
Interurban Bus	150,6	150,5	-0,1	0,0%
Bicing	-	1,81	-	-
TOTAL	**768,9**	**768,9**		**0%**

As seen, in global terms, ATM would no notice any monetary loose, since just a redistribution of the demand and its incomes is considered in this chapter. For operators, the fare integration of Bicing would mean less than a 1% diminution of its revenues.

According to compensation policy, ATM would need to compensate a total amount of 1,81 million € to operators, which means the 0,23% of the global incomes or either increase transport tickets prices. If just the fare integration increases the annual demand of STI system in 2,12 million trips (+0,26%), the monetary losses would be compensated, assuming that in average the revenue per trip is T=0,72 €.

11.5 Impact on Bicing running costs

According to OBIS (European Commission, 2011), the implementation costs in large-scale systems such as Bicing are between 2.500 – 3.000 €/bike depending on the configuration of the system. On the other hand, running costs are variable but can be stated as 1.500 - 2.500 €/bike and year (European Commission, 2011). Considering that in average a bike has a useful life of between 5-10 years (European Commission, 2011), each one implies an extra cost of between 2.000 – 3.100 €/year.

The worst case in which in average bikes fleet has to be replaced each 5 years and implementation and running cost imply 3.000 €/bike and 2.500 €/bike-year respectively, the cost of the service would increase in 3.100 €/year.

If assuming that the operator would like to maintain the service rate of 1,56 available bikes per trip during the peak hour, 347 extra bikes are required. In terms of global cost, it would increase in 1,07 million € (+6%), achieving the rate of 19,08 million €.

Since the extra revenues due to fare integration are estimated in 0,34 million € (Chapter 11.4.2), the increase of 1,07 in running costs could not be absorbed with own incomes and Bicing would need more subsidies. According to the increase in revenues, the service would be capable of assuming 100-110 extra new bikes.

11.6 Coverage

According to the Cost impact, the chapter will expose two scenarios including or not the required changes in the offer. In all cases it will be assume that the cost for bike-redistribution, named as "*"refloating""* will increase lineal with the demand, in order to build the worst-case scenario. According to OBIS-Handbook (OBIS,2011), this cost represents the 30% of the global ones.

Scenario without investment in bike fleet

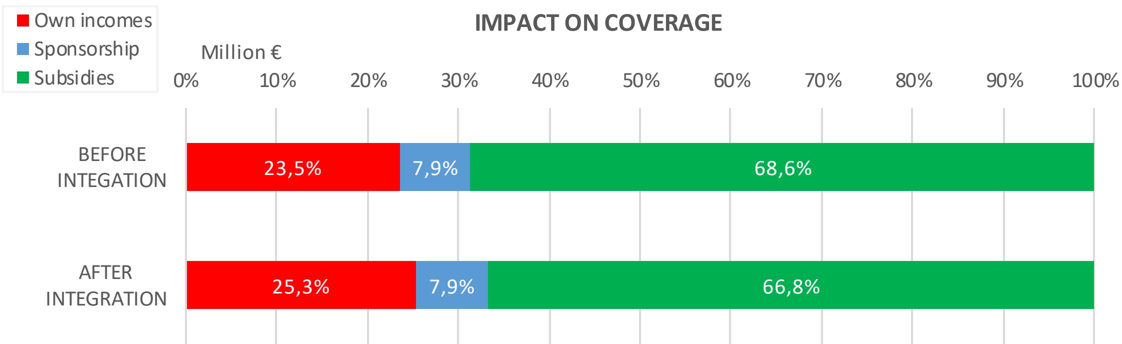
If assuming no changes in bike fleet are required, the cost of running the service would increase due to ""*refloating*"" in a 0,2%. New incomes would increase in an 8% which would assume the cost growth and would let the required subsidies decrease in a 0,2%:

TABLE 11-15– IMPACT IN FINANCING TERMS. SCENARIO WITHOUT INVESTMENT IN BIKE FLEET. TERMS IN MILLION €. (SOURCE: OWN CONSTRUCTION)

	BEFORE INTEGRATION	AFTER INTEGRATION	INCREASE (%)
Own incomes	4,22	4,56	8,0%
Sponsorship	1,42	1,42	-
Subsidies	12,35	12,05	-2,5%
TOTAL	**18,00**	**18,03**	**0,2%**

Saving subsidies would be of 0,15 million €, which could cover the 10% of the compensation of the 1,81 lost million € for other operators due to integration.

Representing the disaggregated incomes in terms of its weight in covering the global running cost, fare integration would mean no notable changes in Coverage terms. Subsidies would still have a big weight in the global financing of the service.



GRAPHIC 11.6 47. – IMPACT ON COVERAGE OF BICING SERVICE. SCENARIO WITHOUT INVESTMENT IN BIKE FLEET (SOURCE: OWN CONSTRUCTION)

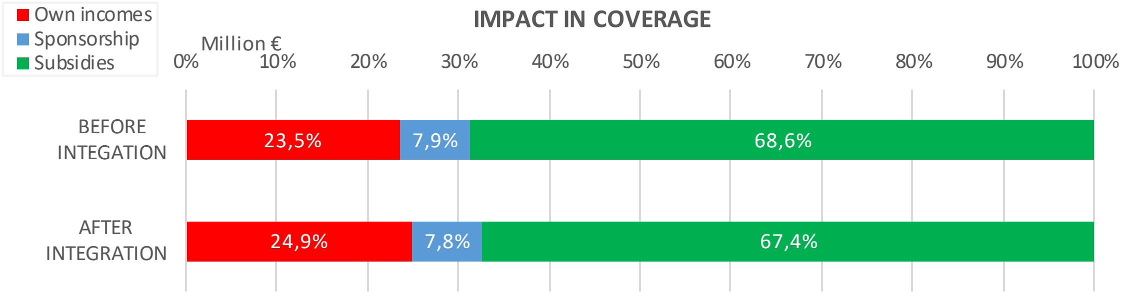
Scenario with investment in bike fleet

If considering the requirement of investment in bike fleet, the limit is fixed in 100 extra bikes, which would mean 7 new stations implemented in a year. With this value, extra revenues could cover the implementation and running costs, without needing extra subsidies:

TABLE 11-16– IMPACT IN FINANCING TERMS. SCENARIO WITHOUT INVESTMENT IN BIKE FLEET. TERMS IN MILLION € (SOURCE: OWN CONSTRUCTION)

	BEFORE INTEGRATION	AFTER INTEGRATION	INCREASE (%)
Own incomes	4,22	4,56	8,0%
Sponsorship	1,42	1,42	-
Subsidies	12,35	12,35	-
TOTAL	**18,00**	**18,34**	**1,9%**

Same conclusion as in the previous scenario is obtained in coverage terms, since subsidies are needed to cover more than the 50% of the global cost:



GRAPHIC 11.6 48. – IMPACT IN COVERAGE OF BICING SERVICE. SCENARIO WITH INVESTMENT IN BIKE FLEET (SOURCE: OWN CONSTRUCTION)

11.7 Capacity of Bicing-service

The chapter aims to estimate the limit of demand the service would be able to assume, without having capacity problems. The demand increase estimated in the chapters before (+6%) corresponds to the ones catched from Metro-mode. However, fare integration could also substitute some trips which are currently done "by-food", so demand could increase and collapse the service.

As seen, in financing terms Bicing would obtain profits from its inclusion inside the STI system, but no notable changes in its coverage. Under this estimation, the capacity of the service is then linked to service indicators by meanings of bike fleet and stations.

In the present, Bicing service offers a bike fleet of 6.000 bikes spread in 420 different stations in the city, for the daily 38.454 trips and its 95.168 annual users (BS:M, 2016A). It covers the 55% of the total area of Barcelona, and 82% of the residents have stations close to its house. Assuming that the peak hour factor is equal to 10%, the available rate during this period raises the value of 1,56 available bikes per trip.

Bicing capacity is related to the offer in amount of bikes available for its users in a peak hour, being the limit in 1 available bike per user, if assuming a homogeneous distribution of trips between stations. The rate corresponds to a limit of 6.000 trips/hour, which means 60.000 trips in a day. Bicing users make and averaged amount of 0,4 trips per day and 131 annual trip, so the limit in subscription terms would be of 148.491, 56% more than the current demand:

TABLE 11-17– CAPACITY LIMITS FOR BICING SERVICE (SOURCE: OWN CONSTRUCTION)

Daily trips	60.000
Trips / peak hour (*)	6.000
Av. Bikes/trip (peak hour)	1,0

11.8 Conclusions

Basically, the inclusion of Bicing inside the fare integrated system (STI) would have a repercussion in the global performance of the STI as well as in the funding principles of the flexible service. The impact was evaluated in terms of changes in demand, revenues and costs.

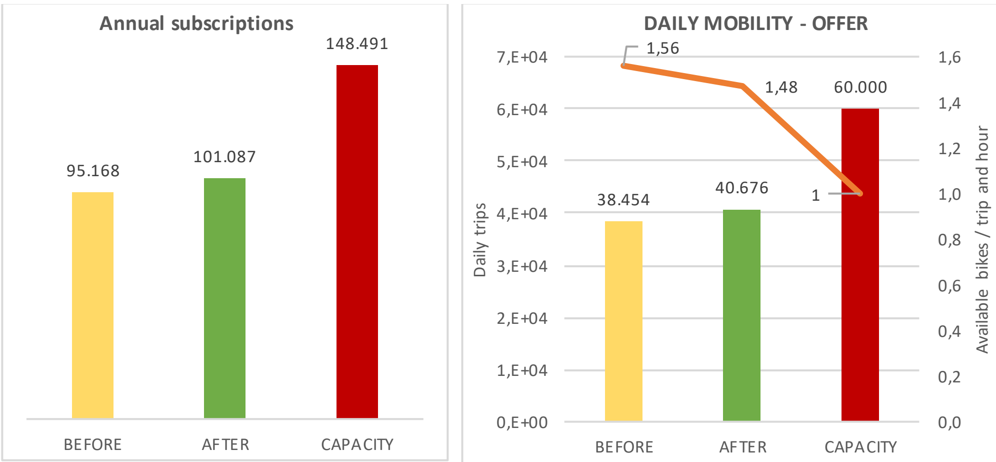
Impact on Bicing service

Direct consequences of allowing the entire ATM-crown using the scheme were estimated in an increase in the demand and incomes, which means that the service would take profits from fare integration, but could cause a reduction in the provided service and increase costs.

Bicing could cover the "last-mile" of some bimodal chains coming from Rodalies and FGC which currently use Metro. No changes in the monomodal demand or intermodal with private or no motorized modes are considered to happen due to the fare integration. According to the hypothesis, residents would not have any motivation to change its behaviour, and just intermodal demand would increase.

Based on the weight of current intermodal chain Rodalies-Bicing (5%) and FGC-Bicing (3%), the number of induced trips was estimated in 0,8 million/year, which mean an average rate of 40.676 daily trips. Specifically, intermodal trips would increase in a 15%, and a 6% in general terms.

However, Bicing could also replace the "last-mile" of some connection-trips currently done by food. In order to analyse the capacity, the number of available bikes per trip during a peak hour was used, being the limit fixed in 1. The capacity was then fixed in 6.000 trips/hour, which means 60.000 trips in a day. Knowing that users make and averaged amount of 0,4 trips per day and 131 annual trips, the limit in subscription terms would be of 148.492, a 56% more than the current demand:



Graphic 11.8 49. – Impact on Bicing annual subscriptions, daily demand and available bikes per trip in an hour (Source: Own construction)

In financing terms Bicing would obtain profits from its inclusion inside the STI system. It would now receive part of the total import coming from integrated tickets and from its current intermodal demand, while it would loss the annual subscriptions of it. According to the ATM implemented distribution rules, the net changes of its incomes was computed in an increase of 8%, meaning 0,34 million € coming from intermodal trips.

In the built scenario, annual subscriptions are kept for residents and users would pay the same amount for a single trip (0,34€ in average), while ATM would pay to Bicing-operator 0,35€ per integrated trip. So, fare integration would no represent any increase in user-taxes in general terms, since transfers are not penalised in monetary terms.

If density of bikes and stations is maintained, the service may provide a lower level of service and extra investment could be needed. Operator would need to provide 347 extra bikes in order to keep the same rate and more subsidies would be need. Fare integration would not improve the coverage of the system, since still more than 50% of the incomes would keep comming from public subsidies.

The following table sums up the impact for Bicing service, in terms of annual demand and revenues after the integration and the growth it would represent:

Table 11-18– Summary of fare integration impact on Bicing service (Source: Own construction)

	ANNUAL DEMAND (Subscriptions)	ANNUAL DEMAND (Million trips)	INCREASE (%)	OWN REVENUES	INCREASE (%)
Monomodal	62.053	8,2	0%	2,75	*0%*
Intermodal	39.033	5,1	+18%	1,81	*23%*
TOTAL	**101.087**	**13,3**	**+6%**	**4,56**	***8%***

According to what has been exposed, the only problem for Bicing service is the limit of capacity, established in a maximum increase of a 56% in annual subscriptions. Based on these results, in order to avoid capacity problems, the service has different options:

- Implement the required bikes progressively, estimated in 100 new bikes, which would mean an increase of 2% global costs and would not require more subsidies.
- Limitation in the amount of annual subscriptions in order to preserve the capacity of the service. Since the service requires a previous registration, limiting the service is possible.
- Increase the price of annual subscriptions until 62,6 €/year, so the service will be able to assume the 347 extra bikes.

Global STI and operators

In both terms (demand and finance), the impact could be null for the global performance of the STI. On the one hand, global demand would not experience any change, since annual subscriptions would be kept and be managed through the operator itself. The inclusion of Bicing's intermodal chains would mean a redistribution of the global demand: diminution of previously considered monomodal trips and same net increase in intermodal demand. Just Metro mode would experience a loose of 0,8 million of annual trips, a 0,2% its global demand.

Under same argument, ATM would no notice any monetary loose, since just a redistribution of global incomes between operators will take place. Individually, decreases on single operator's revenues coming from integrated tickets accounted in a total amount of 1,81 million € were estimated, meaning less than a 1% diminution for each of them and the 0,4% global incomes from STI.

According to compensation policy, ATM would need to compensate the total loses to operators or either increase transport tickets prices. If just fare integration increases the annual demand of STI system in 2,12 million trips (+0,26%), meaning that users which currently use individual transport ticket start buying integrate tickets to use Bicing as a *"last-mile"* -mode, monetary losses would be compensated.

PART IV

Final conclusions

12. CONCLUSIONS

The main motivation of this Project was to study the possibility of fare integrating Bicing inside the fare integrated system (named STI) owned and managed through the transport authority ATM. With this basis, the body of the document was structured in three parts in order to analyse on the one hand the organization of transport modes included in the STI, and on the other, the structure and performance of Bicing service.

First theoretical research was orientated for understanding the integrated running of the system and its weight inside the global public transport in a city like Barcelona. It also enables studying interactions between modes and operators and how the ATM manages its demand and incomes.

On the other hand, the analysis of the own structure of the bike sharing-scheme Bicing and other European experiences was guided to study the possibility of its fare integration. Through its structure diagnosis and its role within the city, it was possible to define how integration could be possible and the impact it would have for the service and for the entire STI.

Basis on this structure, following conclusions were obtained from Part I:

1. **Integration is one of the keys of survival for bike sharing schemes in Europe, understanding the physical, information and fare integration.** From the analysed services, both physical and integrated information have presence in all successful schemes, but fare integration is not always guaranteed and normally only linked to access integration. In some European examples, the schemes are compatible with public transport pass. However, no experience in fare integration and structures of pricing per trip was found.

2. **Bicing is defined as a flexible bike sharing system, which is mainly used as a complementary mode for covering the named "last-mile" and is has not been consolidated yet.** From demand diagnosis, it was concluded that users pay for the annual subscription but rarely use the scheme as a daily-mode, since in average 0,4 trips/user-day are done. However, intermodality has a weight of 40%, especially related with rail modes: *Metro, Rodalies* and *FGC* services.

3. **Two of the three levels of integration can be found in Bicing-scheme: *physical and information.*** Since its implementation, stations were located close to a Metro stop or station and information about the location of close Bicing-stations can be found inside Metro. However, no fare or access integration is provided.

4. **The service receives subsidies which represent above the half of the service financing.** Specifically, 69% of the running cost is payed through public subsidies coming from the city council, 8% from the sponsorship contract with Vodafone and just the 23% come from annual subscriptions.

After analysing the global public transport and the fare integrated system, some conclusions were taken:

1. **Public transport in Barcelona is organized in different juridical layers**, which consists of own operators, public authorities which manage specific modes and the main transport authority ATM. Public transport represent the selected mode of 33% of intern trips and 51% connection ones. The global network consists in a set of urban and interurban modes, which allow connection mobility with other municipalities of the influencing area of Barcelona and within the city, between neighbourhoods.

2. **The three different types of integration are the basis of the STI system: physical, information and fare.** Physical integration refers to the hierarchy of stops and stations, divided into urban

and interurban hubs acting as mode-exchangers. Integrated information is ensured through webs, apps and informative posters. Finally, fare integration consists in a set of homogeneous transport tickets, allowing users access to all modes with same integrated tickets and none penalization for transfers. ATM is in charge of fixing its price structure based in a *"discrete pricing per kilometre"* corresponding to its crowns and a *"fidelizing policy"*, being the unitary price per trip lower the higher the number of trips a user makes.

3. **The performance of fare integration system is based on Distribution – Compensation rules**. In basis of a distribution rules, ATM collects and distributes revenues coming from integrated titles and distribute them to the involved operators. The basis of the distribution is the weighted average fare "A", estimated in 0,69 €/trip (ATM, 2017c). Compensations comes from the possible monetary losses for each operator coming from the distribution from global revenue of intermodal tickets.

4. **Benefits coming from fare integration can be measured quantitatively in demand and intermodality increase, and in qualitative terms in a better perception of the service from users.** Thus, in 2001 after the STI implementation, the number of sold tickets increased in a 7% and intermodality-rate grew from 8,3 to 19%, so no compensation was required for operators.

5. **Fare integrated system has a significant weight in terms of demand and revenue, representing the 72% and 64% respectively of global public transport.** The coverage of the system is estimated in a 55%, requiring public subsidies which are distributed among operators in order to cover its running costs. Users pay an average price of 0,724€/trip while subsidies cover 0,57€/trip. For Metro (which is the larger mode in demand terms), the weight of the STI is greater than the 70%. Moreover, intermodality rate is estimated on a 20%, if considering the bimodal chains between the main modes: *Metro, Urban bus, FGC, TRAM, Rodalies and Interurban bus.* The most significant chains (in demand terms) are the ones involving different urban bus lines and the ones involving Metro with other modes.

After both analysis, the possibility of fare integrating the Bicing scheme inside the STI system was studied. Conclusions and limitations of this possibility are the ones summed up bellow:

1. **Fare integrating Bicing has two "previous" barriers which need to be solve: Access, and Pricing structure.** The access of the service is only available through a magnetic card which is limited just for residents, while public transport uses paper-tickets and are completely open. The launch of the new electronical *"T-Mobilitat"* could delete the access barrier. Regarding pricing structure, the scheme is organized through annual subscription and no experience in paying per trip was found, while public transport operates with a set of discretized prices per travelled km.

2. **Metro is the service which better competes with Bicing in terms of coverage,** since they have a similar presence inside the urban limits of Barcelona. They both cover together the densest parts of the city, which means a 70% of the population. The results link with the fact that the highest intermodal-chain for Bicing is the one involving Metro and with the provided physical integration.

3. **Bicing has some potential in substituting intermodal trips coming from Metro, since it provides a better access and no waiting time.** Comparing the invested time in monetary terms of transfers involving Metro, it was concluded that Bicing provide cost saving in specific connections in which the travelled length inside Metro is lower than 3,2km. The profit comes from the fact that for user's perception, transfers and waiting time are highly penalised if they need to travel short distances.

4. **Transfers involving Metro and Rodalies or FGC have specially interest, since physical integration with Bicing is solved and in average users need to cover a low distance inside**

Metro. The built theoretical transport model shows that in average, users these users travel a distance inferior to 3.2km (2,5 and 2,3km respectively). Thus, Bicing has potential in absorbing part of this demand if users could have access to the service.

5. **On the built scenario, Pricing barrier would be solved if Bicing would manage its own demand and the ATM would be in charge of collecting and distributing the incomes coming from integrated tickets.** According to hypothesis, current users would not change its behaviour since for monomodal trips they would pay a considerable higher price than currently, averaged in 0,34€/trip. Therefore, Bicing could keep the annual subscriptions for the residents as own ticket just as other operators do. It could manage its incomes and keep the "non-competiton" policy with rental bike companies. On the other hand, it would allow access to the entire ATM-system through integrated transport tickets, without transfer penalization and managed through the ATM.

6. **The inclusion of Bicing as part of the fare integrated system (STI) would have a repercussion on its demand and incomes as well as on its funding principles.** According to hypothesis, Bicing could replace the "last-mile" of some connection-trips coming from Rodalies and FGC estimated in an increase about a 6% its global demand (18% if considering just intermodal demand). According to distribution-compenations rules fixed by ATM, Bicing would increase in an 8% its global incomes (23% the ones coming from intermodal demand).

7. **The limits of the fare integration of Bicing are linked to its capacity and the increase in the service cost to provide same level of service.** The service is able to offer an amount of 6.000 bikes, which means that its maximum rate of trips during the peak hour is fixed in this value. Therefore, the limit of capacity corresponds to 148.492 subscriptions, a 56% more than the current value. Due to the demand increment, the operator could need to invest in increasing bike fleet to keep the rate of 1,56 available bikes per trip during the peak hour. Since subsidies would be required to absorb the extra cost, different solutions were exposed:
    - Implement the required bikes progressively, estimated in 100 new bikes.
    - Limit the amount of subscriptions in order to preserve the capacity of the service.
    - Increase the price of annual subscriptions until 62,6€/year, so service will be able to assume the 347 extra bikes and keep the rate 1,56 bikes/trip during the peak hour.

    Under these considerations the rate of available bikes per trip in the peak hour would be of 1,50, and the new bikes would be located in the principal Rodalies and FGC stations: *Arc de Triompf, Sants, Pl. Catalunya, Provença and Pl. Espanya*.

8. **The impact in running costs is null for the global performance of the STI, but operators could lose money.** In demand and incomes terms, the STI would experience the same global values, since just a redistribution would take place. Individually, decreases on annual revenues in less than 1% would be notice, and in Metro in terms of its demand about a 0,2%. According to distribution-compensation policy, ATM would need to compensate the total loses to operators or either increase demand in 2,12 million of annual trips (+0,26%), to cover the lost amount of 1,81 million €.

9. **Limits of the present study correspond to the difficulties in having access to Bicing-data, which dit not allow to provide a consistent and completely analysis of demand impact.** In terms of demand it was assumed just a repercussion on intermodal demand coming from Metro would take place. However, in reality and according to European experiences, bike sharing usually substitute "by food" trips, so the increase in demand terms could be greater. However, the project established the limits of the service and the basis to compute the impact and avoid capacity problems and exceed of costs.

REFERENCES

[1] AJUNTAMENT DE BARCELONA, 2017: Organització municipal de Barcelona. Dades disponibles de población i área per districte i barri. Ajuntament de Barcelona.

[2] AJUNTAMENT DE BARCELONA, 2016: Dades bàsiques de mobilitat del 2015. Ajuntament de Barcelona.

[3] AMB, 2017: Stadistical data and indicators related to mobility inside the AMB. Àrea Metropolitana de Barcelona.

[4] ATM, 2017A: How the integrated tariff system (STI) works. Geographical area and T-Mobilitat. Autoritat de Transports Metropolità.

[5] ATM, 2017B: Integrated transport tickets. Autoritat de Trasports Metrpolità.

[6] ATM, 2017C: *Basic information of intermodal demand.* Information obtained through internal mails with the economic-financial and tariff integration management department. Sistema Tarifari Integrat. Autoritat de Transports Metropolità (ATM)

[7] ATM, 2017D*:* The metropolitan transport authority. Main organization. Available on: Autoritat de Transports Metropolità.

[8] ATM, 2016A: Dades bàsiques del sistema Area. Observatori de la Mobilitat. Autoritat de Trasports Metrpolità. Available in: http://observatori.atm.cat

[9] ATM, 2016B: Mobility Obersvatory: Financing the system. Public transport financing summary. Observatori de la Mobilitat. Autoritat de Trasports Metrpolità. Available in: http://observatori.atm.cat

[10] ATM, 2016C: Annual activity report for the exercise of 2015. Observatori de la mobilitat. Autoritat de Trasports Metrpolità. Available in: http://observatori.atm.cat

[11] ATM, 2016D: Enquesta de Mobiltiat en Dia Feiner 2015. Observatori de la Mobilitat. Autoritat de Trasports Metrpolità.

[12] ATM, 2010: Comparative study of the public transport financing and of the fare policy in different metropolitan areas of Europe. Conference for European Metropolitan Transport Authorities (EMTA).

[13] BS:M, 2017: *General information about the performance and offer of Bicing.* Information obtained through internal mails with the Bicing department. Unitat Bicing. Barcelona Serveis Municipals S.A.

[14] BS:M, 2016A: *Bicing 2007 – 2016.* Barcelona Serveis Municipals S.A. Ajuntament de Barcelona.

[15] BS:M (2016B): *Memòria anual del servei 2015.* Annual report. Barcelona Serveis Municipals S.A. (BS:M)

[16] DAGANZO, C.F., 2010: *Structure of competitive transit network. Particular case of Barcelona.* Working Paper. Institute of Transportation Studies, University of California, Berkeley,

[17] DAGANZO, C.F., 2010: *Public Transportation Sytems: Basic Principles of System Design, Operations Planning and Real-Time Control.* Course Notes. Institut of Transportation Studies, University of California, Berkeley.

[18] FGC (2017): *Data indicators. Official stadistics.* Ferrocarrils de la Generalitat de Catalunya.

[19] IDAE, 2010: *Guía metodológica para la implantación de sistema de bicicletas públicas en España.* Instituto para la Diversificación y Ahorro de la Energía. Ministerio de Indústria, Turismo y Comercio. Gobierno de España

[20] IERMB, 2016A: *Sistema d'Indicadors Metropolitans de Barcelona (SIMBA). Transport públic.* Mobility indicators of Publi Transport in Barcelona. Instituts d'estudis regionals I metropolitans de Barcelona (INECA)

[21] IERMB, 2016B: *Sistema d'Indicadors Metropolitans de Barcelona (SIMBA).* Bicicleta. Bike indicators. Instituts d'estudis regionals I metropolitans de Barcelona (INECA)

[22] MIDGLEY, P., 2009: *The Role of Smart Bike-Sharing Systems in Urban Mobility.* Land Transport Authority JOURNEY, vol.2, no.1

[23] MIDGLEY, P., 2011: *Bicycle-sharing schemes: Enhancing Sustainable Mobility in Urban Areas.* Commission on Sustainable Development, nineteenth sesión. United Nations, Department of economic and social affairs (UN, DESA).

[24] ROSELLÓ, X., 2006: *La gestió del Sistema tarifari integrat del transport públic a la Regió Metropolitana de Barcelona.* IV Jornada Fòrum Català d'Informació i Salut. Autoritat del Transport Metropolità (ATM)

[25] ROSELLÓ X., CALVET, F., 2007: *Procés de modelització de la mobilitat a l'RMB. Elaboració de les matrius futures de mobilitat*. Autoritat del Transport Metropolità (ATM)

[26] QUAY COMMUNICATIONS INC., 2008: *Public Bike System. Feasibility Study*. Quay Communications Inc

[27] TMB (2015): *Memòria anual de l'exercici del 2015*. Annual Report. Transports Metropolitans de Barcelona.

WEB PAGES

[1] BICING: *https://www.bicing.cat*

[2] BIKEMI: *https://www.bikemi.com*

[3] BIZI: *https://www.bizizaragoza.com*

[4] CLEAR CHANNEL: *http://www.clearchannel.com*

[5] CYCLOCITY: *http://en.cyclocity.com*

[6] FGC: *http://www.fgc.cat/cat*

[7] JCDECAUX: *http://www.jcdecaux.com/supplying-self-service-bikes*

[8] KEOLIS: *http://www.keolis.com/fr/notre-offre/offre-transport/velo*

[9] LE VÉLO STAR: *https://www.levelostar.fr*

[10] NEXTBIKE: *http://www.nextbike.net/news/kvb-rad-in-cologne*

[11] RODALIES: *http://rodalies.gencat.cat/es/tarifes*

[12] SANTANDER: *https://santandercyclesmk.co.uk*

[13] SCNF: *http://www.sncf.com/en*

[14] SEVICI: *http://www.sevici.es*

[15] TRAM: *http://www.tram.cat*

[16] TRANSPORTS FOR LONDON: *https://tfl.gov.uk*

[17] VELIB: *http://www.velib.paris*

[18] VELO'V: *https://velov.grandlyon.com*

[19] WIKIPEDIA: https://en.wikipedia.org/wiki/V%C3%A9lo%27v