Planning for a Regional Rail System:
Analysis of High Speed and High Quality Rail in the Basque Region

By

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B.S. Civil Engineering
Ohio Northern University, 2009

Submitted to the Department of Civil and Environmental Engineering in Partial
Fulfillment of the Requirements for the Degree of

Master of Science in Transportation
at the
Massachusetts Institute of Technology

February 2011

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ABSTRACT

The goal of this thesis is to provide guidance for regional rail network planning to achieve the maximum benefits in terms of economic growth, passenger satisfaction, and environmental sustainability. The hypothesis is that a regional intercity rail network can increase accessibility allowing the connected cities to function as a single economy thus increasing overall productivity.

The Basque Y high speed rail (HSR) project in northern Spain will be used as a case study for this thesis. This new system has the potential to significantly reduce regional travel times but due to poor station placement and inadequate operational foresight, speed-focused planning has left key regional markets inaccessible. This thesis recommends a shift in planning that enables regional economic cohesion and increased system ridership through a focus on high quality rail (HSR) that includes the complete door-to-door journey with a customer oriented approach to convenience, comfort, and reliability.

The highly successful Swiss rail network serves as a guide as to how to combine the superior speed of the Spanish system with the superior quality of the Swiss system to provide one which can achieve maximum benefit from the Basque Y investment. A comparison with the Spanish system shows what the Basque Y should do differently in terms of planning and service and accessibility maps help to illustrate the Basque Y system under different planning scenarios. Planning issues examined are station location, integration with local transit systems, and operational fares, frequencies, and scheduling. Finally the regional system is examined politically and a strategy is sketched that can enable the region to modify the plan to obtain the benefits of a high speed and high quality regional rail system.

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ACKNOWLEDGEMENTS

Thanks to the many people that have made the past 18 months worthwhile. Specifically I would like to thank:

Fred and Mikel for challenging me with your advice, insight, and guidance.

John and Nigel for giving your support and sharing your knowledge.

Arantza Tapia and our Gipuzkoa colleagues for your hospitality and generosity.

Mila esker.

Fellow lab mates for the friendship and for making this fun.

Mom and Dad for helping me get here.

Kimberly Jean. You will never know how much.
1 INTRODUCTION

1.1 BACKGROUND

This thesis develops and applies methods to determine proper planning decisions necessary to encourage regional economic cohesion using a regional intercity rail network. The purpose is not to evaluate such a rail network overall, but rather to optimize its design to achieve the maximum benefits. For the context of this thesis, a "regional rail network" will be defined as a connection of cities less than 200km in distance that is competitive with the automobile as a mode of intercity travel. Regional rail networks allow for fast, reliable, and inexpensive trips between mid-sized cities. Examples of successful regional rail networks can be found in Germany and Switzerland where the rail systems allow many mid-sized cities to benefit from the sharing of labor and service markets.

To start it is important to make the distinction between "high speed rail" (HSR) and "high quality rail" (HQR). HSR is designed with the top speed being the primary planning motivation and is becoming increasingly popular worldwide. For example Japan, France, and Spain have HSR lines with speeds beyond 300 kph that compete directly with the airlines. HQR systems, which are typically regional intercity services, depend much more on the quality of the service to attract riders as competition is with the automobile. Among other characteristics, "high quality" can encompass reliability, intermodal integration, centrally located stations, convenience, low fares, and high frequencies. Evidence from Japan, France, and Spain show that HSR can also have the features of HQR, but for competition with the airplane, this is not a driving force for building ridership. The same is true that HQR can also be high speed, but the very high quality Swiss system is overwhelmed with high ridership even though the system rarely exceeds 130 kph. This thesis will examine the specific features of high quality and demonstrate their benefits in the context of a regional rail network.
The benefits of regional rail networks and the need for HQR planning in these systems will be investigated using existing literature and examples of current practice. Benefit/cost project evaluation attempts to quantify the benefits of transportation improvements by looking primarily at the benefits provided to users in the form of time savings. However it is becoming increasingly recognized that there are benefits beyond basic time savings that include wider economic benefits. Wider economic benefits are those associated with the productivity and efficiency gains derived from reduced travel time and costs between people and businesses.

Research shows that there are significant increases in wages and economic output per worker as metropolitan areas encompass larger populations. In his paper Segal (1976) suggests populations greater than two million is required to achieve significant productivity benefits. This exact figure is debated but it is clear that large cities have more economic power than mid-sized cities (Arnott, 1977)(Moomaw, 1981). A regional HQR system has the potential to increase the economic size of a city by connecting population and business centers with fast and inexpensive transportation.

To demonstrate this potential, six European cities were selected from the Foreign Policy/A.T. Kearney Global Cities list. Table 1 shows these cities listed with their metropolitan area population and the 2010 Global City Index rank.

<table>
<thead>
<tr>
<th>Metro-Area Population</th>
<th>Foreign Policy Global City Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>London 12,400,000</td>
<td>2</td>
</tr>
<tr>
<td>Paris 10,400,000</td>
<td>4</td>
</tr>
<tr>
<td>Madrid 6,200,000</td>
<td>17</td>
</tr>
<tr>
<td>Brussels 1,870,000</td>
<td>11</td>
</tr>
<tr>
<td>Frankfurt 1,930,000</td>
<td>20</td>
</tr>
<tr>
<td>Zurich 1,160,000</td>
<td>24</td>
</tr>
</tbody>
</table>

*Table 1: Select European Global Cities (Foreign Policy, A.T. Kearney, and the Chicago Council on Global Affairs, 2010)(Brinkhoff, 2010)*

All of the cities listed are well developed, culturally diverse, and economically influential on a global level. However the last three have very low populations
compared with the first three. There may be other factors that attribute to the global influence of these small cities, but one thing that the three do have in common is that they are all part of regional HQR networks.* This enables them to share service and labor markets with other cities in their region and therefore increase their economic mass. Brussels lies on the main line connecting Paris and Amsterdam and has many trains that connect dense population centers along this route. Frankfurt recently opened an HSR/HQR line to the regional city of Cologne and has direct HQR connections to the airport and other regional cities. Zurich is connected to regional cities, such as Basel and Berne, with a highly integrated HQR system that unifies all major modes of public transit. All cities connected by regional HQR networks can become integrated economies by borrowing labor and services from other regional population and business centers. This gives mid-sized cities the potential to compete in the international economy with larger cities. This thesis will show that the quality of the system is vital in order to achieve this. Building or upgrading a rail line to achieve high speed alone will not inherently bring economic growth.

This thesis will use the “Basque Y” project in Spain as a basis for analyzing the regional rail network. The project is designed as part of an HSR connection between the Basque Country and Madrid. It also provides an essential link between France and Spain. However for the benefit of the Basque County the planned infrastructure will result in an “accidental” regional network. Figure 1 shows a schematic diagram of the Basque Y part of the line. The infrastructure will connect the three main Basque cities, Vitoria, Bilbao, and San Sebastian, which are all about 100km apart, in a Y shape. When completed the line will extend southeast from Vitoria to connect with Madrid, and northeast from Irun to connect with Paris. Specific details on the project are found in Chapter 4.

* For example, the global influence of Brussels may be an outlier due to the fact that it holds the capital of the European Union.
The European Union, the Spanish Government, and the Basque Government all have a part in funding this large and expensive HSR network. In spite of significant investment there are certain major issues that are currently problematic. First there is great doubt as to whether the planned San Sebastian station, located 6km south of the city center, is in the correct place to encourage regional cohesion. Secondly there is no current plan for integration between the local transit systems and the new rail system. Third, while the infrastructure is currently under construction and set to open in 2013, no organization has considered an operating plan or acquired rolling stock. These issues have direct effects on the immediate and future potential for the system. Making the correct decisions now is important to realizing this potential.

The apparent lack of planning is not unique to the Basque Y project. The Spanish style of HSR investment is dominated by a focus on high speed and connections with Madrid. Properly connecting mid-sized cities is not a major consideration of the network development. “The proposed HSR link between Madrid and Valencia, among others [such as the Basque Y], is strictly political and is not backed by any technical study that supports the opportunity of this investment” (Martí-Henneberg, 2000). Martí-Henneberg goes on to state that the investment has not been directed by attempting to
increase economic activity, whether it be in the cities or by the stations. “In fact, any discussions as to the social profitability of [HSR] investments have been largely absent from the political debate” (Albalate & Bel, 2010). The lack of planning risks resulting in missed opportunities especially for the regional networks.

The media reinforces the political desire for HSR. Countless news articles center on the time reductions for very long distance trips. For example in November 2009, The Times (UK) published an article touting the benefits of the new HSR connections between England, France and Spain under the headline: “Rail offers London to Madrid in eight hours.” The article alludes to the “convenience” in the trip by describing that “British travelers will be able to take the Eurostar to Paris in 2 hours and 15 minutes. Allowing for some delay in crossing Paris, they will then be able to board a high speed train from the French capital to Madrid” (Keeley, 2009). This train journey is most likely going to be impractical for regular use. The London – Madrid trip will be made on a two-hour plane flight rather than an eight-hour train trip unless the traveler is willing and able to spend an entire day on a train. Comparisons with similar routes also show that the cost of this service is unlikely to be any less expensive than air travel. The article continues to state that the overall travel time from London to Madrid depends on if the train stops along the way or if it “goes straight from Paris to Madrid.” If anyone can afford a full day to travel then an additional 30 minutes to make a few stops along the way will not affect the choice to take the train. HSR is seen to be a symbol of modernity and this seems to be the driving factor for investment. However it is the frequent use on regional HQR connections that increase ridership and drive the economic benefits of the investment.

1.2 Motivation

The objective of the proposed research is to demonstrate the capability of a regional rail network under certain planning scenarios to increase accessibility and to encourage regional economic cohesion. The Basque Y HSR project in Spain offers a unique opportunity for the region to see a significant reduction in travel times and costs
between the cities. This can be a pattern break that has the potential to sustainably decrease intercity travel times and costs and to stimulate regional economic integration and growth.

The accidental regional rail network created by connecting the region with Madrid gives an opportunity for a significant change in the movement of people and ideas in the Basque Country. Intercity travel in the Basque region is primarily made by automobile and secondly by bus. While an intercity rail network presently exists, the travel times are much slower than the current bus routes and therefore are not considered a part of the practical intercity transportation network. Table 2 shows the current and projected travel times between the cities for automobile, bus and the Basque Y project. The Basque Y is a public transportation system with intercity travel times substantially less than that of the private automobile. All of the projected rail times will be less than 40 minutes, which presents the opportunity for daily commuting trips between the cities (U. Blum, 1997). In many major cities across the globe it is not uncommon to find business, commuting or even leisure trips of more than 40 minutes on a subway or commuter rail, which shows that if done properly the Basque Y has the potential to be perceived as such a service.

<table>
<thead>
<tr>
<th>Travel Times</th>
<th>Car</th>
<th>Bus</th>
<th>Basque Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Sebastian - Bilbao</td>
<td>60</td>
<td>70</td>
<td>38</td>
</tr>
<tr>
<td>San Sebastian - Vitoria</td>
<td>70</td>
<td>90</td>
<td>34</td>
</tr>
<tr>
<td>Bilbao - Vitoria</td>
<td>45</td>
<td>60</td>
<td>28</td>
</tr>
</tbody>
</table>

*www.euskalvasca.com*

_Table 2: Current and Projected Intercity Travel Times in the Basque Country_

Reduced travel times are attractive but it is important to evaluate what these travel times really mean for the region. The benefits of connecting the three cities cannot be measured in time savings alone. In examples from around the world work has been done to show how HQR investment can spur economic vitality of a region.

Additional benefits were forecast to result from achieving a better match between labor demand and supply, both through bringing jobs to workers and
workers to jobs, as well as productivity benefits when labor demand switches to regions of labor supply shortages and environmental benefits arising from more efficient use of land. (Preston & Wall, 2008)

However simply building a line and running trains will not be the answer to increased regional cohesion. Careful planning is necessary to ensure that the network is of high quality so that it can be used to its maximum potential. The infrastructure for the Basque Y is currently under construction, but key planning decisions that can still be modified represent major factors in connecting the cities. These are issues that are important in creating regional cohesion anywhere and are exemplified in the Basque Y case. These decisions include:

- Station placement and mainline alignment in San Sebastian
- Local distribution networks in each city to ensure that the system functions door-to-door rather than station-to-station
- Operating plan for the Basque Y in terms of fares and frequencies
- The future of the regional network in terms of potential ridership, stability, and connections to cities outside the Basque Country
- Land use planning that takes advantage of the new accessibility of the rail system

The research will show the potential for capturing the wider economic benefits and mitigating the costs of the system. Examples from successful networks will be a basis for demonstrating the impacts of the planning decisions on the quality of the system for the user. The purpose is not to justify the six billion Euro investment but rather to propose and support improvements in the network that can make it work optimally as a combination of HSR and HQR.

With improvements in the design, the Basque Y has the opportunity to achieve both high quality and high speed. The definitions of HSR and HQR, as they are used in this thesis, are explained in detail in Chapter 2. Figure 2 shows a graphical representation
of rail systems with respect to their speed and quality. The highly successful system in Switzerland has extremely high quality but it does not have particularly high speeds. Typical HSR enjoys high speed but various systems show a large range in overall quality. The Basque Y as currently planned is an HSR project of low quality. But by modifying the current plans to add aspects of high quality, the Basque Y has the capability to enjoy a mixture of both. This thesis aims to identify what is needed to improve quality to receive the potential economic and social benefits.

Figure 2: HQR and HSR

1.3 Research Questions

The purpose of this thesis is to inform decision makers in the Basque Country on how the new Basque Y can be used to create regional cohesion between the three main Basque cities. It examines some of the important planning details that will have the greatest effect on regional cohesion. These are not unique to the Basque Y but also apply to other regional rail systems that strive for high quality.
The questions posed in this thesis are:

1. Can high speed rail act as a catalyst for regional economic growth?
   a. What is necessary to encourage regional cohesion?
   b. What places in the world demonstrate these effects and what lessons can be learned?
   c. Does the regional HSR network have the potential to give the Basque Region more global economic influence?
   d. What are some of the external costs of regional HSR and how can they be mitigated?

2. What are the local planning decisions necessary to encourage increased access and regional cohesion?
   a. Is high quality more important than high speed?
   b. How important is the location of the station and where is the best place to site an intercity station?
   c. How important is integration with the local public transit network in order to create a door-to-door system?
   d. How do fares, frequencies, and scheduling affect this interaction?
   e. How do these planning decisions affect the economic development of the region and the future of the network?

Main research question examined in thesis:

*Can the Basque Y combine both high speed and high quality to be a catalyst for the Basque Region to join the major regional cities into one functional region and what benefits and costs might be associated with this effort?*

1.4 METHODOLOGY AND ORGANIZATION

The research will cover a qualitative and quantitative approach to evaluating the accessibility gains of the new Basque Y infrastructure under different potential
planning scenarios. A transport model, using the TransCAD software, will be used as a tool to create accessibility maps to understand the implications of different potential future scenarios. The models are intended to show the differences between different scenarios and their impact on the intercity accessibility. Monetized intercity travel costs for different modes will serve as a basis of comparison to show the potential for significant intercity travel cost reductions. Also expected and preferred operating fares and frequencies will be estimated to facilitate this accessibility. A qualitative study based on applying the best practices from Spain, Europe, and the world will be used to supplement these findings.

The base case scenario, or a null hypothesis, evaluates the system as it is currently planned. The stations in each city will be as planned, ideal or not. The intercity rail will be operated under the normal procedures of the Spanish national rail operator, RENFE. After the base case, different planning scenarios will be developed that modify the frequencies, fares, feeder services, and station locations for the system. The accessibility maps constructed from the TransCAD model will be able to show incremental improvements or deterioration in the accessibility as compared with the base case scenario.

The final part of the research will further this scenario planning to examine how these planning decisions not only affect the accessibility now, but also affect the system in the future. The accessibility, and therefore use, of the new system will have direct effects on the future of the system, increases in ridership and frequency, and the role of the Basque cities in the future extension of the HSR network.

The research will be organized into 6 Chapters, with Chapter 1 being the introduction.

Chapter 2 will give an overview of key components of rail networks and system users. This will cover the differences in network structures and the differences in the needs of different types of users.
Chapter 3 will first examine the literature for examples of how transportation, and especially HQR, can create functional regions by encouraging increased labor, business, and leisure travel between cities. With examples of how regional cohesion can be created, a look into regions that have achieved this cohesion will be examined. The case studies will look at the planning decisions that were necessary to encourage these interactions and will evaluate what has worked and what has not worked.

Chapter 4 will explain the current transportation network in the Basque Country and display the demographics of each city. This will give an understanding of the current mobility between the cities and where the major trip producers and attractors are located.

Chapter 5 will use different tools to examine the Basque Y and the necessary planning decisions for a functional economic region. The first part will use TransCAD to develop accessibility maps and charts for each city and scenario. TransCAD and examples from the highly integrated networks of Switzerland will show how integration between the local transit system and the regional rail system can also increase this accessibility. Then using examples from Spain and Switzerland, practical and feasible fares, frequencies, and scheduling will be proposed. A combination of the accessibility analysis and the operation analysis will be the basis for a comparison of the scenarios. The chapter will finish with a brief analysis of the scenario impacts on the land use, economic activity, and future health of the system.

Chapter 6 will have the conclusions from the research, recommendations for the Basque Region, and guidance for other regional rail systems.
2 Key Components for Understanding Intercity Rail Networks

This brief chapter will help to explain some of the important components necessary to understand how regional rail networks function. The first part discusses the differences between long distance rail and shorter distance regional rail. Then, as the purpose of a rail system is to "move people and not trains," it will briefly explain key differences in riders and how their needs as users directly affect the proper planning of the system. This chapter concludes with a discussion on the difference between high speed rail (HSR) and high quality rail (HQR), the planning considerations for each, and how these definitions will be used in this thesis.

2.1 Network Structure

The network structure of rail infrastructure is the physical layout of the rail lines. Figure 3 displays a map of the current European rail network, shown as a spider web of lines connecting large and medium-sized cities. But the structure of the rail network varies in different parts of the continent. Some countries have many lines radiating out from one city, usually the capital, and some have a dense web of lower-speed lines. The differences in these types of networks are important to evaluating the potential for a regional rail network to bring economic cohesion.
2.1.1 LONG DISTANCE NETWORKS

The long distance rail networks are most often categorized as HSR and are synonymous with the networks of Japan, France, and Spain. HSR intends to connect large, relatively distant cities (greater than 400 km) and many times all of the lines radiate out from a central, capital city. These networks typically consist of new, dedicated infrastructure with operating speeds greater than 250 kph (155 mph). The major market and driver for investment is to serve cities that are mostly traveled by short haul airline routes. These networks are specifically designed to compete with the airplane offering shorter overall travel times for distances between 400 and 800 km.
For trips beyond 800 km, the airplane has a strong advantage due to the faster travel time (Givoni & Banister, 2007). With travel times of less than three hours one way between the city cores, long distance HSR networks are particularly attractive for single day business travelers. The fare structure and scheduling tend to function like that of an airline but the HSR has the advantage of city center to center trips and less waiting time and security delay than airports.

The networks of France, Spain, and Japan have almost all of the HSR lines connecting with Paris, Madrid, and Tokyo respectively. The most important planning decision in these types of networks is the overall travel time, and therefore maximum operating speed, as it is the most significant component to ensure competition against air travel. Figure 4, Figure 5, and Figure 6 show diagrams of the French, Spanish, and Japanese Systems."

* Figures 3 through 6 taken from Wikipedia.org
2.1.2 REGIONAL NETWORKS

The regional rail network, as it is used in this thesis, is one that connects cities less than 200 km apart and where the main competition for intercity travel is with the automobile. Although some of these systems are high speed, this does not mean that high speed is necessary. Typically these types of networks are characterized by the need of high quality, not high speed, to attract users. Also, these networks tend not to favor one city, but rather are polycentric in nature and connect many mid-sized cities.
In Europe, polycentric regional HQR networks have formed in Germany, Switzerland, and the Randstad (Brussels, Rotterdam, Amsterdam). Some of these lines have been upgraded to HSR, but many trains, especially those of Switzerland, do not travel much faster than 130 kph (80 mph). In the regional networks, it is important to attract commuters and business travelers that use the system frequently.

A central issue of this thesis will be using the regional HQR network as a catalyst for increased business opportunities and economic growth. The focus will be on the planning decisions necessary to maximize the quality of the network. Planning with a door-to-door approach will be essential for success. Real networks often show aspects of both long distance and regional designs, but for most can be categorized as one or the other. Table 3 gives a summary of the network differences.

<table>
<thead>
<tr>
<th>Distance Between Cities</th>
<th>Long Distance Rail</th>
<th>Regional Rail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Use</td>
<td>Business Travel; Infrequent Personal Trips</td>
<td>Commuting; Business Travel; Frequent Personal Trips</td>
</tr>
<tr>
<td>Primary Competition</td>
<td>Airplane</td>
<td>Automobile</td>
</tr>
<tr>
<td>Important Features</td>
<td>High Speed; Connects Large, Distant Cities</td>
<td>City-Center Stations; Connects Many Mid-Sized Cities; Integrated with Local Transit; Reliable; Convenient; High Speed is Not Necessary</td>
</tr>
<tr>
<td>Examples</td>
<td>Spain, France, Japan</td>
<td>Germany, Switzerland</td>
</tr>
</tbody>
</table>

*Table 3: Long Distance and Regional Rail Networks*
2.2 ORIGIN AND DESTINATION USERS

When analyzing an intercity rail network, or any intercity transportation network, it is important to distinguish between origin users and destination users. This is essential for planning the door-to-door services and mostly applicable to the access and egress modes to the station. The differences will be described using San Sebastian, Spain, a city that will be connected on the Basque Y network.

2.2.1 ORIGIN USERS

Origin users are rail travelers that have their origin in the city with origin users residing in the city of reference. An example of an origin user for San Sebastian on the Basque Y network would be a resident of San Sebastian. An origin user will likely be familiar with the local public transit system: using a local bus or local train to get to and from the Basque Y station will be considered as an option. However this user will also most likely have access to a car, motorcycle, or bicycle, so personal transport will be a potential mode of access to the station, whether it be park & ride or a drop off by a friend or relative. Upon returning to San Sebastian, this user will be able to take that same car, bus, or bike back to his home. If an origin user takes transit to access the station then likely it is by choice and not because there is no other option.

No matter how these users access the station in the origin city, they will have different needs once they arrive in the destination city. Once arrived, they become a “destination” user and will have more limited means of accessing their final destination.

2.2.2 DESTINATION USERS

Destination users arrive by train at the destination city and must find a way to reach the end of their trip. Destination users do not have easy access to personal modes of transportation. Although it is possible to rent a car or take a taxi, this probably will not
be an affordable option for a frequent user like a commuter. Whether the destination user is a commuter, business traveler, or someone on a personal trip, easy access to centers of commerce by walking or public transportation will be an important aspect of the door-to-door quality of the trip.

For rail users arriving in San Sebastian, it is most likely that their destination will be in the center of the city. If the destination is farther than a comfortable walking distance, then the traveler is a captive for a taxi or public transit. But a destination user is going to be less familiar with the local transit system and could be less inclined to use a bus system than would an origin user. If a city is interested in attracting travelers, special attention must be paid to the egress from the station allowing access to key trip attractors. This egress must be fast, easy, and inexpensive. If the final destination is not easily accessible, then the user will be inclined to make the trip by automobile or not take the trip at all.

2.3 Frequent and Infrequent Users

Another important difference to be made is between frequent and infrequent users. Anticipating the needs of these different travelers will also be important to attracting both to the network.

2.3.1 Frequent Users

Frequent users, typically the commuters and many business travelers, are sensitive to the level of service provided. If the trip is something that they are to do on a daily basis, then the overall travel experience must be high quality enough to minimize the disutility of the trip. The network must be inexpensive, reliable, and not need many transfers. The headways on the rail network need to be low enough so that they are not stranded if they miss a train. Access and egress modes must be easily accessible so as to reach their final destination efficiently. Frequent users will be much more familiar with the local transit systems in either the origin or destination city, so they will be more apt to taking a local bus or rail system to get to and from the station.
2.3.2 Infrequent Users

Infrequent users are much less sensitive to fares and the overall level of service as the trip is not part of their daily routine. Infrequent users are more likely to take a taxi to and from the station and are less likely to attempt to navigate an unfamiliar transit system. Infrequent users, however, have the potential to become frequent users. If the traveling experience is high quality then they might be inclined to make the trip more often or suggest the rail option to friends. Providing infrequent users with good information on connecting modes can encourage them to use public transit rather than take a taxi or rent a car. If the system is not high quality, then an infrequent user will choose to either use an automobile for the entire trip or not make the trip at all.

2.4 The Definition of High Quality Rail

The above descriptions and categorizations of different aspects of intercity rail are generalizations to help guide the analysis and thinking. Real networks and users will display more of a mixture of the descriptions. Nevertheless these descriptions are the basis for understanding the definition of high quality rail.

High quality rail, as defined in this thesis, encompasses the entire journey from door-to-door. A trip in an HSR train is a means to and end but not an end in itself. Access and egress from the station is just as important because travelers rarely start or end their trip at a rail station. An HQR system serves key regional markets and has customer oriented ticketing and information. An HQR system is convenient, reliable, comfortable, highly integrated, consistent, affordable, uncongested: the preferred mode of intercity travel. HQR planning is comprehensive; all connected cities on the network need to be integrated into the system and display the characteristics of high quality.

HQR tends to work best in regional networks where users take the system on a regular basis. Regional HQR networks are highly integrated with the local connecting modes of transit that enable high accessibility to the door-to-door system. It is much more
difficult, and in most cases impractical, to enable coordination and high level integration on HSR that connects cities that are very far apart. Long distance HSR needs to compete with the airplane so travel time is by far the most important factor in the design. HSR systems can show some attributes of an HQR system, but these are not as important in building ridership on a successful HSR line. HQR can greatly benefit from high speed but it is not the most important attribute as the Swiss clearly demonstrate.

HQR considers both the origin and destination users when planning stations and intermodal integration. The destination users are of upmost importance because they will have the most mobility need when they arrive in a city. Short walking trips to their final destination are the highest level of service that can be provided. But providing an inexpensive and logical transit system that can enable them to reach a farther destination will greatly add to the quality of the service and connect the users to more destinations. Attracting frequent users of the system, both for origin and destination trips, is important for retaining high ridership. As mentioned above, an infrequent user can become a frequent user if the system is high quality enough to encourage more trips.

These attributes are essential to HQR. High quality can be defined in many ways but for this thesis the quality is in overall door-to-door service provided to the users. The specifics of these attributes will be evaluated with an examination of the literature and existing HQR networks. The Basque Y case study applies this evaluation to the planning of an HQR system.
3 HIGH QUALITY REGIONAL RAIL NETWORKS: COSTS, BENEFITS, AND PLANNING

The following section explores the benefits of a regional rail network beyond the obvious time savings benefits and what needs to be done to obtain these benefits. There will also be a discussion of some of the costs that go beyond the capital and operating costs and ways to mitigate some of these costs. The planning decisions necessary to obtain or mitigate the benefits and costs are then explained.

A regional rail network, as described in Chapter 2, is one that connects mid-sized cities less than 200km apart. In these systems, the main competition for intercity travel is the automobile. In many cases, regional cities are linked with high speed rail (HSR), which is attractive in travel time but often is lacking in the quality needed to encourage frequent use. In these cases it is possible to plan the system so that it is a fusion of HSR and high quality rail (HQR). Because of the reduced travel times and high quality service, regional HQR/HSR can increase economic cooperation and cohesion between connected cities. This section will investigate the possibility of these increased interactions and explore the evidence of their benefits using the current literature and examples from current regional rail networks. The section will finish with planning decisions that are necessary to ensure that a regional rail network is high quality, of which high speed is an important component.

3.1 THE FUNCTIONAL REGION

According to economists, “a functional region is a geographical area that shares a common labor market and a common market for household and business services” (U. Blum, 1997). A functional region could be just a single city, incorporate a metropolitan area, or include other regional cities. The economic size, or effective size, of a region depends on the transportation travel time and costs, and if they are low enough so that many intercity commuting, service, and business trips are made. Blum goes on to state
that the labor sharing aspect of the functional region is the highest importance when determining the effective size of the region.

The functional region concept is important for mid-sized cities that want to compete in the global market. “Economists have long recognized that wages and output per worker in large cities exceed those in smaller ones” (Segal, 1976). In his paper, Segal compared metropolitan populations with the wages and output of each worker and came up with a striking conclusion: cities with a size of two million or greater show a significant increase in wages and output per worker than cities smaller than this size. Other research has challenged this “two million” figure, but all point to the fact that population increases lead to significant productivity improvements for an economic region (Arnott, 1977) (Moomaw, 1981). If mid-sized cities can connect in a way that allows sharing of labor and service markets, they can potentially increase their economic mass.

Other than increasing density, in order to encompass more people into the functional region, transportation must be improved. As transportation becomes faster, more comfortable, and less expensive, the markets for labor and services increase. Businesses in the region have a larger pool of labor from which to select employees and attract customers. Residents of the region have more choices for easily accessible jobs and services.

For these reasons, many governments see it as worthwhile to invest in upgrading transportation infrastructure. Improving the trip for the user, whether that is a reduction time or cost or an increase in comfort and convenience, has the potential to expand the reach of the economic region and allow the population and businesses within it to have greater access. “Modern economies cannot generate wealth and employment without highly efficient transport networks” (Barrot, 2005). With many modern highways reaching capacity and less able to offer greater access, regional planners are considering new options to encourage greater regional cohesion, one of which is regional rail.
3.2 HIGH QUALITY RAIL IN FUNCTIONAL REGIONS

An attractive transportation option to encourage the formation of a functional region is intercity rail. Rail offers the benefits of comfort, efficiency, and high capacity as well as providing competitive travel times between cities. In a polycentric region, intercity rail can create a network of many cities. These connected cities, or “bands of cities,” can be found in many places throughout the world. Some examples include the Northeast Corridor in the United States, the Mittelland corridor in Switzerland, and the Randstad in northern Europe. When the bands of cities begin to share labor and service markets, they become an economical functional region (Steer Davies Gleave, 2002). Regional rail networks play a key role in enabling the economic cohesion, but a functional region cannot live on high speed trains alone.

For a band of cities to develop to a functional region it is not enough just to build a railway for high speed trains. For an integrated corridor to develop there is as a rule a strong need to revitalize the actual cities and, in particular, their cores, as well as to renew the systems of feeder traffic (including car traffic) to extend each participating city region by radically improved contact possibilities. (U. Blum, 1997)

An HQR system relies on addressing the needs of the frequent users. As Section 3.6 shows, stations placed in city centers, integrated station feeder systems, and reliable, convenient operations are essential to HQR. The effort to create a regional HQR system can be daunting, so understanding the benefits of such an endeavor is important to building support. Many planners and government officials look to measure the benefits and costs of such a network. The next two sections will look at the benefits (3.3) and the costs (3.4) of creating a functional region.
3.3 Benefits of a Functional Region

To gain a better understanding of what a functional region is and what it means to the economy of the connected cities, it is important to look at the benefits of HQR, and transportation improvements in general. In conventional project analyses, the total project costs are directly compared with the sum of the monetized benefits. A project's benefits are assessed primarily on travel cost and travel time savings (Jenkins, 2010). A summation of the total travel time by users multiplied by a standard 'value of time' measure (dollars per hour) monetizes the travel time savings. However there are many benefits that this conventional approach does not incorporate. These include some of the wider economic benefits that are derived from the increased productivity and output resulting from increased regional accessibility. Regional HQR, in particular, seems to be a key player in enabling these wider economic benefits for a region.

In addition, benefits of HQR include potential for reduced greenhouse gas emissions, improved air quality, reduced congestion on roads, reduction in automobile expenditures, and induced ridership on local transit systems. Also, the new infrastructure will reduce some of the intercity demand on the existing rail routes, therefore allowing for a more efficient use of the rail network for local rail service and rail freight. "HSR [and HQR] investment not only saves time but also increases capacity, for passengers as well as for freight, both by providing capacity itself and by releasing capacity on existing routes" (de Rus & Nombela, 2007). In his thesis, Kothari demonstrates the operating costs of an automobile as only a small part of the actual cost to drive (Kothari, 2007). If the new infrastructure can reduce the car ownership in the region, then that money will be spent locally. Cars are expensive and savings from reductions in ownership will be a significant stimulus to the local economy. These along with the wider economic benefits are not typically included in a conventional analysis.

Additional benefits were forecast to result from achieving a better match between labor demand and supply, both through bringing jobs to workers and
workers to jobs, as well as productivity benefits when labor demand switches to regions of labor supply shortages and environmental benefits arising from more efficient use of land. (Preston & Wall, 2008)

Of the non-traditional benefits of HQR, the wider economic benefits have received the most attention and have the most potential to add to the value of the investment. In some cases, estimates of the wider economic benefits have been a major factor in building the political support for large projects, as travel time savings alone are often not adequate for justification. “In terms of infrastructure investment, it is extremely difficult to justify new infrastructure based on journey time savings” (Lu, 2003). The fact that these benefits are hard to quantify does not diminish their importance.

Normal analyses typically do not account for the wider economic benefits mostly because they are very hard to estimate and monetize. Increasingly the estimates of the wider economic benefits are clearly recognized and in some cases attempts have been made to measure them.

The Department for Transport (DfT) in the United Kingdom has turned to the wider economic benefits to increase the estimated value of large infrastructure projects. In their analyses, they have sorted out the wider economic benefits of transportation improvement into four categories. Although these may not be easily measurable, they represent the potential of rail as a catalyst for regional cohesion and economic development. They are presented here to help describe the effects of regional HQR and how it helps to create a functional region. The following excerpt, from Feldman et. al, (2008) analyzing the new method for DfT to evaluate transport schemes, explains the categories of wider economic benefits used by the DfT:

- Agglomeration economies – These measures describe the productivity benefits that firms derive from being located close to other firms.
- Benefits from increased competition – The increase in options for producers and consumers has important benefits.
- Increased output – These benefits arise from the reduced cost of transportation. Firms are expected to respond to such cost savings by reducing prices and increasing output.
- Wider benefits arising from improved labor supply – Both firms and workers have a larger market to optimally match employment.

One of the most notable attempts to monetize the wider economic benefits has been the work by Dr. Daniel Graham in estimating the agglomeration economies that benefit from the Crossrail Project in London, which is a major rail infrastructure project in the city core. In describing these agglomeration economies and the methodology behind his estimation, he states:

> If transport investment changes the densities available to firms, for instance through a reduction in travel times or in the cost of travel, then there are likely to be positive gains from agglomeration. Having reliable estimates of the density-productivity relationship allows us to quantify these ‘wider’ economic benefits. (Graham, 2007)

In his study he finds positive and significant estimates for the agglomeration benefits. These are particularly significant for the service industries that are typically found in downtown areas such as real estate, banking, finance, business services, and public services (Graham, 2007). His work is promising, and has greatly helped build political support for the Crossrail Project. But there are some challenges with using his method. The calculated elasticities used in his estimates are for specific business sectors and industries and are region specific. These would need to be recalculated to be applicable in other cities. The data required to do this is high level and industry specific, which makes application only useful in specialized markets where the data is available.

There has also been some work that evaluates the agglomerations economies in US cities by Meijers and Martijn (2009). They suggest “in line with the existing empirical work on agglomeration, we find a positive and significant effect of urbanization
externalities on metropolitan labor productivity.” The research is based on
metropolitan areas, which is not specific to intercity travel, but the areas under study
are “polycentric” in nature and have many smaller centers of urbanization, as many US
metro areas do. Their models suggest “a doubling of metropolitan size increases
metropolitan labor productivity by over 10%,” which is slightly higher than the
“consensus view that a doubling of city size increases productivity by between 3 and
8%.” The same conclusions have been drawn in other studies in urban transit where
“using econometric estimates of the relationship between city size and productivity,
suggest that these effects are large — typically yielding total gains several times larger
than those that would be derived from a standard cost–benefit analysis” (Venables,
2007).

These different studies all suggest that by reducing the travel time and giving access to
larger labor and service markets, there are real and significant benefits to
transportation improvements. However the research into measuring the wider
economic benefits of intercity rail is limited: “genuine HSR [and HQR] networks are
still too much in their infancy to make any reliable estimates of their regional
development effects” (Vickerman, 1997). The attempt to monetize the benefits of
regional rail on any of the wider economic benefits has been difficult to use. Some areas
use regional economic models to attempt to measure these benefits, but the literature
suggests reasons as to why these are not successful.

One reason is that [the regional economic models] have been expensive to use;
another reason is that such models alone can significantly under-estimate the
true value of transportation projects by missing the business productivity
benefits of improving system connectivity and access to markets. (Weisbrod,
2008)

A thorough read of the literature suggests that traditional transport evaluation mostly
underestimates the benefits. Many propose that the wider economic benefits constitute
a much larger share of the impact of transportation improvements than previously
thought. These could be used as an evaluation tool for regional HQR networks in the future, but the purpose of this thesis is not to evaluate a project, but to optimize the design and operations of a regional rail project that has already been approved. Such is the case of the Basque Y in Spain. The value in these studies is the fact that these benefits are proven to exist. Optimizing the details of a regional rail network to make it HQR as well as HSR will ensure that the region gets the maximum benefits. If an expensive project is going to be built, it makes sense to plan it as to serve the connected localities to achieve the benefits of both high speed and high quality.

3.4 **Costs of a Functional Region**

Along with the benefits, there are certainly costs involved in using rail to creating a functional region. The most obvious are the fixed costs associated with the infrastructure: stations, right-of-way, track, tunnels, bridges, and equipment to operate the network are fixed costs that are necessary before trains begin to run. Costs also include the variable operating costs of the service, in terms of energy, maintenance, and personnel. These costs are relatively easy to estimate and can be compared with many of the benefits explained in the previous section. But there are other hidden costs to regional networks that must be addressed.

Hidden costs can include the negative effects of new infrastructure on the natural environment, the emissions due to increased mobility, and increased noise and vibrations due to rail traffic. However one cost that is unique to HSR infrastructure is the potential for a loss of service to smaller cities and towns between the major cities. One of the advantages of HSR is that it is fast but it maintains high speed by eliminating frequent stops along the route. This is a positive thing for the cities that manage to get connected on the line, but smaller cities that were previously connected via intercity rail typically lose service. This loss of service can create “economic holes” in areas that are not well connected (Vickerman, 1997) because all traffic on the new HSR line passes by the small cities.
Eduardo Romo (2010) calls the loss of service the “shadow effect” of HSR. He uses case studies from Spain to illustrate this. For example many smaller cities along the Madrid – Sevilla HSR route, which opened in 1992, lost direct service to Madrid and to other nearby cities. Many now have to take another train or bus to a larger city to transfer to the HSR to get to their final destination.

Planning for an HQR service can mitigate the shadow effect. Romo recommends that multimodal solutions be used to help mitigate and reduce the impact of the shadow effect on the smaller cities. Skipped cities can receive service that is effectively superior to what it was before the new HSR service. It typically requires a transfer at a larger city, but effective coordination of service can help to minimize the hidden cost of the shadow effect. The result can be a better overall service to affected cities and towns, leaving them with an overall improvement in intercity rail service.

Chapter 5 analyzes an example of the shadow effect in the Basque province of Gipuzkoa. This example shows how the cities that will lose direct rail service to regional cities actually end up with better service with a coordinated, integrated HQR system.

3.5 CREATING A FUNCTIONAL REGION

Examples from Europe and from current research continue to demonstrate the potential for functional regions. Regional HQR networks seem to be one of the key components to reducing the time, cost, and congestion for travel between cities, therefore enabling convenient, efficient, and effective travel between them. This next section will investigate the economic components necessary to create a functional region: increased business accessibility, labor markets, and service markets.

3.5.1 INCREASED BUSINESS ACCESSIBILITY

One of the main reasons that many businesses tend to locate in city centers is because of the benefits of frequent face-to-face contacts with other businesses. Frequent
contacts are essential to the “knowledge spillover” effects that are important to make workers more productive (Jenkins, 2010). Regional HQR can significantly increase the access to other businesses in other connected regional cities.

The advantages that in particular the private but also the public sector can gain from improved accessibility do on the one hand come from the possibilities to carry through a larger number of contacts with other firms, i.e. with customers and suppliers. (U. Blum, 1997)

In the German regional rail system, business travelers take advantage of the rail system and compose a significant proportion of the total ridership. According to Michael Wurm, from Deutsche Bahn Logistics in Frankfurt, business travelers make up 25% of the users of the InterCity Express (ICE) system (Wurm, 2010). The regional HSR link between Madrid and Ciudad Real, at a distance just under 200km, also sees a significant number of business travelers taking advantage of the economical opportunity for business interaction. “Travel time [between Madrid and Ciudad Real] is now on average 1 hour and 12 minutes [often less than 60 minutes], allowing new types of relations based on ... day-return business travel” (Ureña, Menerault, & Garmendia, 2009).

Contact with more customers, clients, and competitors have a real positive advantage for businesses. Reduced transportation costs for business trips make conducting business more efficient, and these efficiencies are passed to the firms as increased productivity. Efficiency can also be gained as employees can work while traveling, granted that there are enough seats to allow for a comfortable workspace. The reduced transportation costs also extend to more accessible and low cost trips for firms to access government offices and educational institutions that may be located in other connected cities. Increased accessibility means increased opportunities to interact with more players in the market and increased workforce efficiency.
3.5.2 INCREASED LABOR MARKETS

Another key factor to building a functional region is to enable increased labor markets. This helps both businesses and workers. With an HQR network, firms located in a city can expand their labor pool to include potential employees in the other connected cities. For the residents, they have the opportunity to search for jobs in other regional cities and they can take those jobs without having to move or be subject to a long, costly commute.

Even if the HQR system does make for reasonable commuting times and costs, these will still likely be more than they normally would be within their city of residence. “Wider labor markets, of course, means more frequent and longer commuting trips” (U. Blum, 1997). However econometric studies consistently show that, in general, time spent traveling by public transportation is perceived as less tedious than walking or driving. This is explained by the fact that many transit systems, especially regional HQR, offer a comfortable ride where users are able to use their time productively. “A key advantage of rail is that it is possible to work whilst travelling – something that is generally not possible if travelling by car” (Steer Davies Gleave, 2002). Not only can they work while traveling, but also they could also simply relax on their commute rather than focusing on driving. This makes time during transit more productive and therefore makes longer commutes more acceptable.

Like business travel described in the previous section, ridership on the German ICE system is composed of 25% commuters (Wurm, 2010). This shows that the population and regional businesses are taking advantage of this system. Similar figures are found on regional rail systems in Europe, including a new line in Sweden. “The Svealand line, opened in 1997, provided a high speed regional rail link between Ekilstuna and Stockholm. Rail usage has increased by a factor of 7, with rail’s share of the relevant travel market increasing from 6% to 30%” (Froidh, 2005). Similarly, in Spain there has been substantial growth in commuting from Ciudad Real and Puertollano to Madrid on
the AVE. "In 1992, Ciudad Real had 18 through trains a day to Madrid. By 2005, this had increased to 47 trains" (Alvarez & Corando Tordesillas, 2005).

In order to increase the labor markets, careful planning must be done to cater to the needs of frequent commuters. Emphasis on the quality of the door-to-door service is essential. The stations at both ends of the trip need to be located close to where people live and where employment is so that reaching the final destination does not add significant time on the journey. The system must be reliable so commuters are not afraid of arriving late to work. The system must be inexpensive enough to afford traveling daily. If commuting is not convenient for the user, then the key aspect of the functional region is lost.

3.5.3 INCREASED SERVICE MARKETS

Increasing labor and business accessibility is not the only benefit of a regional HQR network. Along with access to a larger supply of labor, regional businesses have the opportunity to attract customers from a much larger area and residents have more choice in where they receive services. Increased options for service markets also include retail and tourism opportunities in other cities. An increase in accessibility to more services and destinations is an increase in options for discretionary travel. As described in a report on the Northeast Corridor in the Northeast United States,

In an increasingly competitive world, efficiency in business travel, commuting and freight is a vital component for this growth. This is well recognized. What is perhaps less well recognized is that economic growth also increases demand for other categories of transport – leisure and ‘discretionary’ travel – and that these uses can also have significant impacts on the economy and on the sustainability agenda. (Steer Davies Gleave, 2002)

The leisure and discretionary travel, which can be tourism, shopping, or personal trips to visit friends or family, have a significant impact on the quality of life of the residents in all the cities by making these opportunities more accessible. In addition, these trips
increase the use of the network, resulting in a potential decrease in system cost or the increase of operating frequency, which is to the benefit of all. The high capacity characteristics of transit provide for positive scale economies. Unlike highways where additional users degrade and congest the system, additional users on rail allow for more frequent and less expensive service.

3.5.4 Summary of Benefits and Costs of a Functional Region

The economic benefits of a functional region, whether quantifiable or not, seem strong according to the general literature and to what has been observed in Europe. This interaction between the cities benefits business, labor, tourism, and the general population. In all, the benefits seem clear as to the fact that HQR has the potential for a strong impact on the economic growth and sustainability of a region. And as we saw in the Sweden commuting example, a well connected regional HQR system has the potential for a pattern break in the connected cities by opening up opportunities for economic efficiencies and increased productivity.

HQR does come at a cost and it is important for planners to ensure that the system is financially sustainable. The amount of service provided, in terms of frequency, can often require a subsidy, but it should be a subsidy that gives back its worth in public benefit by enabling a functional region and providing socially beneficial transportation options. Other costs, like the “shadow effect”, need careful planning to enable smaller communities in the region to have improved access to the new network.

However, building an HSR link alone will not always result in a de-facto functional region. Proper steps need to be made to ensure that the network will capture riders and provide a level of service that is able to compete with the automobile and attract new, regular riders. The next section will cover the planning decisions needed for an HQR system that enable economic cohesion between cities.
3.6 **HQR Planning for a Functional Region**

In order to gain the potential for the development of a functional region, it is not enough to draw lines on a map and start building infrastructure capable of high speeds. Too often HSR projects build without considering a door-to-door approach. The rail trip between the cities is only a small part of the total journey as most people do not start and end a journey at a rail station. The emphasis should be on combining an HSR and HQR system for the region. This includes qualities such as reliability, ease of use, sufficient capacity for comfort, convenience, and schedule consistency. Important aspects of HQR planning to achieve these qualities include:

- Station location
- Intermodal connectivity
- Fares, frequencies, and scheduling
- Planning applications for the future of the network
- Land use strategy, including parking and intermodal facilities

Combining HSR with HQR results in a highly competitive mode for intercity travel. Planning should be aimed at the inherent benefits of intercity rail. Intrinsic properties include:

- High capacity
- High speed
- No congestion in city centers
- Productive travel time
- Low operational energy requirements

There are substantial literature and examples that demonstrate the quantitative and qualitative aspects of each of these decisions.
3.6.1 Station Location

One of the touted advantages of rail is that it provides a direct link between city centers, unlike airports that have to be located away from centers due to pollution, noise, and safety. “The benefits that confers upon businesses whose employees travel to destinations in the city centre, or start their journey from a city centre location are self evident and reflected in the market shares that rail can achieve for city centre to city centre travel” (Steer Davies Gleave, 2002). The report by Steer Davies Gleave continues to show that intercity rail provides benefits in that by capturing this market segment (city center to city center) it reduces traffic in the cities and also reduces, but not eliminates, the requirement for valuable city center land for to be used for car parking. Provisions for parking, as well as land use, near the station will be discussed later in this section.

The agglomeration economies demonstrated by Graham (2007) and other reports show that the agglomeration benefits for rail improvements are concentrated to areas around the rail stations. When estimating benefits, it was shown that these benefits drop off significantly a 15 to 20 minute walk from the station (Jenkins, 2010). The stations therefore should be situated in areas that have high access to businesses and residences. Whether the benefits can be measured in every case or not, the importance of close proximity to station location makes intuitive sense.

Especially in regional HQR networks for business and commuting trips intercity rail loses its time advantage quickly if a traveler has difficulty accessing the station or arriving at his destination.

Although there is a tendency to think in terms of time, and time thresholds, there is clearly subjective evidence relating to the comfort/convenience factor. City centre to city centre travel by a single mode with higher comfort characteristics than [the car] has difficult to quantify advantages. (Vickerman, 1997)
City centers already have high concentrations of people, businesses and other attractions and walking or a short transit trip can access many of these. It makes sense to focus planning on serving these trips.

Conventional HSR planning often disregards the need for a comprehensive look at the details such as the station and station location. In many cases, the desire for high speed does not allow for the train to maneuver through tightly curved areas in an urban setting. But the dream of connecting very distant cities with high speed is impractical. For example, politicians and media hype the current plan to cut the travel time from Madrid to Paris to less than six hours. This travel time requires that trains not stop or even slow down near many mid-sized cities along the way. But air travel between Paris and Madrid is already less than two hours, so unless a traveler can afford an entire day to travel, then the air trip will likely continue to be the primary mode between these city pairs. And if a traveler can afford six hours of travel, it is likely that an additional 30 minutes to make stops will not affect the travel choice. It is unlikely that the cost of this rail journey will be less expensive than flying because of the long distance.

The notion that very long distance travel on an HSR as a means of practical transportation does not make sense. Planning should be focused on the regional connections that drive economic benefits and ridership.

Cities cannot simply be treated as nodes of different sizes, since at the distances where high speed rail is most likely to be competitive (i.e. under 300 miles), the access time to and from the central station could be a significant part of the total journey time, and factors into competitiveness against the other modes very significantly. (Lu, 2003)

Successful regional HQR networks in Europe and across the globe all share something in common: the rail station is located in or very near the city center. Even in the radial,
long distance HSR networks of Spain and France, most of the stations still are in central locations of each city. However recent HSR construction tends to abandon central locations in mid-sized cities for peripheral locations. The driving force in this decision may be cultural: the desire for faster and faster service with a focus on the largest of cities. While there has been economic and political pressure to build periphery stations, practice has shown that these stations do little for the local accessibility.

A striking example of how station location affects the level of service can be made of two cases in Spain. RENFE, the national passenger rail operator, runs intercity HSR service on the various lines in Spain. Like most rail operators, RENFE provides service based on demand. This case looks at two cities in Spain that have HSR connections. But because of the location of their stations, they have very different levels of service. For this example, the level of service is defined as one-way trains/day to Madrid. This information was taken directly from the RENFE timetables on their website (RENFE, 2010).

The coastal city of Tarragona, Spain, located along the Madrid-Barcelona HSR route, has a peripheral station that is situated 9km north of the city center. This station is accessible only by a 15 minute car or bus trip. As of 2010, 9 daily one-way trains to and from Madrid serve the station. 27 daily one-way trains run from Madrid to Barcelona, showing that the station has enough demand to attract only 9 of the 27, or 33% of the daily one-way trains. Figure 7 is a map of the location of Tarragona and the Tarragona station.
The city of Puertollano, Spain, located along the Madrid-Cordoba/Sevilla HSR route, has a centrally located station. Almost the entire city is within a 20 minute walk of the station. As of 2010, 25 daily one-way trains to and from Madrid serve the station. The 25 one-way trains per day is 86% of the 29 daily one-way trains that run from Madrid to Cordoba, showing that the city attract many more trains, and therefore has much higher service, than Tarragona. Figure 8 shows the location of Puertollano.

When compared with the size of the cities, which can be an indicator of demand, Tarragona's population of 146,000 is nearly three times larger than that of Puertollano, at 52,000. This is clearly not reflected in the amount of service received by the cities.
Figure 8: Puertollano and the HSR Station (shown in red)

Table 4: Tarragona and Puertollano Service Comparison

<table>
<thead>
<tr>
<th>Station Location</th>
<th>Tarragona</th>
<th>Puertollano</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSR Line</td>
<td>9 km to north Barcelona</td>
<td>city center Cordoba/Sevilla</td>
</tr>
<tr>
<td>Time to Madrid</td>
<td>2h 40m</td>
<td>1h 15m</td>
</tr>
<tr>
<td>Trains per day</td>
<td>9</td>
<td>25</td>
</tr>
<tr>
<td>% of trains that stop</td>
<td>33</td>
<td>86</td>
</tr>
<tr>
<td>Population</td>
<td>146,000</td>
<td>52,000</td>
</tr>
</tbody>
</table>

Table 4 shows a summary of this comparison. There may be other factors at play that could further explain the discrepancy between Tarragona and Puertollano, but it is obvious that the low frequency of service at Tarragona has much to do with the location.
of the Tarragona station. From this brief example, it is evident that the provision of services is much higher for places where the station is located where the people and the businesses are. Other examples exist in Spain where the station location was compromised for cost reduction and time savings, such as Segovia, Guadalajara, Sevilla, Zaragoza, and Cordoba. Tarragona is an unfortunate example of how HSR focused planning can result in a loss for the city. Puertollano, on the other hand, managed to have a central station, therefore enabling the city to gain some of the aspects of HQR along with HSR.

One of the advantages of a new rail connection is the potential for economic growth in the form of new land development. In this case, it might seem that a peripheral station would be better as there is more unused land for this purpose. Dense city centers are usually already built up leaving little space for new buildings. However, the rail yard over the station can provide an opportunity for this development. Numerous cities have taken advantage of this space for offices and commercial activity, including Lille, France. Figure 9 shows an example of large office buildings directly over the station in Lille. In Chapter 6, a more detailed analysis of land development potential is made using San Sebastian as an example.
The impact of the city center station is analyzed in Chapter 5 using the Basque Y HSR project as a case study. Data showing the location of population, jobs, and other attractions show the value of arriving in the city center. The project is currently planned to place the station for San Sebastian in the peripheral town of Astigarraga. The station and alignment were designed as such to allow for high speed from Madrid to France. As discussed before this connection will not be a practical part of the overall network. The analysis will show how this decision could be detrimental to the success of the regional HSR network and cause missed opportunities of economic cohesion between the Basque cities. Moreover, if the proposed “solution” to the Astigarraga station is to create an HSR spur to the central station of Atotxa, this could be even worse. Operations on a spur are conducive to trains simply passing the city altogether because of the split in the line. For this reason it is important to ensure through service in mid-sized cities so trains are more apt to stop, as shown in the Puertollano case.
The peripheral station may work for the long distance HSR services because, like the airplane trip that it is replacing, driving out of the city to take the train is not too burdensome for the occasional business or leisure traveler. However functional regions and the regional HQR that serves them depend on high demand from frequent business and commuting travelers. “Regional rail transit systems with transit oriented development around stations tend to support regional economic development” (Litman, 2010). Once the rail service has been established there will be more demand for economic activity at a central station. “The choice of the Central Station [in Antwerp] will imply some necessary complementary measures, namely, to improve the internal accessibility, and the provision of space for HSR related economic activities” (van den Berg & Pol, 1998). Central city stations allow destination travelers, especially business travelers, to arrive very close to their final destination. Special attention should be paid to these “destination” users if a city wants to encourage business growth.* The opportunities for business development and the long term health of the system that central stations afford should be a key driver in the planning process.

The station location issue is an urgent one. Once the infrastructure is completed it is very difficult to change it. The site of a rail station in or around a city is long term – the stations placed 100 years ago are still in use today. This decision will determine the intercity rail planning decisions for decades to come. The location of the station enables the basic elements of HQR. The level of intermodal connectivity and rail operations all depend greatly on where the station is located with respect to the users. Ensuring a city center station needs to be a top priority.

3.6.2 INTERMODAL CONNECTIVITY

Once the decision has been correctly made to place the station in the city center, extending access to more of the nearby population and businesses can help to further the economic benefits allowed by the regional HQR. Connected cities must take an

* See Chapter 2 for a complete description of “destination users.”
active role in transforming the rail station into an intermodal hub, an essential part of HQR.

[The station] also needs to become a multi-modal travel interchange with good integration of local/regional public transport networks if access to it is to be extended beyond the city boundaries to all parts of the regional area. (Preston & Wall, 2008)

This intermodal connection is key to allowing more of the extended city to have easy and efficient access to the station.

The first step to integration is in the physical location of routes, terminals, and interchange points. As many modes as possible should be part of the intermodal hub. If local and regional buses, local and regional trains, cars, and taxis all have a common node in the network, accessing any part of the region will be simplified. Central stations help because many transit lines already serve the existing demand for downtown traffic. With local distribution systems serving the demand for the regional rail system, both the local transportation system and the HQR system have the potential to see higher ridership. Local transit and HQR are complementary, not competitive, modes. As far as feeding the regional HQR network, public transit connections offer high capacity and high efficiency transportation for access and egress to and from the station. Especially if the station is in the city center, using many acres of valuable city land for parking can be expensive and can be an obstacle for future development. Coordination with local transit systems is helpful to avoid this obstacle.

Although provisions for parking are important, promoting intermodality by extensive park and ride is not a good long term strategy for the system. Once parking at a station is constructed frequent users begin to depend on that parking. If in the future it becomes advantageous to redevelop that land for office space or more productive uses, it is very politically difficult to do so. Burgess (2008), in his thesis, examines the trade off between park and ride and transit oriented development. He shows how transit lines
automatically boost the land value in the area and over time this increases with increased ridership. It becomes more and more difficult to convert parking into development once it has been established. Therefore limiting parking availability will enable the surrounding land to be used productively now and in the future.

Examples from Spain show that city center stations do not need much parking to be successful. The Madrid·Atocha station, the busiest in Spain, currently has less than 1,000 spaces. This is very small compared with the 30,000 long distance passengers that use the station each day (Minayo de la Cruz, 2010). Similar parking provisions can be found at the Valladolid station, which has a recently opened high speed connection with Madrid. This station has parking provisions for only 120 automobiles (Leber, 2011). In such a case, it is evident that the station is accessed primarily on foot, by public transit, by taxi, or by kiss-and-ride.* Provisions for these access modes will be a fundamental part of the integration.

Operational integration includes different transit modes and operators coordinating their systems with the operations of the rail network. The integration of modes can also help to mitigate the “shadow effect.” The shadow effect is the loss of direct intercity rail service in smaller cities that are no longer connected after the implementation of a new regional rail service.* In many cases, the new rail lines use the existing city center rail station, and therefore trains share the station with local and commuter rail services. The services can be coordinated in such a way that if a user in a smaller city wants to access the regional or international rail network, they can take a local train to the central station and make an easy transfer to the HQR. If planned properly, this can result in better service to communities that have lost direct service. Although there is a transfer, the overall level of service and time to the destination can be greatly improved.

* See Section 3.4
Providing quality connections between transport modes will be a key driver to the success of the system. Whether it is a bus, a light rail, local heavy rail, or the automobile, "empirical evidence shows that a large portion of public transport journeys involve at least one change of vehicles" (Guo, 2003). The experience of the transfer "significantly affects the travelers' satisfaction with the public transport service, and whether they view public transport as an effective option." If the goal is to encourage greater regional cohesion, then close attention must be paid to the transfer to the urban distribution network in order for the frequent users to be satisfied and comfortable with the service. The access to the HQR network should be extended to reach the most people and businesses possible.

The reason that proper planning of quality connections is so important is the presence of a "transfer penalty." Econometric analyses have consistently found that a transfer within a transportation network results in an additional perceived "cost" to the user. This penalty is in addition to the time to walk between the vehicles and the waiting time between modes. Many people will take a one seat ride to reach their destination even if the total travel time is longer than one with a transfer. This is in order to avoid the inconvenience that is associated with the transfer. Transfer penalties have been estimated using empirical data and it has been found to depend greatly on the transfer conditions. In an area where the transfer is exposed to the weather, or requires maneuvering through a complex, confusing station or street network, the transfer penalty can be much greater than it would be in a simpler and more user friendly system.

However, regardless of the system, the value of the transfer penalty is typically high.

The high value of the transfer penalty indicates that transfer inconvenience can significantly affect travelers' decisions: whether they view a particular mode as being acceptable, which path they will take and how satisfied they are with their travel. Transfers should be one of the major concerns in service operation and planning. (Guo, 2003)
Table 5 shows some values of transfer penalties estimated from multiple reports. These penalties are measured in minutes of in-vehicle travel time. Using this data the “Suburban Rail” could represent a regional HQR network. This collection of values shows average penalty values of 9 minutes for an HQR to subway transfer and 13 minutes for HQR to bus transfer.

<table>
<thead>
<tr>
<th>Source</th>
<th>Location/ Case</th>
<th>Transit Modes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Bus-Bus</td>
</tr>
<tr>
<td></td>
<td>Boston/All Trips</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ottawa/All Trips</td>
<td>22-30</td>
</tr>
<tr>
<td></td>
<td>Edmonton/All Trips</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Honolulu/All Trips</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Taipei/All Trips</td>
<td></td>
</tr>
<tr>
<td>British Railways (1989)</td>
<td>London/All Urban Trips</td>
<td></td>
</tr>
<tr>
<td>Ryan (1996)</td>
<td>London</td>
<td></td>
</tr>
<tr>
<td>Standebuy (1993)</td>
<td>Oslo</td>
<td>8-10</td>
</tr>
<tr>
<td>Piotrowski (1993)</td>
<td>Perth/Work Trips</td>
<td>8</td>
</tr>
<tr>
<td>Prosser et al. (1997)</td>
<td>Sydney/A.M. Peak</td>
<td></td>
</tr>
<tr>
<td>Algers et al. (1975)</td>
<td>Stockholm</td>
<td>50</td>
</tr>
<tr>
<td>Hunt (1990)</td>
<td>Edmonton</td>
<td></td>
</tr>
<tr>
<td>Wardman et al. (2001)</td>
<td>Edinburgh</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Average of values</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Range of values</td>
<td>5 to 50</td>
</tr>
</tbody>
</table>

Table 5: Transfer Penalties in Equivalent Minutes of In-Vehicle Travel Time; from multiple studies (Currie, 2005)
For many trips a transfer may be unavoidable. But multiple transfers of approximately “10 penalty minutes” each quickly deteriorate the advantage of the HQR over the automobile. Minimizing the amount of transfers and facilitating the necessary transfers are essential to making the system accessible as a mode of intercity travel. If a journey requires too many transfers or the transfer experience is burdensome to the user, then the intercity trip will be made by automobile or not made at all.

But just running bus lines to a rail station is not enough. “A higher quality of transfers provides benefits for passengers” (Gomez, 2010). The high level integration includes integrating the local transit networks in terms of fares, ticketing, and user information. An outstanding example of intermodal integration can be found in Switzerland. The rail stations are hubs of activity that include regional trains, local trains, buses, and trams. The Swiss have integrated the transit on a national level so that it is possible to buy a monthly, daily, or one trip pass that can be used on any transit system in any city.

In addition to seamless ticketing, the services are coordinated and planned to minimize the transfer penalty. Since implementing the “Swiss Card” in 1989 and the integration of rail services in 2000, the system has seen record ridership and capacity issues due to high demand (Cosandey, 2010). The Swiss regional HQR system does not run much faster than the automobile but due to the high quality and easy to use system, much of the intercity travel is done on the rail system. A true intermodal, integrated regional transit system, with the HQR network as the backbone connecting the cities, will enable the region to maximize the potential economic benefits.

Chapter 5 analyzes the local distribution systems in the Basque Country and shows how simple improvements in the network can lead to significant gains for the Region. As Swiss style integration is something that is difficult to achieve overnight, it will also explain the incremental steps that can be taken to reach that level, and which planning decisions are most necessary for high quality integration to happen.
3.6.3 FARES, FREQUENCIES, AND SCHEDULING

With an integrated regional HQR system, more people and businesses will have the option, the understanding of how, and the desire to use it. "Frequent [HQR] services and good integrated public transport access to the station interchange can lead to the [HQR] becoming a 'catalyst' for regeneration" (Preston & Wall, 2008). Along with integration, the operations of the HQR itself are very important. Factors such as fares, frequencies, and scheduling must be carefully planned in order to deliver high quality service to the passenger.

The fares on a regional HQR line should take into account the needs of the user. They need to be low enough to encourage as much intercity interaction as possible but they need to be high enough so that the operations are financially sustainable. Typical fare structures can include a certain amount per trip, a discounted book of some amount of trips, or it could be an unlimited pass for some amount of time. Each has its advantages and Chapter 5 analyzes a potential fare structure for the Basque Y that is consistent with successes in countries like Germany and Switzerland.

Careful attention to frequencies is another important part of planning service for a regional HQR. In his thesis, Lu (2003) demonstrates that frequency is more important than travel time, as waiting time is more burdensome than in-vehicle time. He argues that speed, and therefore travel time, seems to be the largest motivators of planning, when the real potential for providing quality service lies in increasing frequency. The time spent on a train can be productive, as detailed on page 43, and therefore the passenger holds the perceived value of this time low. However waiting for a train does not allow the user to sit in a comfortable chair, do work, or relax. Therefore reducing the average waiting time by 10 minutes should have a much larger effect on the quality of service, and therefore ridership, than if the travel time was reduced by 10 or even 15 minutes. This suggests that there might be benefit to running smaller trains at higher frequencies rather than larger trains at longer intervals.
The rail system in Switzerland is again a useful comparison for ideal regional HQR networks. We will look at the connection between Zurich and Berne, a distance of 120km and a direct travel time of just under 60 minutes. The one-way fare for this trip is 47 Francs, or about US$45. This is expensive, however the target here is the infrequent user. Regular commuters or business travelers commonly purchase a monthly or yearly pass, which gives unlimited travel between cities. A monthly pass currently costs 305 Francs (US$290) for the regular adult ticket, which is comparable to the Zone 8 MBTA Commuter Rail Pass in Boston ($265). The frequencies of service between these two cities are two direct trains per hour (56 minutes) and 2 slower trains (77 minutes) that make stops at smaller cities along the way. However both of these services leave in close proximity so the effective headway between the cities is 30 minutes.

The Swiss use careful planning to ensure that these 30 minute headways are consistent. There is a train that leaves every 30 minutes on the hh:02 and the hh:32 from Zurich to Berne, every hour, all day. A frequent user knows these times and can plan his schedule around it so waiting time at the station is reduced to almost nothing. The Swiss and Germans both practice consistency in their schedules and often the train platform is known so that the user will know what platform to walk to even before he arrives at the station. The reliability and convenience associated with the regularity reduces anxiety for the user. A reduction in anxiety means an increase in user comfort and the travel time on the train is more enjoyable and productive. This results in a reduction in the perceived cost of the journey, which makes intercity travel more attractive to the user.

Another factor in operations planning that the Swiss have used extensively is “pulse scheduling.” Pulse scheduling is an operational integration of the HQR and the local transit modes. “Transit lines, including HSR [HQR], are coordinated to include appropriate transfer times, wait times and scheduling confusion are minimized” (Yaro et. al., 2010). Yaro uses Philadelphia as an example for potential pulse scheduling.
Figure 10 shows the pulses at the top and bottom of the hour. The different modes arrive and leave together, allowing passengers to transfer between any mode in these few minutes.

![Diagram of pulse scheduling example for Philadelphia](image)

*Figure 10: Pulse Scheduling Example for Philadelphia (Yaro et. al., 2010)*

The operations of the HQR should not be limited to the frequency and travel time alone.

Evaluation for high speed rail or other intercity transportation technologies should not focus too narrowly on the technical attributes such as journey time, frequency, and capacity. Equally important are the human attributes of how the time on board could be spent and the ability of the technology to adapt to changing human demands. (Lu, 2003)

When attempting to build the demand for the regional rail, and therefore encourage a functional region, amenities on the train themselves can help meet these “human demands.” The human demands include conveniences such as Internet access, electrical outlets, food and beverages, and enough comfortable seating. All aspects of HQR need to be considered in order to derive the maximum benefit out of the system.
3.6.4 Planning for the Future

What is built today will affect not only the transportation system in the short run, but it will have implications for the transportation system in the future. The fact that there already is a rail station in a city center gives us the opportunity to serve it with HQR. Otherwise the cost of acquiring so much city land can be too high to be practical. The benefits of locating the original rail station in the city center are being enjoyed 100 or more years after it was first built. One of the problems with the conventional benefit/cost analysis is that the future is heavily discounted and therefore the impacts on future planning decisions are not considered. And once the infrastructure is built it becomes difficult to move or modify. The decision moment of planning moves in real time, and what happens today may have serious implications on the future. In too many cases the future is discounted away. Setting the stage to move in the direction of where the city wants to go should be an important part of the decision making and planning process.

Some planning decisions are more critical than others. In the HQR case, the station location has the most significant impact on the future of the system and the future development around the station location. “Development opportunities from new networks will occur at locations with good access to the new network and which provide nodal connections to other networks” (Vickerman, 1997). The station location enables growth to occur around the area for many decades. If a city wants to encourage development, then ensuring that the station has good access and high ridership are key to support growth. Once a city center station is established then the opportunities for integration and development arise.

Another planning decision that is important to consider is the future of the network. An HQR line may start out as just a line, but over time more connections are made to more cities. “Typically greater traffic volumes and hence rates of return will be obtained where there is the possibility of the HQR route being integrated with the rest of the network to provide through services” (Vickerman, 1997). Stations that are located on a
spur, rather than on the main line, may experience lower frequencies due to the operating inconvenience of entering and exiting the spur. Only in very large cities such as Paris or Madrid do spur, or terminal rail stations work. Smaller markets in regional cities will be best served by the main line track that passes through the main station. A loss of frequency due to a spur can mean a loss in ridership, which starts a downward spiral such that service becomes too poor or too expensive to encourage the economic benefits of a functional region.

The dynamics of the system in the long term are hard to plan for based on a simple comparison of the benefits and costs discounted to today. In her thesis, Hernandez (2011) explores the long term dynamics of planning decision in transportation and gives insight as to how transportation planners should not discredit the future, but look at the sustainability of the system over long periods of time.

3.7 SUMMARY OF REGIONAL HQR NETWORKS

Experiences from Europe and recent research have shown that there are real, significant benefits to improving regional intercity accessibility. Using HQR as a way to reduce travel times and travel costs, regions can enjoy the benefits of increased business accessibility, and larger labor and service markets. These benefits are difficult to estimate, but they should not be omitted from planning. Instead they should accompany the planning, drawing on successful experiences from existing functional regions such as those in Switzerland and Germany.

Comprehensive planning is important to realizing these benefits, and analyzing the system as a door-to-door service is important in attracting frequent users. Also, attending to the needs of origin and destination users will be important to making sure that all connected cities get a share of the labor and service markets. Instead of one city gaining all the business development and the other cities acting as commuting towns, the flows should be balanced so that each city has both business and residential growth. If a station is located poorly, or services are not integrated, it is likely that the
more connected city will receive the destination travelers, and hence the business growth. An analysis of the station locations, intermodal integration, and HQR operations for each city is necessary to make the system as fluid as possible for the users.

With a comprehensive analysis of existing functional regions, the next section will apply these concepts to the Basque Y project in Spain. Chapter 4 will discuss the details of the project and give background information on the connected cities. Chapter 5 will analyze the major planning components of the region and how they can help create a functional region in the Basque Country. The results from Chapter 5 will give the conclusions and recommendation for the Basque Y and other regional rail systems in Chapter 6.
4 THE BASQUE Y RAIL PROJECT

This thesis uses the Basque Y as a case study for evaluating the planning decisions necessary to create economic cohesion between cities. This section gives an overview of the Basque Y project and the context in which it will operate. The Basque Y is a high speed rail (HSR) project, but it has the potential to become a high quality rail (HQR) system that encompasses both the attributes of high speed and high quality as defined in Chapters 2 and 3.

Section 4.1 provides a basic understanding of the Basque Country, which is the region that the Basque Y serves. Section 4.2 gives an overview of the project and Section 4.3 gives a detailed look at each of the connected cities showing the spatial distribution of employment, population, and the transport network. The demographic data used for the region is from the 2001 Eustat census.

4.1 THE BASQUE COUNTRY

The Basque Country is a politically autonomous community located in Northern Spain and is home to more than two million people. It is composed of three provinces, each with the largest city being the provincial capital. Figure 11 shows the provinces, capital cities, and includes a few other important cities with respect to the planned HSR rail network. Population statistics and other important aspects of the region are described in detail in Sections 4.2 and 4.3.

The Basque Country borders France on the East and the Atlantic Ocean to the North. For the purpose of this thesis, the Basque Region is synonymous with the Basque Country, but technically the Basque Region extends into a portion of France and the Navarre Province of Spain. The people native to the Basque Country speak their own distinct language, Euskera, which is very different from Castillian Spanish. In
Euskera, the region is referred to as “Euskal Herria” and is a term that is frequently used to encourage unity and cooperation between the Basque people.

Figure 11: The Basque Country, 1 inch = approx 30km

4.2 PROJECT DESCRIPTION

The “Basque Y” is the name given to the “Y” shaped HSR network in the Basque Country that is designed as a link between Spain and France. Named as one of 14 “priority” infrastructure projects by the European Union in 1994, the Basque Y lies in a central part of the European HSR network (EuskalYVasca, 2010). Figure 12 shows the location of the Basque Country with respect to Europe and the potential HSR connections to the rest of the continent.

The Basque Y is a 6 billion Euro investment and will be the costliest infrastructure project in the Region’s history. The funding for the project comes primarily from the
European Union (EU) and the Spanish Government. To speed up the construction, the Basque Government is contributing a significant part of the upfront cost with the promise of reimbursement in the future.

This project gets priority status because the EU would like to see a unified HSR connection between the Iberian Peninsula and the rest of Europe. One of the key aspects of this project is the elimination of gauge differences between the standard gauge track used in Europe and the broad gauge track used in Spain and Portugal. This allows for a single train to be able to run directly between most of the European countries. The infrastructure will be capable of handling both passenger and freight traffic. Having a direct connection between France and Spain for freight traffic could help reduce the costly transfer of goods between trains of different gauges at the border town of Irun. These are all politically important to the EU goal of greater cohesion between the member states.
The Spanish Government is using the Basque Y as the northern end of another HSR line radiating out from Madrid. Since 1992, Spain has had a goal of connecting most of the nation’s major urban areas with the capital, creating a radial network of long distance HSR lines. The Basque Region is politically important to connect to the network.

To accomplish their respective goals, the EU and the Spanish Government are building HSR infrastructure that happen to also directly connect the three capital cities of the Basque Region with each other. In doing so, an accidental regional HSR network is formed that the Basque Region can use to create more economic and social cohesion between the cities. A long term goal of the Basque Government is to further the concept of the “Euskal Herria” where the region shares markets and identity.

Before the 1970s, the Basque Cities were very isolated from each other. Due to the rough terrain of the Pyrenees Mountains, it took about 3 hours to traverse the 100km between each city. When AP·1 and the AP·8 expressways were built in the 70s, the distances were reduced to around an hour by car or by bus. This significantly changed how the region functioned and enabled more cultural and economic interaction between the cities. The Basque Y is a further step in that process, bringing the capital cities together in less than 40 minutes. Figure 13 shows a map of the Basque Region with the major expressways in yellow.
Figure 13: The Basque Region and Major Expressways

The highways of the 1970s defined a pattern break where travel times were reduced in a way that enabled much more activity and cooperation between the cities. The Basque Y, set to open by 2015, represents the next opportunity for a pattern break by significantly reducing travel times from the road network. Figure 14 shows a schematic of the Basque Y infrastructure and the future connections outside of the region. Table 6, Table 7, and Table 8 show distance and population data for the principal connected cities.
The Pyrenees Mountain Range dominates the geography of the Basque Region. In order to accommodate high speed trains with top speeds of 220 kph, 70% of the new infrastructure runs in bridges or tunnels. The Basque Y will also be connected to the existing HSR network when the project is completed, with extensions to Bordeaux and Paris to the North and Valladolid and Madrid to the South. Table 9 shows the current estimated HSR travel times to key cities at the completion of the Basque Y project.
Future connections beyond the current planned network also show opportunity for the region to become even more of a transportation hub. Figure 12 on page 69 shows the advantageous position of the Basque Region as a central hub within Europe. Figure 14 on page 72 shows potential connections to other regional cities such as Pamplona and Santander. A possible direct HSR connection with the airport in Bilbao can also provide more transportation options beyond the region and strengthen the HSR network. In her thesis Hernandez (2011) shows how these future connections, specifically the connection to the Bilbao Airport, can ensure many long term benefits.

The regional HSR network will significantly reduce intercity travel times. To travel between the cities today, the options are limited to either the bus or the automobile. The intercity rail network is very slow and infrequent so it is not considered a practical mode of intercity transport. Table 10 compares the current options with the projected HSR times, and hence the potential of the project.

<table>
<thead>
<tr>
<th>Travel Times</th>
<th>Car</th>
<th>Bus</th>
<th>Basque Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Sebastian - Bilbao</td>
<td>60</td>
<td>70</td>
<td>38</td>
</tr>
<tr>
<td>San Sebastian - Vitoria</td>
<td>70</td>
<td>90</td>
<td>34</td>
</tr>
<tr>
<td>Bilbao - Vitoria</td>
<td>45</td>
<td>60</td>
<td>28</td>
</tr>
</tbody>
</table>

*Table 10: Current and Projected Travel Times in the Basque Country*

The politically strategic goal of the EU and Spain to create a direct link from Madrid to Paris is unlikely to be very practical in operation. Even with the expensive, new infrastructure, it will still take more than seven hours to reach Paris from Madrid (Table 9). Eventually the French may upgrade the HSR line on their side of the border.
but reducing this time to less than six hours is still not competitive with the airplane. For a frequent business traveler, it will be much faster and less expensive to fly. The real potential for the network lies in the shorter trips that allow for easy business accessibility and commuting trips in a regional setting. The capability for the Basque Y to attain the benefits of a functional economic region, as described in Chapter 3, exists. It is the ridership and economic growth on the regional scale that will make this project worth the investment.

Construction has already started on the Basque Y with work concentrating on the segments in the heart of the “Y.” However, the areas around the cities and their stations are yet to be started. The planning from Spain and the EU does not seem to consider regional connectivity to mid-sized cities. The Basque Region has the opportunity to tweak the HSR network into an integrated, regional HQR network that could transform the mobility of the region.

4.3 THE BASQUE CITIES

For a successful regional HQR network, it is not enough to connect dots on a map. A thorough look at the demographics and geography of each connected area is important to make sure that the service is efficient and practical for the users. The capital cities of Vitoria, Bilbao, and San Sebastian will be examined for the case study. Here they will be described to gain an understanding of their spatial distribution.

These cities all have historic districts and high concentrations of population, service firms, and commercial businesses in the city centers. They all have the asset of efficient local and regional public transit systems. The primary mode of intercity travel is on the expressway network to which each city has relatively easy access. The local streets are mostly uncongested and getting around in the city by car, bus, or taxi is fairly fast. And each city has unique aspects that are important in analyzing an intercity rail network.
The next section will take a look at these three cities and their surrounding areas. From Chapter 3, issues such as station location and intermodal interconnectivity are important factors related to the geography and demographics of a city. Maps showing key trip attractors and generators and the local public transit systems will be the basis for understanding the intercity mobility need of each city. The following are examples of important aspects of each city:

- Trip Attractors and Generators
  - Residences
  - Employment
  - Shops and Businesses
  - Universities
  - Hospitals
  - Government Offices
  - Tourist Attractions
  - Land Development Opportunities
- Local Transportation Systems
  - Rail Lines and Stations
  - Bus Lines and Routes
  - Intercity Bus Terminals
  - Opportunities for Integration

In each city there are many transit options. All have a local municipal bus system and there are also many intercity bus services, typically operated by private operators under contract. EuskoTren, a local railway company, operates an east-west commuter rail service on a narrow gauge system and Euskotran operates light rail services in Bilbao and Vitoria. RENFE, the national rail operator runs Cercanías service in Bilbao and San Sebastian, which is a commuter rail system. RENFE also operates intercity long distance services that connect the cities with Madrid. All of the RENFE services are on the traditional Iberian broad gauge tracks.
TransCAD, a computer modeling software, was used to create the maps (Figure 15 through Figure 19). These graphics show the population and jobs for each census district as circles of varying size based on the amount. The black section of the circle represents population and the white represents jobs. The purpose of these is to get an idea of where the jobs and population are concentrated in order to best serve the people and businesses. Other important features are labeled on the grid system of each map. A more detailed description of TransCAD and the specific aspects of the maps are in Chapter 5.

Chapter 5 will take a further look into these cities by applying tools to show how access to intercity opportunities changes under different planning scenarios. The purpose of this section is to familiarize the reader with the cities and their makeup.

4.3.1 VITORIA

Vitoria, which is also known as Gasteiz, is the capital of the province of Alava and the seat of the Basque Country Government. It has a population of 217,000 and this constitutes more than 75% of the provincial population; the area outside of the city limits is very sparely populated. Figure 15 shows the dense concentrations of jobs and populations around the historic city center. The northwest part of the city (Figure 15 C-3) is the location of the Basque Government Headquarters, and thus a large concentration of jobs and a major regional trip attractor.

External automobile and bus access to the city is by the E-5/E-80 expressway that runs north of the city. Once in Vitoria, automobile mobility is fairly high as almost the entire city is accessible within a 10 minute drive. The city does have an efficient public transit system with a new light rail line connecting the areas in the Northwest to the center and South. There is an existing intercity rail station in the southern part of the city, but it serves only a few trains per day and does not offer commuter service. The new rail line will not use the existing station, but instead a new one will be constructed in the northern part of the city close to the Government Offices.
Figure 15: Vitoria with Population, Jobs, and Select Transportation Infrastructure

Key Places
- Basque Government Headquarters C-3
- Basque University, Alava Campus E-6
- Historic District E-4

Key Transportation
- Basque Y Station D-3 (red dot)
- HSR Alignment Red Line
- Current RENFE Rail System Green Line
- Existing Rail Station E-5 (green dot)
- Intercity Bus Terminal F-4 (yellow dot)
- Light Rail Transit Alignment Blue Line
4.3.2 Bilbao

Bilbao is the largest of all the Basque cities with a population 350,000 and is the capital of the Vizcaya province. Unlike Vitoria, the population and jobs of the Bilbao area are spread out over a larger area. The dense metro area of Bilbao is estimated at nearly 1 million, which includes smaller cities such as Getxo, Barakaldo, and Etxebarri. As shown in Figure 16 and Figure 17 most of the development is concentrated linearly along the Nervión River. In central Bilbao, there are high concentrations of service and commercial businesses. Approximately 82% of the population and jobs of the Vizcaya province are within the Bilbao metro area.

The topography of the Bilbao area makes for easy travel along the river valley so most of the transportation infrastructure follows this alignment. The city has a metro line that follows the river and splits near the mouth to serve the areas around Getxo and Barakaldo. RENFE, FEVE, and Euskotren offer intercity services from their two separate stations, each shown in Figure 16. A new light rail line, operated by Euskotran, connects the intercity bus terminal with the Abando station and Euskotren station across town. The city also has an extensive local and regional bus system and is home to the region’s largest and busiest airport, which is 3km north of the city. Like the other cities, the local street network in Bilbao is mostly uncongested, allowing for relatively fast movement by car, bus, and taxi. The A-8 and the AP-68 expressways provide access for intercity travel.

The current RENFE and FEVE rail station, Abando, will also serve the Basque Y. This station is located close to the high concentrations of downtown jobs and has connections with the metro, light rail, bus, and Cercanías (commuter rail) services. It has the potential to be extended underground to the North to connect with the airport and eventually Santander and points west. A discussion of this extension and a diagram on the alignment can be found in Section 5.2.2 on page 100.
Figure 16: Bilbao with Population, Jobs, and Select Transportation Infrastructure

Key Places

- University of Deusto  F-3
- Historic District  F-4
- Guggenheim Museum  D-3

Key Transportation

- RENFE Abando Rail Station  F-4 (red dot)
- Euskotren Rail Station  F-4 (orange dot)
- Intercity Bus Terminal  D-4 (yellow dot)
- RENFE Rail Alignment  Red Line
- Euskotren Rail Alignment  Orange Line
- Metro Alignment  Blue Line
Figure 17: Greater Bilbao with Jobs and Population

Important Areas
- City of Bilbao: D/E·4
- Getxo: B·1
- Barakaldo: C·3
- Etxebarri: F·5
- Loiu Airport: F·3

4.3.3 San Sebastian

San Sebastian, locally known as Donostia, is the capital city of the province of Gipuzkoa with a population of 178,000. The larger metro area consists of about 418,000 people, which includes many smaller cities such as Hernani, Zarautz, Zumaia and the dense corridor stretching to the border city of Irun. Gipuzkoa is the most dispersed province, with other cities such as Tolosa, Beasain, and Zumarraga not included in the San Sebastian metropolitan area. About 40% of the jobs and population in the province are located outside the greater San Sebastian area.
Like the other Basque cities, moving around is usually fast and efficient. The automobile access is fairly high, although there can be significant congestion in major corridors because the hilly terrain makes for few alternatives. The local bus system, Donostiabus, is high performing, making it one of the fastest bus networks in the country with many dedicated bus lanes to enable passing of traffic. The recently integrated intercity bus system, Lurraldebus, serves the entire province and provides connections to the other cities in the region. There are currently plans to move the intercity bus terminal close to the centrally located Atotxa rail station.

The RENFE Cercanías system provides commuter service that runs from Irun at the French border, through San Sebastian, and to other cities in the southwest part of the province. RENFE also runs 2 one-way long distance trains to and from Vitoria and Madrid daily. The main RENFE station in San Sebastian, Atotxa, is centrally located just across the river from downtown. Euskotren, a narrow gauge rail system, runs an east-west commuter rail service from another station that is close by, as seen in Figure 18.

The location of the San Sebastian Basque Y station is currently planned to be in Astigarraga, a town of 4000 located 6 km south of central San Sebastian. The connection to San Sebastian would most likely be a RENFE shuttle service on a rail network spur going from Astigarraga to Atotxa. The alignment and station location, as seen previously in Figure 14 on page 72, is one that is currently debated. There are strong arguments for placing the main Basque Y station in Atotxa with through service to Irun and France. The debate over the Astigarraga versus Atotxa station location will be analyzed in depth in Chapter 5, as it is central to the performance and capabilities of an HQR system. Figure 18 and Figure 19 show the location of these stations with relation to the geography and demographics of the area.
Figure 18: San Sebastian with Population, Jobs, and Select Transportation Infrastructure

Key Places
- Basque University, Ibaeta Campus B-4
- Historic District D-2
- Downtown/Business District D-3
- San Sebastian Hospital E-5

Key Transportation
- RENFE Atotxa Rail Station D-3 (red dot)
- Currently Planned Astigarraga Station F-5 (green dot)
- Euskotren Rail Station D-3 (blue dot)
- Intercity Bus Terminal D-4 (yellow dot)
- RENFE Alignment Red Line
- Euskotren Alignment Blue Line
- Currently Planned Basque Y Alignment Green Line
4.4 Basque Y Summary

The Basque Y project has the capability to provide a significant improvement in intercity accessibility. The considerable reduction in travel time can be a pattern break that can provide the opportunity for many of the benefits of a functional region. From the summaries of each city, it is evident that each has benefits that make it an important part of the network. Vitoria will have the strong regional attraction of the...
Basque Government Headquarters. It is located before the HSR network splits; all trains to and from Madrid will have to pass thought Vitoria. Bilbao has the advantage of hosting the largest population and most jobs in the region. The Basque Y station will be well connected with the local transit system at Abando and there is the potential to have a rail link to the Bilbao Airport. San Sebastian has attractive tourism and business opportunities and it is located on the route linking France and Spain. Nevertheless the station location issue in San Sebastian could pose a threat to the success of the regional rail system and this issue will be analyzed in more depth in Chapter 5.

When connected, the combined metropolitan area population of the three Basque cities can work together to become a unified economy. Chapter 3 demonstrated that economic areas with greater populations show significant increases in productivity and wages. The planning of the Basque Y as a high quality system is critical as to not miss this opportunity. The next section looks at the planning decisions and tools that can be used to make the best decisions for the success of the Basque Y.
5 HQR PLANNING FOR A FUNCTIONAL REGION: THE BASQUE Y

The previous chapters have made clear the advantages of implementing a high quality rail system in a region. It is also clear that simply constructing a rail line capable of high speeds is not necessarily high quality and will not inherently stimulate economic growth. The planning necessary to achieve this growth requires attention to the details of the system that contribute to high quality. A high quality system takes into account the needs of a door-to-door trip and enables frequent travel between cities. Frequent users, especially the commuters and business travelers, must find the system convenient, reliable, inexpensive, and practical so as to use it daily.

The purpose of this chapter is to apply experiences and best practices to The Basque Y as outlined in previous chapters. The Basque Y, as described in Chapter 4, is planned as a high speed rail (HSR) project that connects Madrid with the three capital cities in the Basque Region of Spain. It will also eventually include an HSR link across the border to France. The resulting infrastructure is one that connects the Basque cities in a way that has potential to transform the mobility of the region. There are major planning decisions in this network that could be changed to improve the quality of the network. This section uses different approaches to analyze each decision and demonstrates its impact on the present and the future.

This chapter is divided into three parts. Part 1, which encompasses Section 5.1, outlines the tools that are used in the analysis. These tools include modeling software, direct comparisons, monetization of travel costs, and political insights that can build the support to modify the project’s design.

Part 2 encompasses Sections 5.2, 5.3, and 5.4 looking at the foremost planning decisions that are determined to be necessary in order to create a functional region. Planning decisions covered include:
• Station Location
  o Physical location in the spatial distribution of the city
  o Alignment of the track infrastructure
  o Provisions for connecting transport modes, including parking
  o Land use opportunities
• Intermodal Integration
  o Physical (spatial) integration
  o Operational integration
  o System integration
• HQR Operations
  o Fares
  o Frequencies
  o Scheduling

Part 3, encompassing Sections 5.5, 5.6, and 5.7, examines the overall impact of the planning decisions. Section 5.5 monetizes the costs of five intercity travel scenarios that evaluate incremental improvements in the network. Section 5.6 looks at the political obstacles in garnering support for redesigning such a system. To assure that the proper planning decisions are made, an actor analysis for the Basque Y is introduced as a useful guide to shape the political support process for the high quality design. The chapter ends with Section 5.7, which discusses the future of the system and the importance of making the right decisions now with the future in mind. Given the fact that infrastructure projects are typically permanent fixtures that last decades, if not centuries, planning today will affect the transportation potential of the future. Each of the three Basque Provinces and the Basque Region have essential roles to play in developing this vision.
5.1 **TOOLS FOR ANALYSIS**

This chapter uses four main tools to illustrate the impact of planning decisions on the success of the network. The tools are powerful in showing the true impact of certain planning decision on the design of the network. At the same time they are general enough so that they can be applied on many different projects. The analysis includes the following tools:

- TransCAD, a transport modeling software
- Direct comparisons to other successful system
- Monetization of total transport costs
- Actor analysis for building political support

5.1.1 **TRANSCAD**

TransCAD is a GIS-based transportation modeling and planning software developed by Caliper Corporation. It allows the complete transportation network of an area to be analyzed along with spatial demographic data. The TransCAD display is a two dimensional map composed of links and nodes representing the street, road, and rail networks. The program allows the input of transit routes, including running times, fare structures, and headways. Travel times on links for walking, driving, and transit can be specified based on actual conditions in each city. Links are also included to limit access or exclude certain modes. Overall the program takes a complete look at the transportation network for a given area.

The software has the ability to determine the time needed to access different parts of the city using the transportation network model. This is used to make comparisons with how the system is as planned versus modifications in the system to increase this accessibility. These maps are paired with census data to gain an understanding of the location of key transportation trip generators and attractors.
The Basque Y analysis uses three different model files for the three different cities. None of the models were built from scratch – they were adopted from existing sources and updated to reflect the current state of the network in each city. The walking time was assumed to be 5 kph and walkers had access to any link except railways and expressways. Recent studies of each city provided the automobile times on the network using the AM peak travel times (Leber, 2011). The automobiles were obviously not permitted to travel on pedestrian-only streets or rail lines.

For transit movements each city has its own transit system, service times, and schedules. Leber provided the Vitoria and Bilbao maps that include the current transit network. Other than the alteration of the intercity rail station in Vitoria, the Bilbao and Vitoria networks required only minor updates. For San Sebastian the entire bus and rail transit network was added on a new geographic layer provided by Leber. The Donostiabus website provided the route maps and schedules for the local bus network and the company supplied weekday running times for each route (Compañía del Tranvía de San Sebastián, 2010). The Lurraldebus network was added with the information for the routes, headways, and running times coming from the Lurraldebus website and a database of smartcard data provided for the project (Lurraldebus, 2010). To give an accurate picture of the movement of the bus network the AM peak travel times were used because this would represent the conditions for a commuter arriving in the morning. The RENFE and Euskotren websites provided information for the respective services. The train schedules gave the complete running time data, as this does not vary due to peaking (Euskotren, 2010) (RENFE, 2010).

The 2001 Eustat Census data was superimposed on top of the transportation network (Basque Institute of Statistics, 2001). This data, which is divided into census districts, includes information on the amount of population and jobs in each district. The data includes the gender and age of the population as well as job sector categories. The geographical size of the districts varies to account for the disparity in concentrations of people and employment between cities and rural areas. Dense city districts encompass a few blocks and rural districts may cover many hundred acres. For an analysis of
intercity rail, the concentration of population and jobs in each district represent indicators of trip generators and attractors.

The TransCAD models were used to create accessibility maps showing areas of opportunities within certain time thresholds. The first part of the accessibility map is an isochrone analysis from a single, given point. An isochrone is a band of points that have travel times from that single point within a certain range. Figure 20 shows Vitoria’s HSR station as an example walking isochrone. TransCAD calculates the travel time to each node on the network and colors the node according to the travel time interval. Section 5.2 displays isochrones for walking and transit times from the station points in each of the Basque cities.
Figure 20: Example of Walking Isochrones for the Vitoria Basque Y Station

The maps use the following colors to represent their respective bands:

- Blue 0-10 minutes
- Green 10-20 minutes
- Yellow 20-30 minutes
- Orange 30-40 minutes
- Red 40-50 minutes
- Purple 50-60 minutes

In Figure 20, the thin, green network of lines outlines the census district boundaries. The demographic data for each of these districts is then displayed on top of the isochrone map to get a visual of where the people and jobs are located. For this analysis, just the jobs and population are displayed. The jobs located near the city centers are almost exclusively service and commercial jobs. These concentrations of
population and employment are shown as circles, with black representing population and white employment. These circles are located at the centroids of their respective census district. Figure 21 shows an example of an accessibility map as an isochrone map from the Vitoria Basque Y station point superimposed with the demographic census data.

![Figure 21: Example of Isochrones with Demographic Data for the Vitoria Basque Y Station](image)

The maps use following colors to represent the demographic data:

- Size of Circle: Total number of jobs and residents per district
- Black: Proportion of residents per district
- White: Proportion of jobs per district

The isochrones use the total clock times from the station to each node on the network. Transit times include the un-weighted walk access time, the egress time, the waiting time, the in-vehicle travel time, and the time needed to make a transfer, if applicable. If a trip can be made faster by walking than by transit, the walking time is then used.*

* The walking time is limited to a maximum of 20 minutes
The transfer penalty, as described in Section 3.6.2, is not included. The waiting time is estimated as \( \frac{1}{2} \) of the given headway.

An overlay analysis using TransCAD is performed on each of the accessibility maps to estimate the numbers of population and employment within a certain band. Using the average time to reach all the nodes in each district from the station node as described before, TransCAD estimated the number of population and jobs within a certain travel time threshold.

TransCAD is a powerful tool for visualizing the impact of different outcomes. It is also useful in that it makes for simple analysis and is applicable to many situations worldwide. GIS-based models and census data can thus be used to perform similar analysis in other cities that deal with similar issues.

5.1.2 DIRECT COMPARISONS

Another important part of the analysis is a comparison with other cities and regions that have similar demographics and transportation networks. This method is helpful in attempting to identify what to expect from the status quo. It is advantageous to see how successful areas operate and draw parallels to determine what are reasonable decisions for practicality and functionality. This is used to determine what to expect and what is needed from a planning perspective. For the Basque Y case, RENFE is a good starting point to determine what to expect in terms of fares, frequencies, and scheduling, as RENFE is likely to operate some or all of the Basque Y service. Then a look at other successful regional HQR systems, specifically that of Switzerland, shows how a successful system similar to the Basque Y is designed and operated to achieve the benefits of a functional region.

5.1.3 MONETIZATION OF TRANSPORT COSTS

Monetization of the transport costs is a summation of the travel costs and the value of the time spent traveling as perceived by the user. The cost examined using this tool is the cost to the user of taking a marginal trip. Expenses such as an automobile
purchase, car insurance, or a transit pass do not affect the user's cost of an incremental trip. For example, the monetized cost of an automobile trip cost would include tolls, gasoline, and the total travel time multiplied by an assumed "value of time." For this analysis, the value of time is assumed to be a constant €12/hour.* Monetization measures the value of the intercity travel costs based on current options. The analysis starts with a base case scenario where the Astigarraga station serves San Sebastian with an assumed RENFE shuttle service. The following scenarios, starting with a change in station location for San Sebastian, include incremental improvements over the previous scenarios. The final scenario is a Swiss style HQR system that shows the dramatic difference such a system can make.

5.1.4 ACTOR ANALYSIS

The final tool used is a description of the political process for securing the needed planning decisions in the form of an actor analysis. An actor analysis takes a quick look at the priorities, objectives, and plans of different actors in the planning and operations of the system. Actors included are national, regional, and local groups of governments, operators, residents, and businesses. Since the Basque Y is not going to transform into HQR on its own, those that can benefit from such a system need to analyze the current plan and advocate that the appropriate changes are made for the region. This requires political support and understanding of how key actors in the system will respond and react to that advocacy. The actor analysis examines the first assumptions of these positions, which are to be verified through a dialogue with each party.

* The value of time could be discounted for high quality, seated portion of trips where the time can be used productively. Productive use of travel time results from the ability to work, read, or relax comfortable while driving, something that cannot be done while driving a car. Also, the same value of time is applied to all people irrespective of income differences, which can have policy implications. Econometric analyses of travel demand show these differences to exist. A more detailed analysis would account for these differences.
5.2 STATION LOCATION

The analysis of the Basque Y will start with the station location. The station needs to be located next to key regional markets for intercity trips. Many of the opportunities for economic stimulus and intermodal integration depend on where the station is located. In this section, the location of each station in the three main Basque cities of Vitoria, Bilbao, and San Sebastian is examined in detail. The following aspects of the station location are considered:

- Physical location in the spatial distribution of the city
- Alignment of the track infrastructure
- Provisions for connecting transport modes, including parking
- Land use opportunities

This section will directly build off the city descriptions in Chapter 4. The layout of each city is important for many of the HQR planning decisions, but it is most applicable to the station location.*

Accessibility maps for each city show the opportunities accessible within the defined time thresholds. 20 minutes was chosen as a cut off time as that seems to be a limit for the zone of primary benefits for many of the wider economic benefits from a station for business travel (Jenkins, 2010). Also, the Basque Y intercity travel times are all around 35 minutes, so access times longer than 20 minutes on either end of the trip begins to be unrealistically high for frequent travel. The transit accessibility maps include walk only trips for areas close to a station that are easier to reach by walking rather than by taking transit. These maps do not include walk only trips over 20 minutes. For the subsequent overlay analysis there are four 5-minute time bands that encompass opportunities within 20 minutes time of each station that determine the estimated number of residents and jobs.

* Refer to Chapter 4 for a better understanding of key trip generators and attractors in each city.
Each city, as described before, has excellent access by automobile. The analysis does not include automobile access to the station even though the isochrones for the car stretch and cover most of each city within 20 minutes. The city streets typically have low congestion and it is best for the cities that they remain that way, allowing for taxis, and efficient, high capacity transit to move people to and from the station. Section 5.2.5 will show that provisions for extensive park-and-ride consume too much land needed for more productive uses. Section 5.2.5 also shows that the park-and-ride will not be a significant part of the functional region system.

A recurring issue that is important in the station location analysis is the difference between origin and destination passengers. This is detailed in Chapter 2, but the important distinction to make is that a destination user arrives at the end station and does not have access to a car. Reaching the final destination will be done either walking, in a taxi, by automobile pick up, or by public transit. This is an important distinction to make when planning for a station location. In order to have a balanced functional region, each city should attract regular business travelers and commuters. Stations that are not accessible by transit do not provide fast or inexpensive options for local distribution to incoming passengers. A poorly accessible station may result in unbalanced commuting and business flows or little traffic at all.

The cities of Vitoria and Bilbao have central station locations that seem to serve an adequate amount of the population. The Vitoria Basque Y station will not be the same as the traditional long distance RENFE station, but the new station is located close to the Basque Country Government offices and will be connected to the new light rail line.* Bilbao will retain the current central Abando station, which is well connected to major transit lines and located close to a dense employment center. For this analysis, these two stations are analyzed as planned.

* The new light rail line does not connect with the current RENFE station in Vitoria
The San Sebastian station location will be analyzed in more detail. The accessibility maps will make comparisons between the planned station in Astigarraga and the existing intercity rail station at Atotxa. This can hopefully paint a clear picture of the station location issue and show the potential for improvement in accessibility for the people and businesses in San Sebastian and their visitors.

The final part of the station location analysis will look at parking, integration with feeder systems, land use, and land development. These aspects will focus on the San Sebastian station, but the analytical approach can easily be applied to any city.

5.2.1 VITORIA STATION

The Basque Y station in Vitoria is planned to be located along the edge of Arriaga Park on the northern side of the city. The Basque Y will not serve the existing rail station, located on the southern side of the city, which currently offers relatively limited train service. One of the advantages of the proposed new station location is its proximity to the Basque Government Headquarters. It has the advantage of being close to the new light rail line, which can help access to the historic city core and points to the south within 20 minutes. As stated before, the automobile access is high. Vitoria is the most compact of all of the Basque cities and most of the city is within a 10 minute drive from the station location. Even if parking is limited, taxi, drop offs, and pick ups will enable easy access to the city.

The first accessibility map shows the walking time from the Vitoria Basque Y station. Figure 22 shows 10 minute bands around the station located at D-3. The Government Headquarters and the northern edge of the historic district are within the 20 minute band. The TransCAD overlay analysis, which takes the average travel time of all the nodes in a census district, gives an estimate to the amount of opportunities within the bands. Table 11 shows the results in 5 minute bands.
Figure 22: Vitoria Basque Y Station Walking Times (minutes)

Vitoria Station Walk Time

<table>
<thead>
<tr>
<th>Minutes</th>
<th>Jobs</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>608</td>
<td>2688</td>
</tr>
<tr>
<td>10</td>
<td>2150</td>
<td>10423</td>
</tr>
<tr>
<td>15</td>
<td>4192</td>
<td>29946</td>
</tr>
<tr>
<td>20</td>
<td>11257</td>
<td>60260</td>
</tr>
</tbody>
</table>

Table 11: Vitoria Station Walk Access

The transit access from the Vitoria Basque Y station is shown in Figure 23. The transit times include all aspects of the transit trip except the fare and the transfer penalty. The improvement over the walking map is significant as the light rail and bus system help to bring many of the employment and residential centers within 20 minutes transit time of the station.*

* The accessibility that the light rail provides accounts for the waiting time of less than seven minutes between trains.
Table 12: Vitoria Station Transit Access

Figure 23: Vitoria Basque Y Station Transit Times (minutes)

The TransCAD overlay analysis gives an estimate to the amount of opportunities within 20 minutes. Table 12 shows the results in 5 minute bands for the transit access.

Figure 24 and Figure 25 show a graphical comparison of the transit access and the walk access to the station. For Vitoria, access is somewhat limited around the station. This could be due to the fact that it is located next to a large city park and a large boulevard. However transit does offer an expedient alternative to getting to much of the city’s population. More than 90,000 people live within a 20 minute bus or light rail ride to
the station. Improvements in the transit network and future land development offer a
great opportunity to increase this accessibility. The upcoming sections will
demonstrate an example of ways to further improve access to the station.

**Figure 24: Graphical Representation of Vitoria Walk Overlay Analysis**
This analysis does impose the question of retaining the original RENFE station on the south side of the city. It is possible that the traditional RENFE station could actually have more access to key markets than the new station does. A more thorough analysis could compare these station locations and help determine if one has a clear benefit over the other. It does seem as though the traditional location has more walking access to the jobs and population located in the densest part of town. However the traditional RENFE station does not have direct access to the light rail line, leaving the Basque Government Headquarters outside of a 20 minute transit ride.

5.2.2 BILBAO STATION

The current Bilbao main station for intercity rail, Abando, will also serve trains on the Basque Y. The Abando station is well connected, with direct access to the Bilbao Metro, RENFE Cercanías, the FEVE rail system, the Euskotran light rail, and multiple bus connections. It is also located in the heart of the city next to very dense centers of
employment and residences. Most of the core of Bilbao is easily accessible by car or taxi, and like Vitoria, the analysis will include the jobs and population accessible by walking or public transit. Abando currently offers less than 100 parking spaces so park-and-ride represents a very low access mode share with most of the motorized trips arriving by transit, taxi, and drop off (Leber, 2011).

Abando is a terminal station, meaning that there is no through service in Bilbao. All long distance trains that enter the city must leave on the same route. However there is a potential for extending the line underground to connect with the Bilbao airport, located 3km to the North, and then continue west to connect with cities along the Spanish northern coast, including Santander. Figure 26 shows a map of Bilbao with the current RENFE network and Abando (red), the Bilbao Metro (blue) and the possible extension to the Airport and Santander (green).

The first Bilbao accessibility map is the walking time from the Abando station. Figure 27 shows 10 minute bands around the station located at D-3. Bilbao has a particularly high concentration of jobs around this station and there is very high job access within 10 minutes. Important destinations such as the historic district (E-3) and the
Guggenheim museum (D-2) are within a 20 minute walk. Table 13 shows the results of the TransCAD overlay analysis that estimates the number of jobs and population for 5 minute bands.

<table>
<thead>
<tr>
<th>Minutes</th>
<th>Jobs</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>10364</td>
<td>1906</td>
</tr>
<tr>
<td>10</td>
<td>19828</td>
<td>9323</td>
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<tr>
<td>15</td>
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<td>29176</td>
</tr>
<tr>
<td>20</td>
<td>57729</td>
<td>65795</td>
</tr>
</tbody>
</table>

Table 13: Bilbao Abando Station Walk Access

The transit accessibility map from the Abando station is shown in Figure 28. The improvement over the walking is significant for areas in Bilbao outside of the 10 minute walking area. Bilbao is unique in the context of the Basque cities as there are more jobs within the 10 minute boundary than there are residents, however this trend
reverses quickly after 10 minutes. Table 14 shows the estimated numbers of jobs and residents within 20 minutes transit time of the station.

![Figure 28: Bilbao Abando Station Transit Times (minutes)](image)

<table>
<thead>
<tr>
<th>Bilbao Station Transit Time</th>
<th>Minutes</th>
<th>Jobs</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>10364</td>
<td>1906</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>29871</td>
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<td></td>
<td>15</td>
<td>58111</td>
<td>74103</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>94048</td>
<td>157909</td>
</tr>
</tbody>
</table>

*Table 14: Bilbao Abando Station Transit Access*

The light rail, FEVE, and the metro, which have direct access to the Abando, help in expanding the accessibility to the Greater Bilbao area. Even though the 20 minute boundary encompasses only the central part of the city, many areas are able to access the station within 30 or 40 minutes using the metro. The high quality service that a metro can provide may enable many of the residents in these areas to use the metro as
a reasonable means of access to the Basque Y on a regular basis. Figure 29 shows the metropolitan area and the contribution of the metro to these areas (C-1 to D-3).

Figure 29: Greater Bilbao Abando Station Transit Times (minutes)

Figure 30 and Figure 31 show a graphical representation of the walk and transit access to the station. Bilbao has a high walking access, especially for jobs. The transit system seems to be a very good feeder for both jobs and population within the greater metro area. Extending the access on public transit brings almost 500,000 residents and 200,000 jobs within a 40 minute transit ride of Abando.
Bilbao Station Walk Times

Figure 30: Graphical Representation of Bilbao Station Walk Overlay Analysis

Bilbao Station Transit Times

Figure 31: Geographical Representation of Bilbao Station Transit Overlay Analysis

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The high connectivity that Abando has to local feeder and distribution systems is a strong advantage for the station. This is attractive for the residents living in this area that wish to access the Basque Y. The high concentration of employment opportunities around the station is another advantage for Bilbao to attract commuters from around the region. It is unlikely that there is a better location for the station in Bilbao however the city and region should work to ensure that the Abando station does not remain a dead end. Serving through trains that connect with the airport and to Santander will only strengthen the importance of Bilbao on the network and add to the amount of service that it receives.

5.2.3 SAN SEBASTIAN STATION

The Basque Y station for San Sebastian is currently planned to be in the town of Astigarraga, located 6 km south of the city center with a population of 4000. The alternative would be to re-route the main line to pass through the Atotxa station, which is the current RENFE city center station for San Sebastian. This section will examine the station location issue for San Sebastian to help determine the impact of this decision, what is at stake, and how a station at Atotxa can change the design for the better of the system.

ASTIGARRAGA

The current planned station that would serve the San Sebastian area would be located near the small town of Astigarraga, located about 6 km south of San Sebastian. This alignment will pass close to a major access road that extends north to San Sebastian. The Astigarraga Basque Y station is planned to be located near the current RENFE right-of-way. Astigarraga does not have a stop on the RENFE system, but there are two Lurraldebus bus lines from San Sebastian that serve the town. It currently takes about 15 minutes to drive from downtown San Sebastian to where the Astigarraga station would be placed. A bus from Astigarraga to San Sebastian takes approximately 20 minutes of in-vehicle time. Figure 32 shows a map of the currently planned
network, the Astigarraga station (red), the proposed network, and the Atotxa station (green).

Figure 32: Map of Astigarraga and the Basque Y Alignment

Figure 33 shows the first accessibility map for the walking times from the Astigarraga station. The map clearly confirms that walk access from Astigarraga is not going to be an option. Only a small amount of jobs and people are in Astigarraga, which is still a considerable walk from the proposed station. Table 15 shows the results of the overlay analysis in 5 minute bands.
Currently two Lurraldebus lines serve the area near Astigarraga. The current transit network shows a significant improvement over the walking time, but it still puts most of the metropolitan area out of reach of a reasonable access and egress time. Figure 34 shows the accessibility map of the Astigarraga station using the current transit network. The overlay analysis results, shown in Table 16, show little improvement over walking for the 20 minute access.
Much of the San Sebastian metro area, however, is accessible by automobile. The roads and expressways make most of the area drivable in of less than 25 minutes. This might be fine for people living in San Sebastian that have a car, but anyone visiting the city must take an expensive taxi or time consuming public transportation trip.

The analyses of the walk access and current transit access show that getting to and from the Astigarraga station will be challenging without an automobile. However it is possible that RENFE could construct a new station near the Basque Y station at Astigarraga to enable a shuttle service that uses the current Cercanías route. An
example of this integration will help illustrate the difference between Astigarraga and a potential city center station.*

Figure 35 shows transit times from Astigarraga assuming a new station on the RENFE Cercanías rail line. For this model, a new RENFE Cercanías station is constructed alongside the Basque Y station in Astigarraga. This is convenient as the current RENFE tracks will pass very close to the proposed alignment. The RENFE system will serve as a shuttle that can move passengers north and east, passing through Atotxa in central San Sebastian and ending in Irun. At the same time another shuttle will go south toward Tolosa. In addition, the shuttle system was modeled so that the transfer walk to and from the Basque Y station was only two minutes and the waiting time was only 5 minutes, which is assuming the shuttle is coordinated with the operations of the Basque Y.

*An example and a better explanation of the impact of the coordination of services are in Section 5.3.
The RENFE shuttle service greatly improves transit accessibility for the San Sebastian area. Table 17 shows the results of the overlay analysis for transit accessibility using the shuttle service. There is a large increase in accessibility after 10 minutes, which is about the time that it takes for a passenger to arrive from Astigarraga to Atotxa. However, the business traveler or commuter coming to San Sebastian is forced to take this shuttle to access the city core. To access points further than Atotxa will require yet another transit trip and more travel time. The transfer penalty, as described in Section 3.6.2, will be at least an additional 10 minutes of perceived travel time for each transfer. Even with an integrated rail shuttle service, the Astigarraga station quickly erodes the benefit of the high speed system. Although further coordination with the Lurraldebus lines at the Astigarraga station might make for more access by transit, it is likely that the Astigarraga station will not be a convenient destination for frequent travelers.

<table>
<thead>
<tr>
<th>Astigarraga Transit Coordinated Shuttle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minutes</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>20</td>
</tr>
</tbody>
</table>

*Table 17: Astigarraga Station Coordinated Shuttle Access*

**ATOTXA STATION**

The current San Sebastian main station for intercity rail, Atotxa, serves long distance trains from the border town of Irun that continue south to Madrid. Atotxa is located across the river from the downtown area and it also serves RENFE Cercanías for the province on the same tracks. Figure 36 shows the city and the rail alignment. Most of the core of San Sebastian is easily accessible by car or taxi, and like Vitoria and Bilbao, the analysis will include accessibility maps for walking and public transit.
Atotxa has excellent walk access with many opportunities within the 20 minute boundary. Figure 37 shows the accessibility map from this station, with most of the city core within the 20 minute green band. The overlay analysis in Table 18 shows that the opportunities increase significantly after a 5 minute walk, which is the time needed to cross over the river.* However key destinations such as the Basque University at Ibaeta and the large "Residencia" hospital complex in the southern part of the city are outside of the range of walking. The efficient transit network serves these destinations as seen in the next example.

* The overlay analysis for Atotxa station has a small modification over the Bilbao and Vitoria analyses. In this analysis, 6 minutes was used for the first band (instead of 5 minutes) because of the average time to reach the first major census district was slightly over 5 minutes. This makes little difference in the comparisons, but it is worth noting this difference.
The transit system improves on the walk accessibility provided by the Atotxa location. The transit accessibility map, shown in Figure 38, shows a great improvement in access between 10 and 20 minutes. Like the transit access maps in Bilbao and Vitoria, the 10 minute (blue) range is mostly unchanged due to the fact that most of these short trips will be made on foot. The estimates are based on the current transit network as it exists today. Table 19 shows the overlay analysis for the first 20 minutes by transit.
Figure 38: Atotxa Station Transit Times (minutes)

<table>
<thead>
<tr>
<th>Atotxa Current Transit Time</th>
<th>Minutes</th>
<th>Jobs</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6</td>
<td>1536</td>
<td>3402</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>12325</td>
<td>17532</td>
</tr>
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<td></td>
<td>15</td>
<td>27678</td>
<td>50166</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>41379</td>
<td>92320</td>
</tr>
</tbody>
</table>

Table 19: Atotxa Station Transit Accessibility

Figure 39 and Figure 40 show a graphical representation and comparison of the walk and transit accessibility. Unlike the Astigarraga case, these figures are given without modification to the current network. As will be seen in Section 5.3, the integration and coordination of services in San Sebastian show potential for significant improvements in accessibility.
**Atotxa Station Walk Time**

**Atotxa Station Transit Times - Current System**

*Figure 39: Graphical Representation of Atotxa Walking Overlay Analysis*

*Figure 40: Graphical Representation of Atotxa Transit Overlay Analysis*
ASTIGARRAGA VERSUS ATOTXA

A direct comparison between the two San Sebastian station locations is greatly facilitated using the above analysis. Figure 41 shows the walk access from the Atotxa, while Figure 42 shows the transit access from Astigarraga under highly coordinated systems. This analysis does not take into account the transfer penalty or the cost of the system to the user or the operator, which would further limit the Astigarraga access if it were included in those times. Even with the expense of implementing and coordinating a shuttle using the existing Cercanías track, the walking time from Atotxa by itself provides better access than Astigarraga.
Figure 41: Graphical Representation of Atotxa Station Walk Access

Figure 42: Graphical Representation of Astigarraga Station Coordinated Shuttle Access
Especially for users that are destined for jobs or businesses in the downtown San Sebastian area, the Atotxa station makes sense. Users are not forced to transfer to reach their destination and they walk off the train with a sense of arrival. The Astigarraga is planned to be the high speed rail gateway for the province of Gipuzkoa. A “gateway” that is not accessible to opportunities is a poor entrance to a city thus not making it an attractive destination. The accessibility gains provided by extending the line to and through San Sebastian make the effort to move the station worthwhile. As can been seen in the case of Tarragona, it is quite possible that most trains would pass Astigarraga to serve other destinations in Spain and France.

5.2.4 LAND DEVELOPMENT

One of the important aspects that an HQR system brings is the potential for land development. Due to the high land values associated with high access, construction of housing and offices are common near rail stations. Land development is an important part of accumulating the economic growth associated with transportation improvements. Many argue that an advantage of peripheral locations is that there is ample land for development, which is not the case in city centers. This section will show how city centers still can offer land development opportunities by taking advantage of the air rights found above rail yards near the station. This is more costly than surface buildings due to the need for additional structural supports, but it takes advantage of this prime real estate location.

The San Sebastian Atotxa station will be the example used in this section. Images from Google Earth show the station and provide measurements of the area above the track as shown in Figure 43. This measures 18,000 m² of developable space in the immediate vicinity of the station. It is possible that a portion of these air rights will be used for expansion of the station, a potential intercity bus terminal, or a parking garage, which could amount to an estimated 3000 m² of space taken by these uses near the station leaving 15,000 m² for development.
A San Sebastian city center station is likely to attract commercial and office development because of the high business accessibility the Basque Y and the other transit connections provide. In Europe, the average office space needed per employee is around 25 m² (Meel, 2000). If the entire 15,000 m² area over the tracks is developed at this level, then it could provide space for 600 jobs per story of development. Even if a set of modest five story office buildings are constructed, this represents space for over 3,000 employment opportunities.

<table>
<thead>
<tr>
<th>Location</th>
<th>M²² per Employee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central London</td>
<td>16.8</td>
</tr>
<tr>
<td>Frankfurt</td>
<td>25.5</td>
</tr>
<tr>
<td>Amsterdam</td>
<td>24.0</td>
</tr>
<tr>
<td>Brussels</td>
<td>24.0</td>
</tr>
</tbody>
</table>

*Table 20: Average Office Space Per Employee (Meel, 2000)*

This land is likely to be in high value due to its excellent transit access and close proximity to the San Sebastian city core. All of the jobs located in this area will be within a 5 minute walk from the station. For the businesses, their workers will
have easy access to the local transit system and the Basque Y. This makes regional and long distance trips easy and highly productive. In addition businesses located here can attract employees from the entire Basque Country. This new development can complement and benefit from the businesses already located close by in central San Sebastian. Although Astigarraga could develop the land around the station, the potential for this land is not high. Astigarraga is likely to receive service comparable to the Tarragona HSR station, where only one of three passing trains stop. The access to high volumes of people is already present at Atotxa and the Basque Y will only increase this. Taking advantage of these high land values is not unique. There has been a trend toward building offices over the tracks near stations in many cities including Paris, New York, Lille, and even Boston under current plans. The example is also demonstrated locally by plans in the small city of Irun, Gipuzkoa.

5.2.5 STATION PARKING

Parking at a central station, whether it is for the trains or for the development around it, is an important issue to consider. Many authors mention that the automobile is an important access mode to serve at a rail station. But the amount of provisions given to parking spaces should vary based on the need and the opportunity cost of providing it. The Madrid Atocha station, a well connected, centrally located station, offers less than 1000 spaces for the 30,000 long distance passengers that use it daily (Leber, 2011) (RENFE, 2010). San Sebastian Atotxa, with its high connectivity and central location, should only require minimal parking spaces as well.

It is also probable that for the frequent, regional trips there will be less of a need for parking. A commuter will be more apt to take transit because of the low cost and high quality of the local systems in the Basque cities. In any case, whatever limited parking capacity is available is likely to be predominantly used by longer distance travelers to destinations such as Madrid or by short term use for drop off or pick ups. For these trips, the parking costs will be a relatively small portion of the higher cost, infrequent
trips. As mentioned before, the practice at Spanish HSR stations is to provide very limited parking supply compared with the traffic volume. Bilbao Abando and the Valladolid station supply less than 120 spaces each. Because of the central location, high transit access, and high walking access of these stations, other access modes make sense. Any parking available may also be in competition with the needs of the businesses that are located near the station as well. But the high transit and walk accessibility might lessen the requirements needed to support these businesses. In some cases, such as Barcelona, some private businesses may provide some parking in response to perceived demand. But such privately provided parking can be converted to a more productive use as real estate values rise over time.

5.2.6 INTERMODAL INTEGRATION AT STATION

Intermodality is going to be a large part of making a city center rail station work. The focus of Section 5.3 is intermodality, but provisions for this at the station are important. Physical integration in terms of station placement and route alignment for local transit modes will help enable the higher level integration of fare system, information, and scheduling. Therefore, bus terminals should be located at or within the HQR station if at all possible. Bus terminals can share amenities with the rail stations to save costs. These intercity bus connections help to mitigate the shadow effect and increase access to smaller cities that do not have a Basque Y stop. Important local bus lines can be modified to ensure they pass by the main station. Retaining a traditional city center location ensures that the same station also serves the existing local rail system. When different modes share a single station, the system is easier and faster for the user to navigate. The operators also benefit by sharing the costs of facilities and encouraging transfers. These planning aspects should be an essential part of the station design.

5.2.7 STATION LOCATION SUMMARY

In summary, the city center station locations show clear benefits over peripheral stations. The San Sebastian placement issue makes this obvious. Even an expensive,
highly coordinated RENFE shuttle system* from the Astigarraga station is still not as efficient and convenient as walking from Atotxa in terms of access to opportunities.

The most important aspect of a city center location is the convenience given to the destination traffic. It is one thing for a resident of San Sebastian to drive or take a bus to the Astigarraga station to access a job or business contact in Bilbao or Vitoria. It is another for a user coming to San Sebastian and arriving in Astigarraga without a car to take a taxi or rent a car to access the city core. An occasional traveler or a tourist might tolerate this but it is not an attractive option for a frequent user. If San Sebastian wants to take advantage of the economic potential of the Basque Y it is important to serve the needs of the users coming to the city in a convenient way. People and businesses from Bilbao and Vitoria will come to San Sebastian and boost the local economy if the transportation network encourages them to do so. The Atotxa station permits excellent regional access for a business that is looking to locate an office. The natural beauty of the city is an added bonus for a business that is interested in giving employees and associates access to the amenities in Gipuzkoa. The Basque Y station will be the “gateway” to Gipuzkoa and should be planned as such. Ensuring that the station is located in the city center is going to make San Sebastian attractive for businesses.

In addition, a city center location adds to the sustainability of the network. If the three Basque capitals place stations in the city centers, then there will be a sharing of flows between them, not a one-way commuting network where one city dominates the job market. Not only will this help each city develop a strong business core, this will also help to ensure that the trains have balanced and even flows in all directions. This will also help build overall ridership, which can increase frequencies and reduce costs. In the long run, the higher demand for traffic will ensure that long distance trains stop at the city, as seen in the Puertollano case on the Madrid – Sevilla line.

* Assumed in the analysis as possible mitigation for the inconvenient location.
The location of the San Sebastian station is critical for the other Basque cities as well. Table 21 shows the accessibility from Atotxa, Astigarraga, Bilbao, and Vitoria. Using a Basque Y intercity travel time of about 35 minutes, one can approximate the number of intercity opportunities accessible within a time threshold. For example, a 60-minute time threshold gives the 12,000 jobs within 10 minutes of Atotxa access to 58,000 jobs in Bilbao and 7,200 jobs in Vitoria. For the Astigarraga station, the San Sebastian jobs are limited to only 3,300 for this threshold. The Atotxa station is vital in order for Bilbao and Vitoria to take advantage of the increased access to broader labor and service markets.

![Table 21: Transit Accessibility in the Basque Country (Current System)](image)

The essential reasoning behind a city center location is access. From Figure 44 the difference between Astigarraga and Atotxa is clear. The chart is a plot of the cumulative population, which is a representation of city activity and increasing distance. After a distance of 7 or 8 km from either station, the accessibility is essentially equal. The difference is within the first few kilometers. A user must travel at least 4 km away from Astigarraga before significant increases in city activity begins. The central location of Atotxa takes advantage of this urban density immediately. Similar graphics using distance versus jobs, transit lines, or any other trip attractor or generator provide similar results.
5.3 INTERMODAL INTEGRATION

Once a station is planned for a central location, the next step in creating an HQR network is the integration with the local transit modes in each city. The focus of this section will be the needed steps and the potential benefits from transit integration. Transit integration offers inexpensive, efficient, and high capacity movement around a city to areas that are not within walking distance of the station. Integration between intercity rail and local transit involves activity in the following three basic fields:

- Physical (Spatial) Integration
  - Local bus lines with stops immediately outside of the station
  - Regional rail and bus services housed in the same location
- Operational Integration
Schedules coordinated so that waiting times for trains and buses are minimal

- System Integration
  - The sense that the passenger is using one, unified system even if there are multiple operators
  - Ticketing, fare structure, and user information are from one single source

This section will use the Basque province of Gipuzkoa and its capital of San Sebastian as a case study for integration. This section assumes that the correct decision is made to place the Basque Y station in central San Sebastian at Atotxa. Many transit lines already serve areas around the Atotxa station but comparatively few serve the Astigarraga area. Integration at that location would be much more difficult to implement, especially due to the unattractiveness for public transit as an access mode for Astigarraga. Therefore, integration opportunities are inherently better at Atotxa.

This section will also show how integration can mitigate the shadow effect, as described in Section 3.4.

5.3.1 Physical Integration

The station location section (Section 5.2) already discussed the physical integration of the transit networks in some detail. The physical integration of the Basque Y and the local transit systems are important in each city. A city center station operating out of the existing rail station allows for local trains to operate out of the same location. In San Sebastian, the Basque Y and the RENFE Cercanías will be automatically integrated physically in the case of choosing the Atotxa location.

Intercity bus service can also operate out of the same station. In many cities, intercity bus terminals are located close to, on top of, or within rail stations. This allows for passengers in the surrounding area to have direct access to the regional and long distance rail network. In San Sebastian, there are plans to move the intercity bus terminal from its existing location to a site near the Atotxa station. In this case, it
would be best to plan so that the stations for both the trains and the buses are housed so that amenities such as waiting areas, restrooms, luggage lockers, and other operational services could be shared rather than duplicated. This reduces costs for the operators and greatly increases convenience for the passengers.

Physical coordination between the local bus and rail routes is also advantageous for efficiently moving passengers to and from where they need to go. In Switzerland, for example, there are multiple bus and trolley bays immediately outside of most stations. A user does not have to walk far to transfer between the rail and the local transit system. A city center station is again advantageous in this respect because many transit lines already serve the main rail station. It is also likely that many transit lines run very close to the station and a slight route modification enables them to serve the station directly.

The benefits of physical integration help all transit users whether they are planning on accessing the rail station or not. Close proximity to local modes of transit encourages travelers to use those modes rather than taking expensive taxis, drop offs, or walking for a long distance. In turn, this increases the ridership on these routes because a rail station is going to attract and generate riders who need access. Increased ridership allows operators to increase frequencies, reduce costs, or both. This is taking advantage of the intrinsic high capacity and high efficiency nature of transit. Unlike more users on the road network, which causes congestion, typically more transit users results in a more frequent and less expensive system in the long run. The feeder systems will be complementary, not competitive, with the Basque Y so they all benefit from this integration.

5.3.2 OPERATIONAL INTEGRATION

With many transit lines sharing a similar node on the network as described in the previous section, it is now possible to organize the operators and coordinate schedules in order to minimize the waiting times for transfers. This approach is used in many parts of the world and refers to “timed transfer” or the more powerful “pulse
A timed transfer is where two or more transit lines are coordinated to stop at a single point at the same time on the schedule. A pulse is typically at a clockface interval (hh:00 or hh:30) and all of the modes are made to arrive and depart before and after the pulse time. For example, if an intercity train is going to arrive at 12:00PM, the local trains and buses can be organized according to the “pulse” to arrive a few minutes before 12:00 so that the passengers can walk into the station and prepare for the train journey. As the train arrives, the local modes of transit hold at the station. The local passengers board the train while the arriving passengers alight. The intercity train then leaves while the arriving passengers walk to the waiting buses and local trains. A few minutes after the intercity train leaves, the local transit system can leave with the new passengers.

*Figure 45: Pulse Scheduling at Atotxa Station*

In San Sebastian, a coordinated system could be implemented at the Atotxa station. Figure 45 gives an example on how a coordination system might work for the Atotxa station in San Sebastian. This pulse schedule includes:

- The Basque Y – intercity rail
- RENFE Cercanías – Commuter and local rail
• Donostiabus – Local bus network
• Lurraldebus – Intercity bus

In this case, passengers could transfer between any mode whether they are using the Basque Y or not. The station would not simply be the Basque Y station, but it would become the transportation hub for all the transit modes in the provincial capital.

At these intermodal hubs it is important to remember in planning that many passengers could be continuing through and not transferring. Ensuring that the waiting times are minimal will help to ensure that existing passengers can retain their one seat ride without much delay. In some instances, high frequency routes, such as key bus routes in San Sebastian, have high enough frequencies that holding at the station may not be necessary. If another bus is due to arrive in 5 minutes, then it does not make sense to hold the bus for new passengers as they can simply take the next bus that arrives.

The following paragraphs show how operational integration of systems can greatly increase the accessibility of the network by reducing waiting times for passengers. Figure 46 shows the travel times using the current transit network without modification. These are the expected times needed to access the city from the Atotxa station today. Each color represents a 10 minute band. The transit access around the city core is high, but there are lots of significant job and population markets that lie outside of the 20 minute band. The next example shows how a coordinated system improves access to these other key areas.

* Includes other intercity bus operations that are not included in the Lurraldebus system.
A pulse schedule would be simple between the Basque Y and the RENFE Cercanías with the station physically integrated. Figure 47 shows the accessibility map with this coordination. In the model the maximum waiting times for the Cercanías lines were reduced to 5 minutes. This demonstrates the ability for a passenger to walk across the platform and board a waiting train. The benefit of this coordination is impressive. In Figure 47, areas of blue (under 10 minutes of time) appear at the nearby Cercanías stations as seen at F-5 and E-2 and F-2. The downtown area is mostly unchanged, but the nearby stations show significant improvement in these areas. Results of the overlay analysis, Table 22, show a 25% increase in transit access to residents and 20% increase in access to jobs within 20 minutes as compared with the system as it exists today.
To further the integration, key bus routes on the Donostiabus system can be modified. There are three major bus routes in the Donostiabus system that operate on 5 to 8 minute headways.* Routes #5, 13, and 28 serve key destinations in the West, East, and South, respectively. These routes can be modified slightly to enable them to pass by the Atotxa station. To incorporate this change a local one-way street would need to be converted to enable two-way traffic. This street does not see much traffic so this change may be reasonable for application. It is possible that there is a better solution to serving the station, but this is an illustrative example on how a simple modification of three bus routes can significantly increase local accessibility. This scenario includes the integrated Cercanías system from the previous example. This modification helps to increase the 20 minute access band to include 40% more residents and 25% more jobs than the existing transit system.

* Of course a connection to the Basque Y will likely increase ridership and this frequency could increase to an even higher level in the future.
Figure 48 shows the results of this change. There is a large improvement in the 10 to 20 minute band (green) in areas that are not served by the coordinated Cercanías system. These areas include the western area with the Ibaeta Campus of the Basque University (B-4) and the southern area by the "Residencia" hospital and Miramón areas (E-6).

![Figure 48: Atotxa Station Transit Times with Integrated Cercanías and Donostiabus (minutes)](image)

Table 22 and Table 23 show the overlay analysis results of the approximate amount of employment and residences within the 20 minute time threshold. Table 22 shows the current accessibility compared with the total values due to the integration as illustrated in Figure 47 and Figure 48. Table 23 shows the absolute increases in accessibility from the current system.
Table 22: Transit Accessibility from Atotxa Station Resulting from Integration

<table>
<thead>
<tr>
<th>Minutes</th>
<th>Current Transit Access</th>
<th>Integrated Cercanias</th>
<th>Integrated Cercanias and Donostiabus</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1536</td>
<td>3402</td>
<td>1536</td>
</tr>
<tr>
<td>10</td>
<td>12325</td>
<td>17532</td>
<td>14179</td>
</tr>
<tr>
<td>15</td>
<td>27678</td>
<td>50166</td>
<td>30287</td>
</tr>
<tr>
<td>20</td>
<td>41379</td>
<td>92320</td>
<td>48946</td>
</tr>
</tbody>
</table>

Table 23: Accessibility Increases as Compared with the Current System

<table>
<thead>
<tr>
<th>Minutes</th>
<th>Integrated Cercanias</th>
<th>Integrated Cercanias and Donostiabus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jobs</td>
<td>Population</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>1854</td>
<td>3220</td>
</tr>
<tr>
<td>15</td>
<td>2609</td>
<td>10142</td>
</tr>
<tr>
<td>20</td>
<td>7567</td>
<td>23006</td>
</tr>
</tbody>
</table>

These examples of integration are simple and inexpensive. They require little modification to the network and almost no cost in infrastructure. These two basic integration techniques bring over 10,000 additional jobs and over 35,000 additional people within 20 minutes of the station. Coordination with the Lurraldebus and Euskotren systems has the potential to augment this increase further.

Enabling such a system would be much more difficult at Astigarraga. There are two Lurraldebus lines that pass through the city and these could be rerouted to serve the station. Also, a new station could be constructed along the RENFE Cercanías right-of-way that could serve as a shuttle. But the transit options are very limited. The city core, which is walk accessible from Atotxa, would require a transfer and access to any other part of the city would require two transfers at least. This completely degrades the benefit of a rail system that can bring passengers directly to the heart of the city. The rail and bus lines that already pass nearby Atotxa make this station ready to become an intermodal hub.

In addition, the coordination of transfers delivers a large improvement in the quality of the system with respect to user comfort and convenience. As discussed in Section 3.6.2,
the addition of a transfer adds a "transfer penalty" onto the disutility perceived by the passenger. The need to transfer adds uncertainty, inconvenience, and anxiety to the trip and therefore increases this disutility. The transfer experience at a high quality timed transfer is substantially less unpleasant than the normal experience. Reducing this additional trip "cost" increases the overall quality and will encourage more riders.

The integration of the operations can also help to mitigate the shadow effect. In the province of Gipuzkoa, smaller cities like Tolosa, Beasain, and Zumarraga will lose the direct long distance rail service to and from Madrid that is currently provided by RENFE. The service to Madrid takes approximately five hours today and two trains per day make the trip. The loss of this service can be mitigated by the coordination of the Cercanías services with the Basque Y. For example, a user from Tolosa can take a 20 minute train on the existing tracks to Atotxa station and walk to a train bound for Madrid. The resulting travel time could be well under 3 hours between Tolosa and Madrid, which is an overall reduction by two hours even with a transfer. The Basque Y will likely increase frequencies and add to the number of destinations that rail users from these city can access, including areas in France. With the coordination of these services, the entire province sees an improvement in the quality of the service.

This mitigation of the shadow effect is theoretically available to Astigarraga as well. But the Astigarraga station poses two problems in this respect. First by moving the station to Astigarraga the city of San Sebastian itself then becomes part of the shadow effect. Also, this mitigation would require that the high speed trains actually stop to serve the station. As evidence in Tarragona, in comparison with Puertollano, there is a significant risk that many trains may not stop at a poorly accessible station such as Astigarraga.*

Figure 49 shows the accessibility map for portions of the province. The importance of this coordination is highlighted in the accessibility provided to the smaller cities. Irun

* See the Tarragona/Puertollano example on page 50.
and Tolosa (B-6) stations are shown to have rail access to Atotxa in about 20 and 30 minutes respectively. These times could be further improved by running express trains from these cities to Atotxa. Figure 49 also shows the disadvantages of un-integrated systems. The east-west commuter rail system of Euskotren has a station in San Sebastian, but it is about 1 km away from Atotxa. This puts the Euskotren service at a disadvantage for accessing the Atotxa station for intercity rail services. The small city of Zarautz (A-2.5) has a Euskotren station but the lack of integration does not bring the city within 60 minutes of the Basque Y. That is why it would be advantageous for the region to consider methods for integrating this service to have better connectivity to the other modes. A simple coordination with Lurraldebus using a new bus terminal at Atotxa could greatly improve the access for small cities like Zarautz and Zumaia.

Figure 49: Cercanías Coordination and the Shadow Effect

With a centrally located station, many operational integration techniques are easy and very effective. These improvements can be furthered by an integration of the entire system so that the travel experience is truly seamless. The next section will discuss the advantages and ways in which to go about this.
5.3.3 System Integration

The system level is the highest order of integration and can take the most amount of work. Users feel as though they are using a single, unified system even if there are multiple operators. Ticketing, fare structures, and user information should all be from one source. The Swiss have mastered this with their travel pass card. Using this system, a user can buy a daily, weekly, monthly, or even annual pass that is valid on all forms of transit within a specified zone. Some passes include access to all transit in the entire country. A user can then take a bus or a trolley to the station, walk on to an intercity train, and then take a ferry or connecting train to reach his final destination. All of these transfers are enabled without the need to have multiple fare cards or tickets. The Swiss manage to do this with hundreds of individual transit operators. All of the user information is provided on unified maps. This cohesive system is easy and comfortable for the user because it takes the confusion out of navigating multiple systems.

Gipuzkoa has already started this high level integration. In 2006, the intercity bus operators were integrated under the Lurraldebus brand (Laidig, 2010). Since then, bus operators have a similar brand colors, unified passenger information systems, and a single fare system. Figure 50 shows the Lurraldebus smartcard, which is now accepted on Lurraldebus, Donostiabus, and the local bus networks of other provincial cities such as Irun and Hernani. This represents the first step toward unifying more of the transit operations in Gipuzkoa and eventually the Basque Country.

* As the printing of this thesis, an agreement was reached for the Lurraldebus card to be accepted on the local RENFE and Euskotren systems in Gipuzkoa in the near future.
But implementing such a system is easier said than done. Ensuring that all operators can cooperate and settle disputes over revenues can be challenging (Gomez, 2010). It would be ideal for the region to work toward a unified system. A user in Vitoria could buy a fare card that would be valid for all of the modes in Vitoria and San Sebastian, including the Basque Y. This unified system could greatly ease the everyday commute between the cities. Places like Switzerland show that it can be done and that this does not only unify the systems for easier use, but it helps to solidify the identity of the region.

5.4 FARES, FREQUENCIES, AND SCHEDULING

This section looks at some of the operating practices for a regional rail system, specifically the Basque Y. In particular it looks at the fares, frequencies, and scheduling of such a system in terms of what to expect and what is practical. An examination of the fares and frequencies of the current RENFE system serves as a direct comparison for what to expect. The system is further compared with the systems in countries like Switzerland to draw parallels to determine what is necessary and practical for a successful functional region.

5.4.1 FARES

This section will examine the current RENFE fare structure and determine whether the expected fares are affordable for frequent rail travel on the Basque Y. It makes
sense to start with the national rail operator, as they are most likely to be operating trains on the network. It is possible for other operators to run trains on the infrastructure, so if the region determines that they need or want a better system than RENFE is willing to provide, then they have the capability to run trains themselves.

RENFE prices their long distance services proportionally to the distance between cities to ensure equity among the different routes in Spain (Minayo de la Cruz, 2010). Figure 51 shows the relationship between fares and distances for a select sample of city pairs in Spain (RENFE, 2010). Vitoria, Bilbao, and San Sebastian are approximately 350km, 400km, and 420km from Madrid respectively.

![RENFE Fares and Distances for Select City Pairs](image)

*Figure 51: RENFE Fares and Distances for Select City Pairs*

From this graphic, estimates of the fares between each city and Madrid are:

- Vitoria – Madrid €60
- Bilbao – Madrid €68
However cities with similar distances of 100 km such as Madrid – Toledo and Madrid – Segovia have regional HSR services that fall below this trend line. These cities enjoy one-way fares of €10, with frequent user discounts as low as €4 per trip (Basque Government, 2008). From this comparison, the Basque Y could realistically have a fare structure such as the following:

- San Sebastian – Bilbao  €10, frequent discount €4
- San Sebastian – Vitoria  €10, frequent discount €4
- Bilbao – Vitoria  €8, frequent discount €3

It is important for the Basque Country to make the case that the Basque Y is not a long distance HSR service. The high quality aspects and the potential for frequent commuting, business, and leisure trips make it closer to the Cercanías system than the AVE. The Cercanías enjoy broad governmental subsidies and RENFE has recently campaigned for more government funding to run these regional HSR services (Minayo de la Cruz, 2010). This is good news for the Basque Country as €4 fares are reasonable to expect for a daily commute or frequent intercity trips of other purposes.

5.4.2 FREQUENCIES

In order to gain the economic and social benefits of an HQR system, trains must be frequent enough to compete against the automobile. At the same time it is important to ensure that trains are not running so frequently that only a few seats are filled. This section analyzes the operational headways of long distance and regional services. It is important to start to examine the infrastructure as to what is expected and then show what additional service, if any, is needed to encourage economic cohesion.

The expected frequencies for the Basque Y are first analyzed from Madrid. ADIF, the Spanish national rail infrastructure company, is currently building the Basque Y infrastructure as an extension from Madrid. With this in mind, it is expected that the
primary planned operating goal is then to run trains between Madrid and the Basque Country. A comparison with existing RENFE service can help evaluate the current practice when attempting to predict the service headways on the Basque Y and the HSR link from Madrid.

RENFE is a public corporation that runs the entire HSR network in Spain. The operations are demand responsive where a base service is provided at the initial opening of the line and then it is gradually increased following increased demand (Minayo de la Cruz, 2010). The current RENFE high speed trains have capacities between 300 and 400 passengers. For reference, Figure 52 shows a map of the current Spanish HSR network.*

![Figure 52: The Spanish HSR Network](image)

A comparison with other city pairs in Spain can help determine what to expect for service to the Basque Y. Table 24 shows operational frequencies, given in trains/day, according to the RENFE schedules (RENFE, 2010). Madrid is central to the HSR

* The map was taken from Wikipedia.org
market and all of the lines radiate out from this capital city. Evaluating the timetables from Madrid gives an idea as what to expect from the start. Although there are some skipped hours in off peak time periods (mid-day) RENFE does operate many of its trains on a regular timetable, meaning that trains depart on the same minute each hour.

<table>
<thead>
<tr>
<th>Origin</th>
<th>Population</th>
<th>Destion</th>
<th>Population</th>
<th>Distance (km)</th>
<th>Trains/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Madrid</td>
<td>3256000</td>
<td>Toledo</td>
<td>82000</td>
<td>80</td>
<td>11</td>
</tr>
<tr>
<td>Madrid</td>
<td>3256000</td>
<td>Guadalajara</td>
<td>83000</td>
<td>60</td>
<td>13</td>
</tr>
<tr>
<td>Madrid</td>
<td>3256000</td>
<td>Zaragoza</td>
<td>674000</td>
<td>310</td>
<td>18</td>
</tr>
<tr>
<td>Madrid</td>
<td>3256000</td>
<td>Cordoba</td>
<td>328000</td>
<td>400</td>
<td>34</td>
</tr>
<tr>
<td>Madrid</td>
<td>3256000</td>
<td>Sevilla</td>
<td>703000</td>
<td>530</td>
<td>22</td>
</tr>
<tr>
<td>Madrid</td>
<td>3256000</td>
<td>Malaga</td>
<td>568000</td>
<td>540</td>
<td>12</td>
</tr>
<tr>
<td>Madrid</td>
<td>3256000</td>
<td>Valladolid</td>
<td>318000</td>
<td>200</td>
<td>13</td>
</tr>
<tr>
<td>Madrid</td>
<td>3256000</td>
<td>Barcelona</td>
<td>1622000</td>
<td>610</td>
<td>27</td>
</tr>
<tr>
<td>Madrid</td>
<td>3256000</td>
<td>Tarragona</td>
<td>140000</td>
<td>540</td>
<td>8</td>
</tr>
<tr>
<td>Madrid</td>
<td>3256000</td>
<td>Ciudad Real</td>
<td>74000</td>
<td>210</td>
<td>25</td>
</tr>
<tr>
<td>Cordoba</td>
<td>328000</td>
<td>Sevilla</td>
<td>703000</td>
<td>140</td>
<td>30</td>
</tr>
<tr>
<td>Cordoba</td>
<td>328000</td>
<td>Malaga</td>
<td>568000</td>
<td>160</td>
<td>17</td>
</tr>
<tr>
<td>Ciudad Real</td>
<td>74000</td>
<td>Puertollano</td>
<td>52000</td>
<td>40</td>
<td>23</td>
</tr>
<tr>
<td>Burgos</td>
<td>179000</td>
<td>Valladolid</td>
<td>318000</td>
<td>120</td>
<td>9</td>
</tr>
<tr>
<td>Madrid</td>
<td>3256000</td>
<td>Vitoria</td>
<td>236000</td>
<td>350</td>
<td>2</td>
</tr>
</tbody>
</table>

Population within city limits, 2009
Renfe Schedule Dec 1 2010

Table 24: Current RENFE Operational One-way Frequencies Between Select Spanish Cities

For a normal weekday, a typical span of service from 6:00AM until 9:00PM encompasses 15 hours. This means that frequencies of about 15 one-way trains per day are approximately hourly service. With a few exceptions, the cities on the network get at least this hourly service. Frequencies are evaluated in one direction. It is assumed that the same number of trains will operate in the opposite direction. Zaragoza and Sevilla, for example, get 1 train per hour from Madrid all day with a few extra trains in the morning and late afternoon peak times. Barcelona has trains leaving and arriving from Madrid every 30 minutes. Cordoba, which is the last station before the line splits between Sevilla and Malaga (See Figure 52), gets a train every 30 minutes as base service with one extra train per hour during the morning and late afternoon peak times.
Another important examination of service is to look at the frequencies on the HSR lines, not just city pairs. Table 25 shows the frequency (trains/day), travel time to the farthest city, and the cumulative population of the cities connected on the lines. Both the Barcelona and Sevilla/Malaga line get at least 2 trains per hour and the shorter, and less populated, Valladolid line has 1 train per hour. The Valencia line opened in December of 2010 and currently receives 16 one-way trains/day, or hourly service.

<table>
<thead>
<tr>
<th>Line</th>
<th>Population</th>
<th>Trains/day</th>
<th>Time to End Stop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barcelona Line</td>
<td>2436000</td>
<td>27</td>
<td>2:40</td>
</tr>
<tr>
<td>Sevilla/Malaga Line</td>
<td>1725000</td>
<td>34</td>
<td>2:30</td>
</tr>
<tr>
<td>Valencia Line</td>
<td>809000</td>
<td>16</td>
<td>1:38</td>
</tr>
<tr>
<td>Valladolid</td>
<td>318000</td>
<td>16</td>
<td>1:05</td>
</tr>
<tr>
<td>Basque Line</td>
<td>1273000</td>
<td>unknown</td>
<td>2:40</td>
</tr>
</tbody>
</table>

Table 25: Population, Time, and Frequency for the Major Spanish HSR Lines

A quick comparison from Table 25 demonstrates that the Basque Y line, which is an extension of the Valladolid line, will receive at least 1 train per hour per direction. There is reason to believe that this may even be a low estimate. If RENFE opens the service with 1 train per hour, it is likely this will grow into more frequent service that compares with other lines with similar populations and equivalent travel times.

However, this does pose questions for the Basque Y. Like the Sevilla/Malaga line where the route splits at Cordoba, trains coming to the Basque Country from Madrid will have to either go to Bilbao or to San Sebastian after they pass Vitoria. Also, the link between San Sebastian and Bilbao could potentially receive low service from RENFE, as it is not connected on a direct route to Madrid. The upcoming paragraphs look at how RENFE might serve the Basque Y.

The Bilbao link is expected to open earlier than the San Sebastian link, so initial service will most likely be hourly to Bilbao. This is consistent with an expectation of ridership for the line. HSR between Bilbao and Madrid is primarily designed to compete against the airlines to provide a better and less expensive service. According to the EMMA 2007 Bilbao Airport travel survey, about 955,000 passengers traveled
between Bilbao and Madrid during that year (AENA, 2010). Assuming that most of these flights were done on work days, the one-way air traffic per day between Bilbao and Madrid – Barajas is about 1500 passengers, or about 100 passengers per hour. The Basque Y is expected to capture almost all of this traffic and it is reasonable to believe that this number will increase due to induced demand resulting from lower costs and trip times. In addition the service will capture many of the long distance auto trips to and from Madrid. Also, ridership between cities along potential routes, such as Bilbao – Vitoria, Burgos – Bilbao, and Valladolid – Vitoria for example, will also add to the demand and help fill those hourly trains.

Once the Gipuzkoa section opens, it will be difficult to remove service from Bilbao and direct it to San Sebastian. Additional service might be added, perhaps once every two hours, through Vitoria to San Sebastian. However it is possible that the connection to France will be important enough to serve Gipuzkoa with one train per hour in each direction. Regardless, as the Tarragona case exemplified, the station location, and therefore the demand, in San Sebastian will determine the actual level of this service.

Assuming that the correct decision is made on the San Sebastian station, it is both possible and realistic that RENFE will eventually serve the Basque Country with two trains per hour: one to Bilbao, and one to San Sebastian and points beyond. But this says little about the Bilbao – San Sebastian service that is not included in the Madrid connection. There is some reason to believe that there will be trains that run between Bilbao, Bordeaux, and Paris that pass through San Sebastian, but it is hard to predict the frequencies of such trains without comparisons since almost all of RENFE’s service corresponds with Madrid.

Nevertheless the schedules do show that RENFE is running high speed trains regionally instead of only from Madrid. The Cordoba – Sevilla link is an example of such regional service. RENFE provides 34 daily one-way trips from Madrid to Cordoba of which 22 continue to Sevilla. However there are 37 daily trips between Cordoba and Sevilla alone, of which 30 are high speed trains (45 minutes) and 7 are Regional
Express (75 minutes). This shows that RENFE does recognize and serve regional HSR demand and might offer some service in the Basque Region that does not correspond with Madrid. Again, service provisions will likely follow demand, so the station location in San Sebastian is necessary to attract this service.

The actual demand for the three links in the Basque Country is still in question. It is outside of the scope of this thesis to make detailed estimates of what to expect for ridership. However, a regional HQR system in the Basque Country could be compared with other, similar systems to get an idea of potential service and riders. A strikingly similar comparison for the Basque Y is the “Swiss Triangle.” The Swiss Triangle is a regional HQR network that connects the cities of Zurich, Berne, and Basel. This is a very close comparison with the Basque Country due to similar city sizes and distances.* Figure 53 shows a view of the Basque and Swiss regions with the exact same scale. Table 26 shows the population of each city within the city limits and the distances between each city.

* Because of their similar distances, the driving times between the cities are very comparable with the Basque Country.
The Basque Y infrastructure will have an advantage over the Swiss in that it is being constructed for high speeds, and therefore train travel times between cities will be much less than in Switzerland. Travel times between the Swiss cities are around 55 minutes while the Basque Y travel times are 35 minutes or faster. However the Swiss do have the advantage of quality and the coordinated, integrated service seems to make up for the lack of speed. But if the Basque Y is able to modify the infrastructure to allow for a fusion of HSR and HQR, then they effectively will have a system that is better than the Swiss. In all, the similarities between the Basque Y and the Swiss Triangle show that the Basque Y can emulate the very successful Swiss system to encourage the regional economic and social stimuli.

Currently, the Swiss run two direct trains per hour between Zurich, Berne, and Basel in each direction averaging about 55 minutes in travel time. Two additional feeder trains stop at the smaller towns along the way that take about 90 minutes and help to eliminate the shadow effect that the direct trains create when they pass these towns. Therefore, the service between these Swiss cities is effectively two trains per hour, and this seems to be enough to satisfy the demands of the region for economic and social cohesion.

The ridership on the direct trains between these Swiss cities is high. It is noteworthy to add that in spite of train travel times not much faster than auto times, the modal split seems to favor the rail due to its high quality features in terms of convenience and seamless transfers. To handle the increasing demand, the Swiss Federal Railways,
SBB, recently ordered a new fleet of 59 bi-level articulated trains with capacities of about 600 seats (Montanaro, 2010). This suggests that the flows between these three cities are around 1000 per hour assuming a load factor of ~80%. The Swiss trains do continue past these cities and connect with regional cities outside of the Swiss Triangle, therefore not all of this ridership is for direct service within the Swiss Triangle. The demand is built up along the line and includes passengers destined for other regional markets including Lausanne, Geneva, the Zurich Airport, and Southern Germany.

It is then reasonable to expect that a well integrated, high quality Basque Y system that includes destinations outside of the Basque Country could have ridership levels at least comparable to those of the Swiss. The current HSR trains run by RENFE have capacities between 300 and 400 passengers. It would be realistic to expect enough demand to justify two trains per hour on such a network. For 30 minute service for 15 hours per day represents about 9,000 daily one-way seats available on each leg of the Basque Y.

Drawing from many sources of demand can reasonably fill these seats. Long distance air service to Madrid is approximately 1500 one-way passengers per day. This does not include the air markets to destinations that can be served in France. Long distance air and automobile trips between markets in Spain and France could supply additional passengers on each leg of the Y. In addition, the Basque Y will likely draw most of the current intercity bus ridership. For example, Lurraldebus currently runs service between San Sebastian and Bilbao at two buses per hour. This service had an average weekday ridership for the month of October 2009 at 2140 passengers (Lurraldebus, 2010). The Basque Y is also likely to take many of the 47,000 daily intercity passengers that take the automobile between the three cities (EuskalYVasca, 2010). Including other regional destinations, such as Burgos, Biarritz, and possibly the Bilbao Airport and Santander can add to the ridership on this service. Furthermore there will be significant induced demand that arises from people choosing to travel on the Basque Y that could not afford intercity auto travel before.
The Swiss system seems to imply that two trains per hour is a minimum reasonable frequency to achieve the economic benefits of a functional region. Switzerland enjoys the benefits of a functional region with many of the cities sharing in economic markets and 30 minute headways seem sufficient to enable such cohesion. Coincidentally RENFE has shown willingness to run regional HSR service that does not correspond with Madrid, as shown in the Sevilla – Cordoba case. It is possible that RENFE could run a similar service, as a regional shuttle, on the Basque Y segments.

The following paragraph shows an example of how a coordinated shuttle service can operate in conjunction with the long distance trains to ensure 30 minute headways on all of the segments. This example assumes 2 long distance trains per hour to and from Madrid, with one train going to Bilbao and one to San Sebastian. A supplemental shuttle service could be run that would ensure that all of the cities receive 30 minute headways between each city and 30 minute headways to Madrid.

A long distance train arriving in Vitoria from Madrid is bound for Bilbao. Those passengers destined for Bilbao remain on the train. For those destined for San Sebastian, a Basque Y shuttle train is waiting for them at the Vitoria station. Both trains depart Vitoria shortly after each other to arrive at their final destinations. This same operation could work in reverse and it could also work for long distance trains headed to San Sebastian rather than Bilbao. It would require a constant 30 minute headway shuttle between Bilbao and San Sebastian, but this could be part of a longer service that connects with cities in France and, in the future, potential connect with the Bilbao airport and Santander to the west.*

From the Swiss comparison it seems as though the 30 minute headway level of service is necessary and able to derive the cohesion benefits. However the Basque Region should not expect RENFE or any agency in Madrid to provide this level of service. If

* A more detailed example of these operations can be found in Section 5.4.3.
the Basque Country wants to enable the functional region, then they must petition for the service they need. This could be done by reasons of equity: Cordoba and Sevilla enjoy frequencies greater than two per hour as do other regional links in Spain. The link between Bilbao and San Sebastian is also likely to be problematic due to the non-direct connection with Madrid but is necessary for the system to function properly. To request this service is not unreasonable but the Basque Region should be prepared to make a strong case. The Basque Y is not a typical HSR service but rather it is part of an HQR network that will involve many commuting, business, and leisure trips that are essential to growing the Basque economy. The Spanish government already recognizes that these kinds of trips are worthy of funding due to the existing subsidies in the RENFE Cercanías system. Arguments on the basis that the Basque Y is more akin to the Cercanías in terms of its use may help to build that support.

Ensuring that the service begins with a minimum of two trains per hour should be a high priority for the Basque Government. The infrastructure is only a few years from completion and there has been little thought into acquiring trains or running service. This demonstrates the importance and urgency to start thinking and planning for service now so the new infrastructure does not end up sitting vacant when completed. There is some possibility that the Basque Region may run part of the service. They might provide some leverage on sensitivity to local needs, particularly the San Sebastian – Bilbao segment, which does not correspond directly with Madrid, but the Basque Provinces should not rely on this. Whether RENFE or the Basque Region provides the service, the Basque Provinces need to insist on Swiss style convenience, reliability, and integration. This is attainable without many of the congestion problems the Swiss have on their dense network due to the fact that the Basque Y will be new, dedicated, high capacity infrastructure.

5.4.3 SCHEDULING

In the Swiss system, the timetable is the most important planning tool so that the infrastructure is designed to meet the requirements of the timetable, not the other way around. The Basque Y, because it is an accidental regional network, must work with
the current infrastructure to create consistent and reliable timetables for the users. However the Swiss approach to creating a schedule still can apply for this network. One of the key aspects of the Swiss timetables that seems to have a very large effect on the quality of service is consistency. For the direct trains on the Swiss Triangle, the trains leave a city on the hh:03 and the hh:33 (for example) on every hour, all day, every day.* Even in the off peak times the same schedule is run so a business traveler or a leisure traveler always knows they can show up at the station at the hh:03 or the hh:33 and there will be a train ready to leave. Building in consistency and reliability is an important part in delivering quality to the user. The following section will examine the operations for the Basque Y and give an example of a reliable and consistent timetable that is coordinated to achieve greater frequencies to the cities for long distance connections.

The first step in scheduling is to examine the network to determine how the system might operate. Figure 54 shows the network as it is currently planned. The blue circles represent stations and the red lines represent the rail network. Stations that have red lines through them mean that trains can operate as a through service. The travel times for the Basque Y were taken from the Basque Y information website and the shuttle service between Astigarraga and San Sebastian is based on an estimate from the RENFE Cercanías system that runs on the existing route (EuskaLYVasca, 2010).

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* This does exclude the late evening and night hours.
Figure 54: Currently Planned Basque Y Network

Figure 54 is a complex network with spurs and dead ends, which could be problematic for creating enough demand on the system to justify the 30 minute headways. The Swiss are able to fill many of their trains on the Swiss Triangle network because it allows for through traffic that helps to build the demand along the line instead of just serving a city pair. The current Basque Y network does not allow for this flexibility. However, a change in the network that allows through trains to access the Atotxa station in San Sebastian greatly simplifies the network, as seen in Figure 55.* Allowing through trains can help build the demand along the line at some of the other stops to ensure higher ridership and the needed frequencies for the route.

* For the network in Figure 55, the same travel times are used between the cities even though the Atotxa station is 6km farther than the Astigarraga station. However without a stop at Astigarraga the additional travel time will add less than 2 minutes onto the trip, so for the purpose of this example the times will remain the same. Table 27 shows the estimated travel times used for the timetabling example
The following is an example of a coordinated timetable that could be implemented on the Basque Y. For the simplicity of explanation, the frequencies on the network are only one train per hour. The timetable could easily be modified for two trains per hour by simply running the same schedule at the opposite side of the clock (e.g. if a train departs at hh:05, then the “opposite side of the clock” is hh:35). Also, this example includes Irun in the network. Irun, which is a small border city in Gipuzkoa, is included to show the benefits of through traffic at San Sebastian. Although small, Irun still holds a significant concentration of jobs and population that could benefit by
inclusion in the Basque Y service. These trains could easily continue past Irun to connect with Biarritz, Bayonne, Bordeaux, and Paris.*

The following is a list of arrival and departure times for each city in the network listed by the segment. These are designed to that the trains will depart consistently at the same time each hour of the day. The listed times are the approximate times for the "pulse schedule" as described in Section 5.3.2.

* Also, Irun has the capacity and the workforce that can store and service the trains when they are not in use. This could be advantageous for the network, as many cities do not have much space in the expensive downtown areas for such needs.
- Bilbao – Vitoria
  - Arrive and Depart Bilbao at hh:00
  - Arrive and Depart Vitoria at hh:30

- Irun – San Sebastian – Bilbao
  - Arrive and Depart Irun at hh:00
  - San Sebastian to Bilbao at hh:15
  - Arrive and Depart Bilbao at hh:00
  - San Sebastian to Irun at hh:45

- Irun – San Sebastian – Vitoria
  - Arrive and Depart Irun at hh:30
  - San Sebastian to Vitoria at hh:45
  - Arrive and Depart Vitoria at hh:30
  - San Sebastian to Irun at hh:15

This schedule is visualized and displayed in Figure 56 and Table 28. It would take five trains to operate this hourly schedule: one train for the Bilbao – Vitoria segment and two trains each on the other two segments. Increasing the frequency to two trains per hour would require ten trains.
Figure 56: Example Schedule for the Basque Y

<table>
<thead>
<tr>
<th>ARR</th>
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<tbody>
<tr>
<td>Bilbao</td>
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<td>Vitoria</td>
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<table>
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</tr>
<tr>
<td>Irun</td>
<td>54</td>
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<table>
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<th>DEP</th>
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</thead>
<tbody>
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<td>SS</td>
<td>08</td>
</tr>
<tr>
<td>Irun</td>
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</tbody>
</table>

Table 28: Example Schedule for the Basque Y

Figure 56 is understood by reading the departing and arriving times at each station for each leg. The Irun – Bilbao segment will be used as an example. A user in Irun would board the train and depart at hh:05. This train would arrive in San Sebastian at hh:14, spend 2 minutes at the station, then departs for Bilbao at hh:16. The train arrives at Abando in Bilbao at hh:54. Any segment could be followed the same way.

Contrary to conventional scheduling this timetable operates best when it is consistent throughout the day. Typically schedules offer more service during the peak commuting times and less service during the off peak hours, directly following the demand. Pulse scheduling requires a regular and consistent timetable all through the day independent of the peak and off peak demand so that passengers can rely on the service to be there
whenever they need it. It is also important to plan for a sufficiently long enough span of service so that users are sure to get a trip home if their work or business runs later than usual. This can lead to high loads during the peaks and low loads in the off peaks, but the Swiss system demonstrates the benefit of such a schedule. Even if a user does not plan on traveling at off peak time, knowing that there is a train consistently leaving during these times gives them more comfort and flexibility in case their plans change: an aspect of convenience similar to that of the automobile.

The power of this schedule lies in the convenience provided to the user and the operator. Any of these trains could be routed as a through train as long as there is one to take its place on the return trip. For example, the hh:01 train from Bilbao to Vitoria could be a Madrid-bound train. In this case, a user in San Sebastian could board the train to Vitoria at hh:46, arrive in Vitoria at hh:20, and be ready to catch the Bilbao-Madrid train as it stops in Vitoria at hh:29. This allows for short, convenient, and reliable transfers to ensure regular long distance service to all of the cities. Also any of these trains could run any of the segments. Again using Vitoria as an example, a train traveling from Bilbao to Vitoria arrives at the Vitoria station at about the same time as the train coming from Irun/San Sebastian. In this case, both trains could reverse and traverse the same route as before, or they could just as easily switch and serve the opposite city. This does not make a difference to the user but could be advantageous to the operator if there is a need to shuttle trains around the network for maintenance.

The intention of this scheduling example is to show the power and versatility of planning such a schedule. But like the fares and frequencies, this is not going to be simply given to the Basque Region. Long range planning and foresight is needed to get this done. The goal is to know what to expect from the status quo and then know what to ask to meet the needs of the region.
5.5 **Monetized Travel Cost Estimates**

The following section is designed to estimate the true value of a high quality network to a user. This is a scenario building exercise that builds off of a base case scenario, which expects the Basque Y project to proceed as planned. Then, applying some of the techniques necessary to enable a fusion of HSR and HQR, the reductions in intercity travel costs are monetized.

A monetized transportation cost is the sum of the monetary and the time cost to make a marginal trip. In this section, four modes of intercity travel will be considered for the Basque Y.

- The automobile
- The automobile with double occupancy (business and leisure travel)
- The bus
- The Basque Y system

The monetized cost estimates provide a basis for understanding the marginal cost of traveling between the three Basque cities. The actual perceived cost of travel will vary depending on personal preference and actual origin/destination of the trip. Econometric analyses show that different people have different values of time and money depending on the mode they spend it on. This analysis recognizes the potential advantage and disadvantage of those differences, but does not account for the differences directly. These estimates are intended to give an idea as to what advantages some modes have over other modes. These estimates do not include accessibility measures, but access to opportunities is an important consideration when reviewing the following estimates.

**5.5.1 The Base Case**

The base case uses the Basque Y as it is currently planned. The estimates are for city to city travel. The following are assumptions that the calculations use.
• Access and Egress Time, minutes
  o The estimated time to access and egress the main mode of transportation. This could be by walking, local bus, metro, or light rail.
  o For the Bus and the Basque Y, it was assumed that a typical user would take about 15 minutes in each city to reach his destination for a total of 30 minutes. This could mean 20 minutes in one city and 10 minutes in the other.
  o For the automobile, because it is “door-to-door” this time was assumed to be a total of 10 minutes as there needs to be time to walk to and from parking.
• In-Vehicle Time, minutes
  o This is the travel time from station to station or from city center to city center for driving. Estimates used for intercity travel time are found in Table 29.
• Waiting Time, minutes
  o This is the amount of time spent waiting for the train or bus. For this example it is assumed that the user knows the schedule and arrives 10 minutes before the train or bus departs.
• Toll/Fare, €
  o Toll rates are found in Table 30
    ▪ Discounts for frequent users are examined in following scenarios.
    ▪ The toll is halved for automobiles with two occupants.
  o The bus fare was taken from the operator website. Discounts for frequent users are examined in following scenarios.
  o The Basque Y fare was determined to be €10 (Bilbao – San Sebastian) €10 (Vitoria – San Sebastian) and €8 (Bilbao – Vitoria) as that seems to be achievable on RENFE’s fare scheme for cities with similar distances.
• Operating Costs, €
  o This applies only to the automobile and reflects the operating cost of €0.12/km.
- This is halved for automobiles with two occupants.
- Parking/Local Transit Fare, €
  - A parking fee of €5 is common in the Basque Country for a short stay of two or three hours.
    - This is halved for automobiles with two occupants.
  - A public transit fee will be necessary for some, but not all users.
    Therefore €3 was the assumption for both bus and train.
    - This will not affect users that walk
- Astigarraga Shuttle
  - For the Astigarraga station, it is assumed that there will be a coordinated shuttle that will bring users to the downtown area. For this case, an additional 15 minutes representing the combination of travel time and waiting time.
  - There is no fare for this system and the transfer penalty is not included
- Value of Time, €/minute
  - A value of time of €12/hour or €0.20/minute was applied to the sum of the travel times for all trips

<table>
<thead>
<tr>
<th></th>
<th>San Sebastian - Bilbao</th>
<th>San Sebastian - Vitoria</th>
<th>Bilbao - Vitoria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
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<td>70</td>
<td>45</td>
</tr>
<tr>
<td>Bus</td>
<td>70</td>
<td>90</td>
<td>60</td>
</tr>
<tr>
<td>Basque Y</td>
<td>38</td>
<td>34</td>
<td>28</td>
</tr>
</tbody>
</table>

*Table 29: Estimated Intercity Travel Times by Mode, in minutes (EuskalYVasca, 2010)*

<table>
<thead>
<tr>
<th></th>
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<td>Base Rate Pay as you go</td>
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<td>Discount 75% &gt;21 trips/mo</td>
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<td>€ 2.39</td>
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*Table 30: Toll Rates for the Basque Country (Bidegi) (Interbiak)*
Table 31 shows the computation of the monetized costs using the above assumptions. The Basque Y is an improved alternative to the automobile and the bus and is competitive with the double occupancy automobile. The largest gains in the region seem to be between Vitoria and San Sebastian.

<table>
<thead>
<tr>
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<tr>
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Table 31: Monetized Travel Costs for the Basque Region: Base Case Scenario

The base case does not take into account the accessibility restrictions that the Astigarraga station places on the network. It is one thing to offer low transportation costs, but it is important that as many people as possible take advantage of these costs. Even with the significant reduction in cost, the Astigarraga Shuttle requires users to spend 90 minutes to arrive at the destination in the San Sebastian downtown area. This quickly erodes the benefits of a high speed connection. For a person commuting on a regular basis, this will probably not be a realistic option. The total cost for user on
the San Sebastian – Vitoria segment would be approximately €60 round trip of which €26 is out-of-pocket expense. This is not an affordable trip on a daily basis for most people.

5.5.2 The City Center Station

From the San Sebastian station location analysis in Section 5.2, the accessibility is much better from the San Sebastian Atotxa location. Therefore, the next case eliminates the Astigarraga shuttle and brings users directly to the San Sebastian city center.

<table>
<thead>
<tr>
<th>Location</th>
<th>Car (single)</th>
<th>Car (double)</th>
<th>Bus</th>
<th>Basque Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Sebastian - Bilbao</td>
<td>€39.10</td>
<td>€26.55</td>
<td>€34.67</td>
<td>€28.60</td>
</tr>
<tr>
<td>MONETIZED COST</td>
<td>€39.10</td>
<td>€26.55</td>
<td>€34.67</td>
<td>€28.60</td>
</tr>
<tr>
<td>San Sebastian - Vitoria</td>
<td>€43.30</td>
<td>€29.65</td>
<td>€38.67</td>
<td>€27.80</td>
</tr>
<tr>
<td>MONETIZED COST</td>
<td>€43.30</td>
<td>€29.65</td>
<td>€38.67</td>
<td>€27.80</td>
</tr>
<tr>
<td>Bilbao - Vitoria</td>
<td>€33.35</td>
<td>€22.18</td>
<td>€28.70</td>
<td>€24.60</td>
</tr>
<tr>
<td>MONETIZED COST</td>
<td>€33.35</td>
<td>€22.18</td>
<td>€28.70</td>
<td>€24.60</td>
</tr>
</tbody>
</table>

Table 32: Monetized Travel Costs using the San Sebastian Atotxa Station

In this case the monetized costs are reduced only for the Basque Y mode. These are €3 less than the base case, which is significant but not drastic. However, the accessibility is greater along with the significant time reduction. The travel time here is estimated at 70 minutes, but this could be less for people destined for the city center. All of the following scenarios will use the Atotxa station as this is necessary to arrive at the upcoming scenarios.

5.5.3 Frequent Travelers

One of the most important aspects of a functional region is frequent trips between the cities, and in many cases there will be significant travel discounts applied to all modes. The station location is an enabler of frequent trips. The next analysis will use best case scenarios for the cost of travel. For the toll roads, there is a 75% discount on the toll if a
user makes more than 20 trips in a month (Bidegi).* The bus users can receive up to a 90% discount if they travel more than 70 times in a month. However, this only applies to these trips and therefore an expected value of the bus travel would be about 50% for an average trip. The Basque Y frequent user discounts could be as low as €4 or 3 will be used as mentioned in Section 5.4.1.

The results of the monetized travel costs for the frequent users are in Table 33. The travel costs for all modes are significantly reduced from the Base Case mentioned above due to the fare and toll discounts. However the public transport options become even more competitive than in the base case. The Basque Y seems particularly attractive for San Sebastian as the travel times to and from this city are significantly reduced from the other modes. A frequent user will be much more likely to be willing to spend €40 roundtrip than €60 mentioned in the base case.** However, this is still rather high and still might deter some from seeking frequent opportunities in other Basque cities.

<table>
<thead>
<tr>
<th></th>
<th>Car (single)</th>
<th>Car (double)</th>
<th>Bus</th>
<th>Basque Y</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>San Sebastian - Bilbao</strong></td>
<td>€ 33.03</td>
<td>€ 23.52</td>
<td>€ 26.40</td>
<td>€ 21.10</td>
</tr>
<tr>
<td><strong>Monetized Cost</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>San Sebastian - Vitoria</strong></td>
<td>€ 35.58</td>
<td>€ 25.79</td>
<td>€ 30.40</td>
<td>€ 20.30</td>
</tr>
<tr>
<td><strong>Monetized Cost</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bilbao - Vitoria</strong></td>
<td>€ 26.19</td>
<td>€ 18.60</td>
<td>€ 24.35</td>
<td>€ 18.10</td>
</tr>
<tr>
<td><strong>Monetized Cost</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

*These reduced tolls will be used in this estimate but it is likely that the toll could be significantly higher.
**These are monetized costs and include the value of time. The out-of-pocket expense for the Basque Y in this scenario is €11.

5.5.4 RELIABLE AND COORDINATED SYSTEM

As an improvement on the previous scenarios, this scenario estimates travel costs for a system that incorporates the additional high quality attributes of reliability and system coordination. In this case, a typical user's waiting time is reduced from 10 minutes to 5
minutes. Because of reliable service for all modes of transit, the user can spend less time waiting because of an increase in certainty in the system. A more reliable transit system may also mean a reduction in times for access and egress from the station. For this case, the access/egress time was reduced from 30 minutes to 20 minutes. Both of these time reductions apply to the Basque Y and the bus, as the intercity bus will be part of this integrated network. Table 34 shows the results of this scenario.

<table>
<thead>
<tr>
<th></th>
<th>Car (single)</th>
<th>Car (double)</th>
<th>Bus</th>
<th>Basque Y</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MONETIZED COST</strong></td>
<td>€ 33.03</td>
<td>€ 23.52</td>
<td>€ 24.95</td>
<td>€ 18.10</td>
</tr>
</tbody>
</table>

Table 34: Monetized Travel Costs under a Reliable and Coordinated System

The incremental improvements over the previous scenario are visible for the bus and the Basque Y. In this case, the Basque Y is the clear winner for intercity travel and even the bus is competitive with the automobile. The last scenario will examine the highest level of integration for the transit network. It does seem likely at this point that the Basque Y will take most, if not all, of the intercity bus ridership serving the capitals.

5.5.5 HIGH LEVEL INTEGRATION: A UNIFIED SYSTEM

In this scenario, the assumption will be made that the culmination of the quality aspects in the previous scenarios will be included with a high level integrated system that incorporates a single ticket similar to that of the Swiss system. In this case a Basque Pass can be purchased monthly or annually so the marginal fare of taking a trip will be zero. This means that the fare for the bus, the Basque Y, or any connecting transit system is not included. The fixed cost of such as pass is not included. This is consistent with the analysis of the automobile because the long term fixed costs of buying a car and car insurance are not included in this analysis. Table 35 shows the result of the monetized trip costs.
In this case, the reductions in the trip costs are drastic for the bus and the Basque Y. The transit option becomes the clear option for intercity travel and the €20 round trip cost is an affordable commute, business trip, or leisure trip that can be done on a regular basis.

5.5.6 Monetized Cost Scenarios Summary

The above five scenarios represent incremental improvements in the Basque Y network that transform it from a poorly integrated HSR system to a Swiss style combination of HSR and HQR that gives the Basque Y a clear advantage for intercity travel. Reducing the travel costs for the automobile is difficult since the highway network is developed to a point where significant improvements in travel times will not happen. Reductions in tolls and operating costs are also unlikely due to the rising costs of maintenance and fuel. Therefore, from the beginning the Basque Y shows a clear improvement over the existing system. This improvement becomes even more pronounced as the costs for intercity travel are reduced to approximately 1/3 of what they are today by automobile. And as ridership grows on the Basque Y the reductions in costs to the user will continue to decline.

This is going to have significant impacts on the mobility among the Basque Cities. The current intercity travelers will benefit from cost savings as they switch from the automobile. The reduction in cost on the Basque Y is also going to stimulate growth in intercity travel. Those that could not afford intercity travel on a regular basis are now able to do so. This induced traffic will come from business, commuter, and leisure

Table 35: Monetized Travel Costs under High-Level Integration

<table>
<thead>
<tr>
<th></th>
<th>Car (single)</th>
<th>Car (double)</th>
<th>Bus</th>
<th>Basque Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Sebastian - Bilbao</td>
<td>€ 33.03</td>
<td>€ 23.52</td>
<td>€ 22.00</td>
<td>€ 12.60</td>
</tr>
<tr>
<td>MONETIZED COST</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>San Sebastian - Vitoria</td>
<td>€ 35.58</td>
<td>€ 25.79</td>
<td>€ 26.00</td>
<td>€ 11.80</td>
</tr>
<tr>
<td>MONETIZED COST</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bilbao - Vitoria</td>
<td>€ 26.19</td>
<td>€ 18.60</td>
<td>€ 20.00</td>
<td>€ 10.60</td>
</tr>
<tr>
<td>MONETIZED COST</td>
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</tbody>
</table>
travelers and it is key to the cohesion of the region. Moreover, the intercity bus systems that currently serve this market will most likely not be able to compete with the Basque Y because of the consistently lower cost that the Basque Y can provide. The passengers from the bus services will switch to the train, so the Basque Y can enjoy the increased riders switching from this mode. It is reasonable to guess that any travelers that are within a short distance to the rail station will choose the Basque Y for intercity travel. The fact that the overall marginal transportation costs are significantly less than the alternatives suggests that rational behavior will make the Basque Y the top choice.

This analysis assumes that the trains will run on 30 minute headways and have reliable and consistent schedules. This might not be a valid assumption for the base case, in which the monetized costs perceived by the rider would be higher due to the inconvenience of the Basque Y operations. But for the higher quality examples of integration, the operations will also be high quality in terms of providing service to the users. The low travel costs support these frequencies by a high mode share compared with the bus and the automobile. The cost reduction would also signify a large increase due to induced demand.

Another aspect of monetizing intercity travel that was not included was the differences in the value that people place on time for different modes. Transportation users value their time differently depending on how comfortable, productive, or difficult the travel experience is. This is a large advantage for the Basque Y in that a user can spend the travel time productively on the train rather than have to spend it all driving a car. A more detailed analysis and estimate of these different values of time might show an even greater advantage to the Basque Y over the automobile. However, the value of time is dependent on many factors, including the provisions for and comfort of seating. If a passenger cannot sit due to capacity constraints, or his seat does not allow a comfortable space for work or other activities, then the passenger would experience more disutility in this time. Also reliability of the train makes a difference. A rider
that knows exactly when a train will arrive at the destination and can consistently trust this timetable will be much more relaxed about completing his journey.

These additional factors can all be used to the benefit of the Basque Y. Ensuring a high quality system will enable the system to capitalize on these benefits and make them part of the travel experience. This can only capture more and more riders, which in turn makes for a better system for all.

5.5.7 APPLICATION OF THE MONETIZED COSTS

It is not enough to say that the travel times are reduced between the cities. It is more relevant to pair this information with the accessibility maps provided in Section 5.2. Using these figures, we can see how accessibility is increased for different actors. For example, a business located in downtown San Sebastian can use the Basque Y to increase the number of potential employees for new job openings. The current driving times and costs make it too expensive to commute daily between the cities for most people. But using the Basque Y there are about 12,000 jobs within 10 minutes of the Atotxa station. Using the estimates above for Scenario 3, each of these jobs is accessible by 160,000 people in Bilbao and 92,000 people in Vitoria, each having a maximum travel cost of about €20 in each direction.* This is a huge increase in the labor market and has proven to generate productivity improvements due to a better match between labor and jobs. Similar comparisons could be made for people looking for future employers, businesses needing meetings with associates in other cities, and residents looking for services. This example could apply for different businesses in different cities with different thresholds. There are many different comparisons that could be made by paring this information to determine the effect of the Basque Y on people and businesses in the region.

*This example assumes the total access and egress times of 30 minutes and Scenario 3 is Section 5.5.3.
5.6 Political Will

Converting the Basque Y into an integrated transit system that is both HSR and HQR will not happen on its own. The Basque Country as a whole needs to recognize the potential the Basque Y has to transform mobility between the capital cities. It also needs to act now on the planning decisions that are necessary to enable the HQR network to emerge. The Basque Y system has the promise to become a world class fusion of HSR and HQR that could even supersede the Swiss to become a criterion for regional rail networks worldwide. But this is easier said than done.

The first issue to tackle will be the realignment of the network to include a through station at Atotxa. This decision is crucial to enabling the other aspects of integration and high ridership to occur. With the station moved, the region can then focus on ensuring that RENFE is willing and able to run consistent trains at 30 minute headways between each of the three cities. Then focusing on the local issues of integration and scheduling will continue to add quality.

An important exercise in garnering the political ability to get what is needed is an actor analysis. The Basque Country and Gipuzkoa should consider the standpoints and priorities for all of the different agencies involved. Some of these actors may not have any reason to work with the Basque Region to accomplish the HQR network. Other allies can be identified that can help lobby for support. In the Basque Y case, the following actors should be considered:

- RENFE
- ADIF
- France
- The Basque Country
- The Basque Provinces
- The Connected Cities
- The Un-Connected Cities
• Regional businesses, both current and future
• Local business in each city
• Local residents of each city
• Land Developers
• Regional suburban interests

The purpose of the actor analysis is to review the first assumptions of where different interest groups stand. These hypotheses are to be verified through communication with each of the affect groups. The following should be listed and assumed for each actor:

• Role in the system
• Overall interest
• Likely attitude
• How they will support their attitude
• Ways in which they can become allies or supporters if not already

The Basque Region will need to convince most of the parties that it is in their interest and benefit to support the regional network and the proposed changes to the design. From the evidence shown in this thesis each of the actors have something to gain from the success of the Basque Y. However it is not given that the actors will inherently have a positive attitude toward these objectives. The Basque Region and the Provinces must make the case to each through conversation and dialogue so as to create as many allies and supporter as possible.

This thesis will not go into depth on the range of priorities and reactions that each of the above listed entities may have. But the simple task of understanding where each group stands will be important for the Basque Country to work toward taking full advantage of the Basque Y. The Basque Country and the territory of Gipuzkoa need to stand up and be resolute in ensuring that the proper decisions are made to enable those benefits.
5.7 Planning for the Future

Most of this thesis has focused on the near term planning decisions required to enable the functional region. But equally important is viewing the system from a long term perspective. In her thesis Hernandez (2011) discusses the long term sustainability of a regional HSR network. She looks at the development of the network, using a potential extension of the Basque Y to the Bilbao Airport as a case study. The methodology examines the dynamics of the system, showing how a line extension to a key trip generator or attractor can improve ridership, and therefore increase frequencies for everyone.

What is planned and built today will affect the starting place for decisions long into the future. If a station is constructed in Astigarraga and that becomes the main station for San Sebastian and Gipuzkoa, it is likely the province will be cursed with this station as the main intercity rail station for many decades. Once established as Astigarraga, it will be very difficult to move the alignment and abandon the station. In this case the Basque Country and Gipuzkoa need to consider their long term goals. If the goal is regional economic and cultural cohesion, then now is a one time chance to take advantage of an infrastructure that can do just that. Typical analyses of projects discount the value of the future away, but the good infrastructure decisions of the past are what enable much of the possibilities for today.
6 CONCLUSIONS AND RECOMMENDATIONS

This thesis examined regional rail networks and the ways in which they can affect the mobility of the connected region. The first part established the difference between high speed rail (HSR) and high quality rail (HQR) and the implications each have on mobility. Many regional rail networks are created when a country builds new high speed rail infrastructure. Typical HSR design connects large, distant cities that are within 800km making the HSR competitive with the airplane. However in building such infrastructure many mid-sized cities typically acquire stations. These mid-sized cities can take advantage of the new connection for better access to other cities along the line but systems designed for high speed often compromise the quality of these regional connections.

The distinction made between HSR and HQR lies in the main objectives of planning. HSR is designed with the top speed being the primary planning motivation. In order to compete with the airlines, the system is designed for minimum possible travel times, which may mean avoiding stops at some smaller markets along the route. On the other hand HQR systems, which are typically regional intercity services, depend much more on the quality of the service to attract riders as competition is with the automobile. Among other characteristics, “high quality” can encompass reliability, intermodal integration, centrally located stations, user convenience, low fares, and high frequencies. Evidence from Japan, France, and Spain show that many times HSR can also have the features of HQR but for competition with the airplane this is not a driving force for building ridership. The same is true that HQR can also be high speed, but the very high quality Swiss system is overwhelmed with high ridership even though the top speeds rarely exceed 130 kph. Chapter 2 elaborates on this distinction and it also introduces other key concepts that are necessary for understanding important aspects of rail systems.
Chapter 3 examines the benefits, specifically the economic benefits, of a regional HQR system. Existing research shows how a well connected regional rail network can bring economic cohesion between cities within the system. Economies work more efficiently as labor and service markets are increased. A regional rail network can enable mid-sized cities to share economic mass, and therefore become more competitive in the global economy. But simply building an HSR line between two regional cities will not inherently bring these economic and social benefits. To enable intercity cohesion, the rail system must encompass the aspects of high quality that can compete with the automobile for work, business, and leisure related trips. In Europe examples of successful rail-enabled regional cohesion can be found in Belgium, Germany, and Switzerland.

The planning aspects of HQR discussed in Chapter 3 that seem necessary for the regional economic cohesion include:

- Station placement and mainline alignment
- Integration with feeder and distribution services
- Operational fares, frequencies, and scheduling
- Future of the network
- Political will for implementation

Each of these features is important for creating an HQR network. The incremental benefits of each additional part can help the overall system to deliver a convenient option to the user. The intent was not to financially justify a regional rail network, but rather to optimize its design to maximize its potential.

Chapter 4 introduced the Basque Y project in Spain. The Basque Y is an HSR infrastructure project that is designed as a link connecting Madrid with the three largest Basque cities. The resulting arrangement is a regional rail network that has the ability to significantly reduce the travel times between the cities, which are about 100kms apart. However this “accidental” regional rail network is not being planned to
enable the economic cohesion benefits. When viewed from the point of view of the Basque Region, one of the most significant problems with this network is the station location in the city of San Sebastian. In this city the station is planned to be located in a small town 6 km south of the city center. This decision significantly reduces the city's access to the network and can hamper the potential for regional connectivity. But the construction is yet to be finished and therefore there is an opportunity to modify the network to enable the aspects of high quality for the Basque Region. As demonstrated throughout the thesis, the Basque Y has the potential to fuse HSR with HQR to make a system that supersedes that of even the highly integrated and successful Swiss model. Issues such as station location, integration with local transit, and the operations of the Basque Y need to be reevaluated to better understand their impact on the regional network.

Chapter 5 examined the Basque Y from an HQR perspective. The key planning elements were analyzed using tools and comparisons to illustrate their impacts. TransCAD, a GIS-based transportation planning software, was helpful in demonstrating the impact of certain planning decisions on accessibility. Direct comparisons from similar systems were valuable for furthering this understanding. The Spanish rail system and the national rail operator RENFE served as a comparison as to what to expect in terms of the planning of the rail operations. The Swiss system was a model of success that proved useful in showing what is needed for regional cohesion and how a high quality system can enable it.

A monetization of marginal transportation costs further demonstrated the potential of the Basque Y. The reductions in travel cost, which include the monetary and time costs of the trip, are drastic for the Basque Region under a fully integrated system. The marginal cost of making an intercity trip is as low as a third of the current cost of using an automobile. This shows that the Basque Y is likely to receive a very high mode share for these intercity trips. The analysis involves a series of scenarios that include incremental benefits in quality to the system, with decreases in costs that are substantial. As currently planned, a one-way intercity Basque Y trip would cost around
€30 and would have infrequent service due to low demand. However, a high quality system that delivers passengers to well connected and well integrated city centers could provide travel costs of €15 or lower. Especially when considering that the Basque Y trains can allow for productive use of travel time, the cost of intercity travel perceived by the user becomes low enough to capture existing demand and induce a high number of intercity interactions.

Nevertheless it is clear that the Basque Region, or any other similar region, must act to ensure that the correct decisions are adopted. A brief actor analysis was done in Chapter 5 to help understand the positions of key planners in Madrid and France as well as other interest in the region.

6.1 Station Location

Of all the planning decisions that help to build an HQR system, the station location is the most critical. Rail needs to serve key markets to build ridership and improve service. Dense city centers offer large numbers of trip attractors and generators in close proximity. A rail journey is a means to an end, not an end in itself. Therefore ensuring that passengers have convenient, door-to-door access to origins and destinations is vital. City centers offer access by short walk trips and by dense networks of public transportation. Collocating transit lines with the rail station can further improve the access using low cost, high capacity modes such as local rail and bus.

The examination of the station location does not consider the potential differences between moving the location the distance of a few city blocks. Rather it compares a city center location with a peripheral station location that can result from high speed focused planning. Almost all cities have the benefit of a central rail station that remains from the original rail construction in the 19th century. These stations are usually surrounded by dense development and have access to many transit and walking
opportunities. If possible and practical, these stations should be used. This will help to deliver ridership and service quality to all the users.

The Spanish rail experience shows examples of well and poorly located stations. The small city of Puertollano managed to secure a city center station on the Madrid – Sevilla line.* This small city attracts 83% of the passing AVE trains to stop. On the other hand the city of Tarragona has an HSR station located 9km north of the city in a rural area along the Barcelona – Madrid line. This station attracts only 33% of the AVE trains yet the city has a population three times that of Puertollano.

San Sebastian risks a fate similar to Tarragona. The station is currently planned to be in the small town of Astigarraga, which is 6km south of the city. Although this city is accessible by automobile, walking and transit options are limited and costly. This results in burdensome and inefficient access for those destined for the city. The alternative would be to reroute the mainline to the existing intercity rail station, Atotxa, in the city core. This option eliminates the problems posed by Astigarraga. Long distance trains that connect with Madrid and France would benefit from taking the time to stop at San Sebastian, as the Puertollano case suggests.

Securing the Atotxa station location is not important just for San Sebastian, but for the entire region. A high quality rail network depends on balanced flows between all cities and sufficiently high ridership to justify the needed service frequencies. The periphery station offers neither. With access mostly limited to the automobile, the Astigarraga station will not be attractive to rail users with their destinations in San Sebastian. Many users will not likely be inclined to arrive at a station without a car or unable to walk to a destination. This ensures that the Astigarraga station will be used mostly by locals that wish to visit other cities, resulting in unbalanced flows. Also the inaccessibility of the station will reduce overall ridership, which in turn degrades the service, making it less attractive for use, and eventually the station would receive low

* The population of Puertollano is 52,000

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enough service and ridership that it would not be very useful for the Gipuzkoa Province. Each regional city should have a centrally located station for their benefit and for the benefit of the entire network. Any major exception to this could result in the inability of a true HQR network to form.

In conclusion, the station location is the most important issue for many reasons. For one, it is the heart of the network. The goal of a rail system is to offer a high capacity, low cost link between dense areas. Using the rail as it is intended, city center to city center, makes practical sense. Secondly, access to key markets and existing transit lines will help build a sustainable demand for the service. Finally, the station location is a fixed and final decision. Once the infrastructure is built it becomes very hard to change.

6.2 INTEGRATION

Another key aspect to creating a functional region is to have integration with the local distribution systems in each of the connected cities. This is vital to making the system door-to-door rather than station-to-station for as many users as possible. There are three levels of integration that are important in creating high quality connections.

- Physical Integration
  - Local bus lines have stops immediately outside the station
  - Regional rail and bus services are housed in the location
- Operational Integration
  - Schedules are coordinated so that waiting times for trains and buses are minimal
  - The coordinated schedules occur in pulses when possible
- System Integration
  - A sense of a single, unified system for the user
  - Ticketing, fare structure, and user information come from one single source
Each level of integration offers an improvement in quality. Physically integrated systems offer users more choice in access and egress modes. Transit operators benefit from the increased number of passengers and the ability to share station facilities instead of building multiple stations with duplicate services. The operational integration allows for a reduction in waiting time for the users. This also has the potential to reduce the disutility of the transfer, or the transfer penalty, by making the transfer easier and more comfortable for the user. Finally complete system integration, similar to that of the Swiss, can enable a seamless system that extends access to areas much farther than the city center.

The Basque Y has many opportunities for integration. Bilbao and Vitoria stations are well connected with transit. The central station in San Sebastian is also the main station for the Cercanías service for Gipuzkoa. There are also plans to move the intercity bus terminal to the Atotxa station, providing even more integration. A simple re-route of a few of the local bus lines could provide access to many more residents and businesses at a minimal costs. The integration of services can also help to mitigate the shadow effect by providing high quality connections to the other regional cities and markets. Also, a connections with the airport could further this integration by allowing air travelers to use the Basque Y to get to different European and regional destinations. Examples of how these simple physical integration techniques improve the accessibility are detailed in the Chapter 5.

Integration is essential to the long term success of the system, but it is something that depends on opportunities granted by the station location. Integration is something that can be implemented gradually over time, but should not be neglected. Taking the fastest possible steps to giving the user the most seamless journey is needed to realize the maximum potential of the system.
6.3 **FARES, FREQUENCIES, AND SCHEDULING**

The operations of the rail system are as vital to the success of the system as the station location and integration. An HQR system needs to have fares that are low enough to encourage frequent travel between cities. This should be affordable to everyone in the region and needs to be reasonable for daily travel. Frequencies need to be high enough for convenient travel but a balance must be made to ensure cost effectiveness. Also, the operator should acquire the right amount of rolling stock so a reliable, consistent, and convenient schedule can be run according to the needed frequencies.

In terms of fares, examples from regional HSR networks in Spain were used to get estimates of what reasonable fares for the system might be. For cities of comparable distance, the following seems to be a realistic estimate of the regional fares:

- **San Sebastian – Bilbao** €10, frequent discount €4
- **San Sebastian – Vitoria** €10, frequent discount €4
- **Bilbao – Vitoria** €8, frequent discount €3

These fares are very reasonable and are such that a frequent user would not be dissuaded from using the system. A fare structure similar to this would be practical and successful for use in the Basque Y. These fares could be incorporated into the integrated ticketing and fare structure of the Basque Y.

The Swiss cities of Basel, Berne, and Zurich were used for comparison of frequencies for the Basque Y as these cities have similar sizes and distances. The Swiss system currently operates on 30 minutes headways for direct trains between the three cities. This seems to be a sufficient frequency to achieve the regional cohesion benefits that the regional needs. 30 minutes also seems to encourage ridership growth as the Swiss system has recently been overwhelmed with increased riders. The Swiss have recently purchased new trainsets with capacities of around 600, demonstrating the need to offer 1200 seats per hour between these key cities. A typical HSR train in Spain offers 300
to 400 seats, implying that the Basque Y will need to move between 600 to 800 passengers per hour between the three Basque capitals. Filling these trains to a reasonable level can be done using similar techniques of attracting riders from many markets and encouraging ridership by providing excellent quality. The specific strategies and sources for ridership come from many sources of intercity travel, as shown in Chapter 5.

The schedule to run these trains should be consistent, reliable, and convenient to the passenger. The trains should enter and leave the stations at regular intervals and they can be coordinated so that trains arrive from multiple destinations simultaneously. A timed-transfer method called “pulse” scheduling seems to provide significant benefits in the Swiss system by providing minimum waiting times along with consistent and regular timetables. A detailed example of a potential operating scheme for the Basque Region is found in Chapter 5. This timetable incorporates a pulse schedule and allows for long distance trains to supplement parts of the Basque Y services. This allows for maximum frequency to serve all points and it allows for many markets to build the demand.

6.4 STRATEGY FOR IMPLEMENTATION

The Spanish national government and ADIF, the national railway infrastructure company, are currently in charge of planning the Basque Y. Their goals and strategies are very different from the needs of the Basque Region. There is no evidence that they have any intentions of paying attention to the details needed for the regional rail network. If the plans proceed, then San Sebastian will be stuck with an impractical rail station and any prospects of the Basque Y bringing strong Basque cohesion will be lost. The Basque Y system has the promise to become a world class fusion of HSR and HQR that could even supersede the Swiss to become a criterion for regional rail networks worldwide. But this is easier said than done.
The Basque Country, The Basque Provinces, and the affected cities need to recognize the potential the Basque Y has to transform regional mobility. They also need to act now on the planning decisions that are necessary to enable the HQR network to emerge. The aspects of high quality need to be comprehensive in all of the cities or else the network will not be successful. Chapter 5 outlines an actor analysis that is useful in examining what parties have a stake in the project and where allies and opponents stand. Negotiations to modify the system should happen now to secure the ability to create an HQR network. The following building blocks seem to provide a reasonable approach to the task of revising the plan.

1. **Work with the existing infrastructure.**
   The Basque Y is a €6b project. This has been decided and construction is underway. Therefore most of the alignment is fixed but modifications can be made to the incomplete areas around the cities, including the station location. The Basque Region does not need to justify this infrastructure cost but instead negotiate changes so its full value can be achieved.

2. **Secure the city center station location in San Sebastian.**
   The current station location in Astigarraga is problematic and needs to be changed immediately. This is the most important modification as it enables the other aspects of HQR to happen. Along with the city center station, the mainline running through to the French Border should be secured as well. The other cities seem to have reasonably well located stations but the success of the entire regional network depends on the San Sebastian station.

3. **Design the Operations.**
   Once the station location is secured, the next step is to build an operating schedule based on the fares, frequencies, and level of service needed to meet the demand and enable regional cohesion. RENFE currently does seem to offer regional HSR fares that are low enough to be affordable for daily travel. The Swiss show that 30 minute frequencies are both necessary and practical for regional cohesion. The Basque Region will
most likely be able to meet the demand of 30 minute frequencies between each of the main cities. A mixture of long distance trains can perform this 30 minute frequency while regional shuttles fill the gaps between long distance services. The schedule should incorporate the advantages of regular and consistent timetabling. Pulse scheduling should be a cornerstone of the network to allow for easy transfers and easy connections between the shuttles and the long distance trains. Once the schedule is determined rolling stock needs to be acquired operations can begin as soon as the infrastructure is complete.

4. **Initiate the Integration of Feeder and Distribution Services.**

Once the station locations are set and the operations are designed, the coordination and integration of the local transit modes in each city will be the next step in achieving high quality. Eventually it would be ideal to have all the modes in all of the Basque Cities operating under a single consortium. To arrive at this goal, the modes must be integrated first physically, then operationally, and finally a system wide unification for the benefit of the users. Gipuzkoa is already moving in this direction. The decision to move the intercity bus terminal to Atotxa is a step toward the physical integration. The Lurraldebus network and card are operational and system integration steps have been taken in the right direction and could one day include intercity trips on the Basque Y.

5. **Develop a Land Use Plan for the Stations.**

The land around the stations is likely to increase in value due to the improved accessibility at those locations. However, dense city centers offer few alternatives for new development. The land above the station track offers a unique opportunity for new development to take advantage of the high access. It is possible that this land can significantly increase the amount of space for employment in areas that are within five minutes walking distance from a regional transportation hub. A plan to enable and encourage this high value investment can help bring high productivity jobs to the city center.
Figure 37 shows these five steps as the building blocks needed to achieve the goal of creating a high quality system capable of increasing the regional economic and social cohesion. The steps build upon the other sequentially; it is unlikely that a high step can fully work without the completion of all the lower steps. The Basque Y is an opportunity for a pattern break that could forever change mobility in the region. But the region must act now to secure the changes needed to enable these benefits.

![Diagram of the Five Steps of High Quality Rail Implementation](image)

**Figure 57: The Five Steps of High Quality Rail Implementation**

### 6.5 Future Research

This thesis gives an overview of the potential of regional HQR networks and the planning decisions needed to make them high quality. However, improvements on these approaches could solidify the justification for the modifications and be helpful in strengthening the case for regional rail networks. The following are areas of potential future research:

1. Measuring the wider economic benefits of regional agglomeration. This thesis examined the existing research that shows evidence of wider economic benefits that result from economic productivity increases from transportation cost reductions. However, it was beyond the scope of this thesis to actually place a
numerical value on these benefits. Extending of the agglomeration research by Dan Graham (2007) and others and applying it to a regional rail network would strengthen the justification for such a system and would help optimize the station location in each city.

2. Measuring the value of “Swiss Style” operations. The Swiss have spent a great deal to coordinate schedules and enable high level integration to reduce the disutility of the transfer. They have seen overwhelming ridership on a system that is hardly faster than the automobile, showing that there is some perceived value in such a coordinated system. Extracting that value in terms of monetary or ridership benefits could be useful in convincing regional governments to take on such a task.

3. Improving upon the monetized intercity cost estimates. This thesis examines the monetized travel costs between the Basque cities but it does not take into account some of the perceived costs of travel that a detailed econometric analysis could show. The value of time on a comfortable transit trip could be less burdensome than driving due to the fact that transit time can be productive where auto time must be spent driving. This could also show the real value of transfers in the Basque Country and could lead to finding ways to improve the transfer experience.

4. Optimizing the integration of the feeder and distribution services. The transit services in each city will need to be modified to enable the maximum amount of access to the network for the local businesses and residents. Modifications in routes, interchange points, and new infrastructure can facilitate access and improve on overall mobility in the cities and regions. This thesis demonstrated the potential that these modes have to increase this access. A more detailed analysis could provide guidance as to how to integrate all of the local modes into the system.
6.7 CLOSING REMARKS

There exists a false premise that the very long distances will be well served by HSR. The Paris – Madrid connection will one day be less than six hours, which is a drastic improvement over the ten or more hours needed today. But even at six hours it is unlikely that this will be an option for frequent travel due to the lower cost and much lower time already offered by air service. The key driver to demand along this expensive HSR infrastructure will be connections with the mid-sized cities along the route. Replacement of air travel will occur in the 400 to 800km range with connections such as Bilbao – Madrid. But even that service will need to rely on frequent regional commuters to fill the trains, increase the frequency, and justify the very high cost of the investment. Too often these mid-sized cities are excluded from the benefits of the rail network because of the “need” for higher speed. But passing these cities is a missed opportunity for the whole system because of the impact these mid-sized cities can have on ridership and the economic benefits derived from the regional services.

Connected and affected regions need to step up and ensure they gain direct access to the new infrastructure. The station location and mainline alignment are crucial to the success. Other aspects of high quality can follow once the cities gain access. Not every single city needs to be connected but it does not make sense to pass key markets. The small city of Puertollano demonstrates that even a small city of 52,000 can attract a large majority of the HSR trains to stop as they pass through.

The benefits of these regional connections are needed for the short and long term sustainability of the system. The long term future of the network is at stake when planning these stations and connections. Tarragona missed an opportunity and will continue to receive low quality service from the HSR network. It is up to the Basque County to think of the long term goals as the dynamics of the system in the long term are hard to plan for based on a simple comparison of the benefits and costs discounted today. In her thesis, Hernandez (2011) explores the long term dynamics of planning decisions in transportation and gives insights as to how transportation planners should
not discredit the future, but look at the sustainability of the system over long periods of time. The long term impacts of many of these decisions are illustrated by showing how station location, integration, and connections with other key markets, such as the Bilbao airport, can build future demand and quality in the system.

In conclusion, it is clear that an HQR system can enable regional cohesion and drive ridership. This is something that needs to be recognized and incorporated with the traditional HSR planning. The high quality aspects of the network should also be comprehensive in all of the connected cities. Cities should draw on their individual benefits to encourage business growth in their cores and therefore attract frequent intercity travelers for commuting, business, and service trips.

The perception that high speed automatically means high quality is a myth that needs to be reconsidered. HSR has its benefits and its place in the rail network. But when the focus of high speed becomes so great that access to important nodes on the network are compromised, a readjustment in planning focus is needed. HSR infrastructure is very expensive and it is beyond the scope of this thesis to justify such investment. However if there is the political will to build such a costly system, then connecting key markets in a way that can enable high ridership and regional economic growth should be the basis for planning.
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