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Creating a High Speed Rail Network For Australia

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Designing a High Speed Network for Australia

Beyond Zero Emissions

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Abstract

Australia's rail network does not provide enough for its passengers. It lacks a high speed network and is disconnected: providing travel radial with respect to Melbourne and Sydney, but no crossing lines. The team utilized the experience of international rails to examine Australia's transportation needs, based upon coverage, convenience, and cost. Drawing upon rail networks from other countries, the team proposed a new rail network for Australia that was accessible to 80% of the population. The final proposal was based upon coverage, convenience and cost, and offers travelers within Australia with a more connected rail network and access to high speed lines.

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Authorship Page

Kerrin Beovich – Contributed to the Introduction and Background Chapters. She wrote Most of the "Global Warming" and "Transportation" sections of the Background chapter. She wrote "The Gap" sections and parts of the "Rail Network Coverage" and "Convenience" sections as well. She wrote the "Research Methods", "Why the Analysis of US Rail" and "Analyzing the Collected Data" sections. She also researched the information regarding France and the US and wrote their corresponding sections in the Findings chapter, as well as the "International Rail Networks Information", "Cost per Kilometer of Rail", "Possible Upgrades/Proposals", "Limitations of Research", and "Information Acquisition" sections of the Findings chapter. She wrote/compiled Appendix A and formatted most figures and tables throughout the report. She also contributed to the general editing and revising of the report, the gathering and formatting of the Appendices, and she managed the format and structure of our paper.

James DeCelle – Wrote most of the executive summary and the introduction chapters. He contributed to the research of the "Transportation" and "Building a Successful Rail Network" sections of the Background chapter and wrote the "Global Warming" section, "Buses" section, "Trains" section, all of the "Australian Rail" sections, much of the "Rail Network Coverage" and "Convenience" sections, and the "What Is Missing" section. He also wrote all sections, excluding the Why the Analysis of US Rail section, in the Research Methods. He researched the information regarding Great Britain, Italy, and Japan, and wrote their sections in the Findings Chapter as well. He wrote the conclusions and recommendations chapter and contributed to the general editing and revising of our report.

Shaun Marshall – Contributed to the Background and Findings chapters, researching all information on Germany and Switzerland. He also wrote the "Cost", "Frequency" and "Travel Times" sections and parts of the "Accessibility" section in the Background chapter. He also contributed to the Findings chapter and wrote the "Station Location and Population" section. He also wrote Appendices B-G. He contributed to much of the general editing and revising of our report.

Wilfredo Ramos – Contributed to Background and Findings chapters. He gathered research on Spain and Australia, and wrote their corresponding sections in the Findings chapter. He generated all population density, elevation, and rail network maps using both Photoshop and GIS software. His main focus was the revising of our paper.

Executive Summary

Introduction and Background

Global Warming is a complex yet serious societal issue resulting in rising sea levels; sea-surface temperatures; and humidity, and the disappearance of glaciers (IPCC, 2007). Global Warming occurs as excessive amounts of greenhouse gases, for example *carbon emissions*[1], are released into the atmosphere (Carbon Dioxide Information Analysis Center (CDIAC)). Once released, carbon emissions are absorbed by sinks, such as plants and oceans, which process the carbon dioxide until oxygen is released; however, the sinks are not able to support the current rate at which carbon dioxide is being emitted (EPA). Steps must be taken in order to decrease the amount of carbon dioxide released into the atmosphere (Agency, 2006).

In the year 2000, transportation was the third leading contributor to greenhouse gases world-wide. Road transportation was the second leading contributor among all sub-sectors[2], where public transportation was one of the least carbon emissive among all sub-sectors (World Resources Institute, 2008). By 2007, the transport sector had become the second leading contributor of carbon emissions (Internation Transport Forum, 2010). Studies show that trains emit up to 75% less carbon emissions per passenger kilometer[3] than automobiles; therefore, creating a shift from road to rail transportation has the potential to reduce world-wide carbon emissions from road transportation by as great as 75% (Ludewig & Aliadiere, Rail Transport and Environment: Facts and Figures, 2008).

In order to create the shift from road to rail, rail transportation needs to become more appealing to passengers (UNEP). A common method doing so is to create a high speed network that enables passengers to reach their destinations at speeds of 250km/h or faster, which countries such as France, Italy, Japan, and Spain have already begun to utilize (See Appendix H). London and the United States are currently in the early stages of constructing new high speed rail networks through planned proposals, the High Speed 2 and America 2050, respectively (ibid). In addition to constructing a high speed network, providing the desired road to rail shift can be achieved by creating a rail network that *covers* (*rail network coverage*)[4] enough of its targeted population and is adequately *accessible*[5]. Studies in England have concluded that one of the main reasons automobile users do not use public transportation, such as trains, is that the trains are not accessible to passengers (Kamba, O.K. Rahmat, & Ismail, 2007). The same study also concluded that the lack of public transit use is due to *convenience*[6]

[1] Carbon, an element, is not a greenhouse gas; however, carbon dioxide, which is a greenhouse gas, is commonly shortened to carbon for ease of reference (Torchbox).

[2] Each sector of carbon emission sources is broken into multiple sub-sectors, such as air travel, rail transport, road transport, etc. Of all these sub-sectors, road transportation is the second leading contributor

[3] Passenger-kilometer refers to the one kilometer traveled by a passenger (someone who is traveling by the method of transportation reference [car, train, etc.])

[4] The rail network's accessibility to its passengers and its ability to provide the options of high speed (250+ km/h), fast (200-250 km/h), or basic (<200 km/h) trains within the city of the station or an adjacent city

[5] The rail network's ability to provide its passengers with access points and destinations that fulfill their needs

[6] The rail network's ability to provide services frequently throughout a daily operational period that is able to fulfill passengers' needs

(ibid). In order to entice people into consistently using the trains, rail networks are being operated on frequent intervals, such as offering train services 2-4 times per hour (See Appendix H.1.3).

While rail network coverage and convenience are factors that can help or hinder a shift from road to rail, there exists a limitation: *cost*[7]. Providing coverage to 100% of a region's population and operating trains that run every 5 minutes would certainly enable a massive (if not complete) shift from road to rail; however, it is unrealistic due to the cost. Depending on the distance covered and the type of terrain involved, high Speed rail lines within a rail network can cost upwards of $100 billion AUD; the cost of the high speed line between Melbourne and Brisbane (a distance of 1600 km) is estimated between $61-108 billion AUD (Rood, 2011). Furthermore, the price of extending and/or upgrading a rail network is dependent on the type of work done on the rail lines within the network. Upgrading an existing rail line is cheaper than building a completely new one, and rail line costs vary depending on the terrain (tunneling, bridging, etc.) (See Appendix H). Funding is a limited resource and plays an influential role in all major decisions; thus, understanding the cost of its various components of it enables the construction of a rail network that will appeal to its target population both effectually and economically.

Australia is in the process of extending/upgrading its rail network. The country's rail network lacks any high speed rail lines and is very disconnected (See Appendix C). Australia's flawed rail network hinders its ability to shift its passengers from road to rail, even though, in recent years, there has been a growing desire for public rail use. Studies have been conducted throughout Australia; areas such as Melbourne are showing an increased desire to use public transportation; and additionally, there has been an increase in rail usage (Low, 2008). Unfortunately, the current rail network does not have the capacity to support this growing desire; however, the government recognizes this and is researching high speed lines and upgrades to the current rail network (ibid).

High speed lines have been, and are being researched, to connect the major cities[8] of Australia (Rood, 2011). The major cities are not only home to over 50% of the population of Australia, but are popular tourist attractions (both domestically and internationally), thus, justifiable of a high speed rail (Tourism Research Australia, 2011). A rail network that can compete with automobiles, and airplanes, in terms of travel times and *frequency*[9] between the major and popular cities can give the public an alternative option to driving their automobiles. Upgrades to the current rail network, such as new crossing routes and a new line connecting Melbourne and Mildura, are also being researched (AECOM, 2010). The lack of *connectivity*[10] and the need for more rail lines are recognized and a new proposal is in the making (ibid).

Beyond Zero Emissions (BZE), a non-profit organization, has begun researching the current state of Australia's rail network and creating its own rail network proposal, both upgrading current rail lines and creating new rail lines (such as a high speed line) (Wright & Hearps, 2010). The organization

[7] Cost of building the rail lines which includes the planning and land costs, infrastructure building costs, and super structure costs
[8] Perth, Adelaide, Melbourne, Sydney, and Brisbane (the 5 most populated cities in Australia)
[9] The interval at which a train departs from a train station
[10] The average number of connections a station provides (See Appendix C for further detail)

collected data on Australia; however designing a rail network should consider the rail networks of other countries, especially ones that are considered to be successful, or ones that are currently going through upgrades and installations similar to those necessary for Australia's rail network. If the other countries with successful rail networks can be analyzed to determine why they are successful, the knowledge gained from the analysis and studies can help with the construction of our rail network proposal. Also, understanding why other countries' rail networks fail, or do not perform as well as others, can be of use.

Research Methods

We acquired information on international rail networks regarding *coverage*[11], *convenience*, and *cost*. After analyzing the data found on other countries, we constructed a rail network proposal for Australia. In order to achieve this goal, the completion of three objectives was necessary:

- Gathering information on the entire[12] rail networks of France, Germany, Great Britain, Italy, Japan, Spain, Switzerland, and US
- Analyzing these countries' rail networks using the criteria of rail network coverage, convenience, and cost
- Proposing a feasible rail network that covers 80% of Australia's population

The selection of countries for this study was carefully considered. European countries were chosen because they contain some of the most prominent, widely utilized rail networks in the world. Europe possesses a high amount of high speed track, and many countries either have plans or are already in the process of expanding their current network. For example, Great Britain has a High Speed 2 proposal that has been approved by the government (Department for Transport, 2012). Similarly, the United States is creating a high speed rail proposal (America 2050), which the country currently lacks (High Speed Rail in America). The proposals in Great Britain and the US proved useful because they are similar to the types of upgrades and installations that Australia desires. Japan's rail network was chosen for study because it is the pinnacle of high speed rail. Many countries around the world base their high speed train technology off of Japan's (Mong, 2010). The country is also home to the most high speed track, as of 2008 (Milmo, 2009). Once the desired countries for this study were selected, we began collecting our data.

An Excel spreadsheet was constructed as a template in order to organize the information on each country's rail network. The spreadsheets were organized into the three main categories: coverage, convenience, and cost. Each category was comprised of specific information.

Coverage information contained station location with respect to the population of each country and the *type of rails*[13] along each rail line within the rail networks. When gathering and organizing the

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[11] Italicized words can be found in the glossary (See Appendix A)
[12] Including all high speed, fast speed and basic rails throughout the country

station population and population data, each city/town with a train station was found and placed into the excel spreadsheet. The sum of the people residing in a city/town with a train station was divided by the total population of the given country. This statistic was called “Station Population Ratio (SPR).” Adjacent cities/towns were not included in this SPR because we did not have access to such sophisticated software or sufficient data, to allow for it. We countered this lack of data by superimposing maps of each country’s rail networks over maps of the population densities. These maps allowed us to study the location of train stations in relation to the population of each country. In addition to SPR, the group determined the type of train that each train station utilizes. These data was mainly used to determine where the high speed trains stop. These data allowed the group to compare the accessibility and coverage of the various rail networks.

Convenience information contained data regarding the service frequency offered along the different rail lines and the travel times between popular destinations. The service frequencies and the travel times evaluated the ability of the rail networks to be convenient for its passengers, which was a major influence on whether people use public transportation (Kamba, O.K. Rahmat, & Ismail, 2007).

The cost spreadsheets were comprised of different situational costs and total length of various rail line/network projects all over the world. A normalized[14] cost per kilometer of track was sought for each country. This information was important in estimating the cost of the rail lines within our Australian rail network proposal. The cost of other projects around the world, along with the cost of prior Australian projects, was used by a member of BZE to construct an estimate of cost per kilometer of track for different terrains (Urban, Tunneling, Mountainous, Elevated Track, Undulating, and Flat Farmland) (See Appendix H).

Important Findings

Our data showed that:

- Coverage
    - Majority of tracks (for international rails) lie in highly populated areas (See Appendix H)
    - International rails have a higher connectivity than Australia (See Appendix C)
        - Australian average number of direct connections: 1.5
        - International networks range from 2.3-2.6
    - A high speed line should not have many stops
- Convenience
    - The more successful rails run more frequently (See Appendix H)
- Cost
    - Cost ultimately comes down to what terrain the rail must cross/cut through (See Appendix G)

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[13] Refers to the maximum speed a train is able to run along a give rail line. These are classified into three main categories: High Speed (250+ km/h), Fast Speed (200+ km/h), and Basic Speed (<200 km/h)
[14] The cost of building a rail with no obstacles or terrain difficulties

The SPR for the international rails ranges from 19% (US) to 66% (Great Britain). Some countries had a low SPR because the train stations were located just outside of major cities (See Appendix H). A majority was found in larger populated cities/town, but for every country, we found stations (high, fast and basic) in very small cities/towns. These small cities/towns were usually major tourist attractions (i.e. Ueno, Japan and Limone, Italy).

As for frequency, each rail differed depending on the time of day and the day of the week. Rail networks run trains at higher frequencies during rush hour[15]. Japan had one of the best train schedules due to its use of all three types of trains on the same track during the same hour; many of the rails in Japan run the high speed train 4 times an hour throughout the day, with 1 or 2 more trains operating during rush hour. In most other countries, it was normal to see the high speed train run on a track once or twice an hour (See Appendix H.1.3).

The cost[16] also varied country to country, but more notably was the cost for building a new rail, upgrading a current rail, and tunneling. Denmark began building a metro line which consisted of all underground routes and was estimated at $247.5 million/km. Upgrades in France, England, Switzerland and Spain cost about $24 million/km, $44 million/km, $83 million/km, and $1.6 million/km, respectively. To build new high speed rails in France, Spain and Italy, the normalized cost for both France and Spain is approximately $11.5 million.km, while in Italy the normalized cost is about $28.8 million/km (See Appendix H.1.2).

While the information collected on each country proved useful, the rising question was whether the countries studied were comparable to Australia (See Appendix H). Countries such as France, Germany, Great Britain, Spain, and Switzerland are comparable to Australia because these countries are densely populated in and around their major cities, just as Australia. The major difference between these countries and Australia is that Australia is at least 12 times larger (ibid). The US is similar to Australia because a large amount of people are concentrated along the east and west coast and there is a large amount of land in the middle of the country with lower populated areas. The similarities with Italy and Japan, however, need to be more closely looked at. Italy is more densely populated than Australia, but like Australia, it is very populated in and around the 5 or so major cities (Rome, Milan, Venice, Naples, etc.) and a big drop off in population density the further away one is from the major cities. Japan needs a much closer look; the entire country is densely populated, with no real unpopulated areas. What makes Japan comparable is its similarity to the southeastern and eastern coast of Australia. Much of Australia's population is located along this strip (between Melbourne and Brisbane) and is comparable to Japan. The rail networks of Japan can play an important role in the high speed proposal located along the Melbourne-Brisbane corridor. Although the similarities can be inconspicuous, the countries chosen all have their similarities to Australia that allowed for helpful information while constructing our proposal of Australia's rail network (See Appendix H).

[15] 06:00-10:00; 15:00-18:00
[16] Necessary adjustments were made to normalize the different costs, inflation and currency exchange rates were used for normalization (Coinnews Media Group LLC) (OANDA, 2012)

Conclusion and Recommendations

Figure 1 is our proposal for Australia's rail network. After careful consideration of the different rails, we determined that these routes would be the most beneficial for the majority of the population as well as the most economical. Although some rails may not be the most direct path, some lines allowed for a larger portion of the population to use the high speed rail.

For further studies, we recommend that the following areas are researched in more depth: station placement, cost analysis, environmental cost, societal costs, exact track placement, and frequency. Due to time constraints, few of these areas were examined, but altogether could provide more useful and justifying information for building a successful rail network.

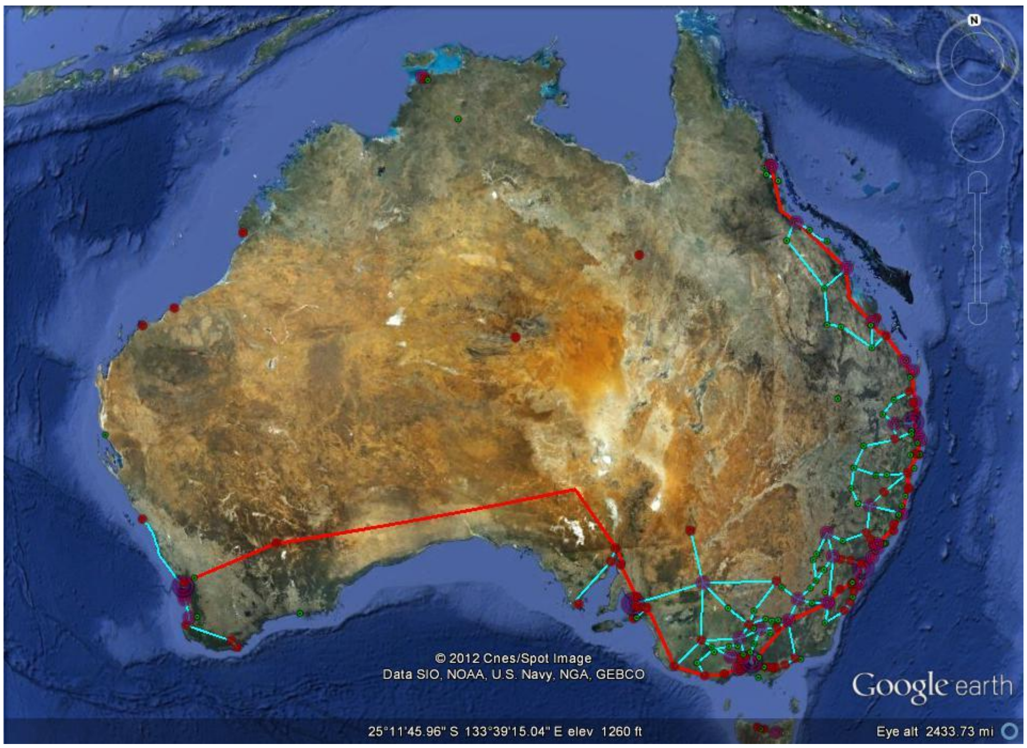

Figure 1: Final Proposal (red = high speed, light blue = fast/basic lines)

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I. Introduction

Global warming is an enduring societal issue that is devastating the world, partially due to human activity. According to research done by NASA's Goddard Institute for Space Studies, transportation was the number one contributor for the reported 30.4 billion tonnes, of carbon emissions throughout the world in 2011, and will continue to be the leading cause unless something is done to change people's method of transportation (Rogers & Evan, 2011). However, the lack of a viable, alternative compels people to drive automobiles, which emit up to four times more carbon per passenger-kilometer[17] than public transportation (Quarmby, 1967). Although some countries are beginning to take action by giving their citizens incentives to buy eco-friendly automobiles, most countries are concentrating on upgrading their public transit in an attempt to increase the ridership of trains and buses (Burwell, 2010).

Australia has taken the initiative to reduce carbon emissions from its transport sector by improving its current rail network, which is lacking in many areas. The Australian rails lack speed, convenience, and accessibility. The rails in Australia are either basic speed (<200km/h) or fast speed (200-250km/h), but they are missing the high speed rail technology which allows trains to travel at speeds of up to 350km/h. The network is very difficult to utilize since it is very disconnected, making short distance trips take longer than intended, and is inaccessible to many people throughout Australia. People would use the rail network if it was easily accessible and provided more frequent and faster services than it currently does to popular travel destinations (Wright & Hearps, 2010).

Currently, Australia is looking to connect its major cities[18] using a high speed rail network, which in turn will connect the majority of Australian citizens. This project proposed a rail network with stations providing access to 80% of the population. It was important to investigate economic and technical factors that contributed to the creation of a successful high speed rail network, including acceptable *coverage*, *convenience*, and an understanding of *cost restraints*. Research was done on notable rail networks throughout the world in order to create a basis for the Australian proposal. The knowledge of how other countries built their rail networks and their plans for extending them provided helpful insight to better understand the development of Australia's high speed network.

Beyond Zero Emissions (BZE), a non-profit organization, is directing utility research and creating a high speed rail proposal. We assisted BZE by creating a rail network proposal that connects the major cities across Australia with high speed lines, and fast/basic speed lines branching out to achieve a coverage of 80% of Australia's population. Data justified this proposal with numeric and qualitative characteristics in regards to coverage, convenience, and construction costs of rail networks from other countries. These data included population distribution vs. station placement, rail types and corresponding speeds and the cost of building these different tracks.

[17] Passenger-kilometer refers to the one kilometer traveled by a passenger (someone who is traveling by the method of transportation reference [car, train, etc.])
[18] 5 major cities (population >500,000) Perth, Adelaide, Melbourne, Sydney and Brisbane

II. Background

1. Global Warming

Global warming has become a popular topic for discussion and entertainment. Movies such as *The Day After Tomorrow* portray the effects of global warming as apocalyptical, with numerous extreme natural disasters such as massive tsunamis and tornadoes. Although the full extent that global warming will have is unknown, it is a very real issue that, if ignored, will do irreparable damage. In order to attempt stopping the process of global warming, the source of its existence must first be understood.

1.1. What Are Carbon Emissions

Greenhouse gases are molecules released into the atmosphere by multiple sources which absorb infrared radiation[19] and reflect some of the captured infrared radiation (in the form of heat) back towards the earth (Carbon Dioxide Information Analysis Center (CDIAC)). A component of engine exhaust is carbon dioxide, a greenhouse gas. Once released, these emissions are normally absorbed by sinks, such as plants and oceans, which process the carbon until oxygen is released (EPA). Unfortunately, carbon is being heavily emitted into the atmosphere at a rate that the sinks cannot adequately support (ibid). The infrared radiation that is absorbed by the greenhouse gases is responsible for keeping the atmosphere at a sustainable and balanced temperature. These gases act as a blanket around the Earth; however more radiation is being retained as more carbon is emitted into the atmosphere, leading to an increase in temperatures, hence 'global warming' (West).

1.2. What will happen if the level of carbon emissions is not reduced?

Research has shown that as carbon emissions increase, the atmospheric temperature of the world will increase (IPCC, 2007). Slight changes in global temperatures can cause glaciers to melt, which inevitably leads to a rising sea level (ibid). These changes affect society in many ways; for example, the flooding of low lying coastal areas, contamination of freshwater reservoirs and disruption of agriculture and life around the world (ibid). The initial signs of coastal flooding, limited supply of fresh water, extreme weather, and disruption of eco systems have begun to emerge, but these issues have the ability to exacerbate (ibid). Steps must be taken to reduce carbon emissions before it is too late; a major step that is being put into effect is to decrease the amount of carbon released by the transportation sector.

2. Transportation

Transportation is responsible for 24% of the world's carbon emissions (Fischlowitz-Roberts). This percentage takes into account only the amount of carbon emissions released by transportation, and does not include the amount of carbon emissions released during the construction and implementation of the different methods of transportation (i.e. carbon emissions released by factories that produce automobiles)(ibid). In order to lower carbon emissions in the transportation sector, an assessment must be made of the different forms of transport in order to find which mode is the most beneficial to the

[19] Electromagnetic waves that are given off by warm objects (i.e. the sun) and heat objects that come in contact with them (Michaud, 1999)

environment, economy and society. The major modes of transportations that will be discussed in this chapter are automobiles, carbon-free methods (biking and walking) and public transportation (buses and trains).

2.1. Automobiles

In a study of England's transportation, participants were asked what factors encouraged them to use cars as their mode of travel. 44% of participants believed that using an automobile decreased their travel time, while another 39% could not get to their desired destination via public transportation (Kamba, O.K. Rahmat, & Ismail, 2007). This study demonstrates that automobiles are the preferred choice because of their convenience (ibid). There are many different types of automobiles, but those we focused on are gas-consuming, hybrid, and electric.

2.1.1. Gas-Consuming Automobiles

With today's technology, automobiles are becoming more advanced and more fuel efficient (All facts and figures). Today's average automobile emits twenty-eight times less carbon per kilometer than those of 20 years ago (ibid). Despite the large decrease, automobiles still release roughly 196 g/pkm (grams of carbon per person kilometer) (Chefurka, 2007). A study conducted in Germany determined that one person traveling via automobile emits approximately 100 kg of CO_2 on a 545km trip making gas-consuming automobiles one of the highest carbon emitting modes of transportation (Ludewig & Aliadiere, Rail Transport and Environment: Facts and Figures, 2008).

2.1.2. Hybrid and Electric Automobiles

In recent years, manufacturers have developed hybrid and electric automobiles. Hybrid automobiles run on gas energy and electric energy generated by the gas, while electric automobiles run strictly on electric energy. Driving a hybrid emits roughly 148 g/pkm, while driving an electric automobile emits about 135 g/pkm (Chefurka, 2007). If these automobiles are better for the environment and they still provide the same comfort and convenience of a gas consuming automobile, then why do few people drive them?

There are multiple concerns with these automobiles, especially electric. To begin, an electric automobile can only travel a certain distance on one charge and there are very few places to recharge their batteries. The average distance electric automobiles can travel is approximately 65km. Meaning a person driving an electric automobile can either travel 32.5 km before they would need to turn back to recharge, or hope that there is a place to recharge within the next 32.5 km (AFP, 2010). Another problem that researchers are currently working on is how to quickly recharge the automobile batteries. It is recommended to recharge automobile batteries overnight to be fully charged in the morning, but this impedes people's freedom of traveling at their leisure. Finally, electric cars are expensive to purchase and maintain. One may believe these automobiles are affordable because they eliminate the cost of gas, but one of the cheaper electric cars, The Leaf, costs $32,780 (Jaffe, 2010). It is believed that batteries will last an average of three to five years and to replace a battery could cost well over $15,000 (Gunther, 2011). "Very roughly… electric-car batteries cost up to $1,000 per kilowatt. The Leaf has a 24 kwh [kilowatt hour] battery, the Volt a 16kwh battery, so their upfront costs are thousands of dollars higher than comparable gas-powered cars" (ibid). Some battery manufacturers claim that battery prices will drop after a decade of production, but Menahem Anderman, principal of Total Battery Consulting Inc., does not believe this, arguing "The cost reductions aren't attainable even in the next 10 years… We still don't know how much it will cost to make sure the batteries meet reliability, safety and durability standards. And now we are trying to reduce costs, which automatically affect those first three things (Ramsey, 2010)." Although electric automobiles sound good in theory, they are not ready to be marketed in full force, eliminating them from the search for a reliable and energy efficient mode of transportation.

2.2. Carbon Free Methods of Transportation

Although these methods are often overlooked, biking and walking can be practical forms of transportation. After the cost of purchasing a bike, the upkeep is relatively inexpensive (replacing parts, flat tires, etc..); such costs are non-existent for walking (Kansas State University's Physical Activity and Public Health Laboratory, 2009). Biking or walking also allows people to be on their own schedule, while incorporating physical activity into their daily routine (ibid). For small trips, biking and walking are both feasible methods of transportation, but there are many variables that make these two methods less practical. What happens when the weather isn't good? What if you need to carry multiple or heavy items? What about long trips? During a Kansas State study, many of the participants said they would consider walking or riding a bike if the trip took 20 minutes or less. In 20 minutes, at an average walking speed (~5km/h) and average biking speed (~24km/h), one can get about 2.4km and 8km, respectively (ibid). Other concerns included the lack of storage space for the bikes and a place to freshen up before class or work (ibid). Though these carbon free methods of transportation are ideal, their inability to provide long distance travel in a timely manner hinders their utilization. The next option is public transportation.

2.3. Public Transportation

There are multiple modes of public transportation, but our focus was on buses and trains (Kamba, O.K. Rahmat, & Ismail, 2007). Looking back at the study carried out in England, automobile users were also asked what would get them to switch to public transportation. The top two responses were the modes' ability to run on time and a greater accessibility for users (ibid). Although buses and trains cannot run as frequently as automobiles can (people can simply drive their own automobile whenever they please, but trains/buses do not operate every minute), they can still operate often enough to warrant an increased usage (ibid). The real question is which of the two, train or bus, is worthwhile to make more accessible to the public?

2.3.1. Buses

Buses offer commuters a method of transportation that emits significantly less carbon than automobiles, per passenger-kilometer. A report by Andreas Schafer and David Victor shows that buses only produce 1.1 MJ/p·km (Megajoules per person-kilometer[20]), compared to the 2.2 MJ/p·km produced by automobiles (Schafer & Victor, 1998). Another table in the Schafer report shows that the bus travels at a much slower average speed during its route, taking into consideration the numerous stops a bus makes (ibid). While a bus is half as energy intensive as an automobile, it cannot compete with the automobile's average speed during travel. An ideal form of transportation should not only be less carbon emissive, but should also run at an average speed competitive to that of an automobile, to allow for better travel times (Kamba, O.K. Rahmat, & Ismail, 2007).

2.3.2. Trains

Although, we have discussed and researched many different methods of transportation, the well rounded[21] and preferable option is rail. Research has shown that when single occupancy drivers switch a 30km daily round trip commute to public rail transportation, their CO_2 emissions will decrease by approximately 2,200kg per year, equating to a 10% reduction in a two automobile household's overall carbon footprint (Public Transportation Helps Protect Our Environment, 2011). In another study, a person traveling by train on a 545km trip only emits 25kg of carbon[22], compared to the 100kg emitted by an automobile along the same trip, making public transportation one of the most effective ways to reduce harmful carbon emissions per individual (Ludewig & Aliadiere, Rail Transport and Environment: Facts and Figures, 2008). Furthermore, Schafer's study shows that electric rails produce a miniscule 0.4 MJ/p·km, compared to the 2.2 and 1.1 produced by automobile and bus respectively (Schafer & Victor, 1998). In many cases trains travel faster than automobiles, up to speeds of 320km/h (ibid). Non-high speed trains are able to provide average travel speeds that are more competitive than buses (trains travel 50% faster than buses) (ibid). Trains are one of the least carbon emissive (pkm) forms of transportation and can travel at speeds similar to (and in the case of high speed trains, faster than) automobiles; hence they become the optimum alternative to automobiles.

3. Australian Rail

Australia recognizes the advantages of providing a good rail network to draw people away from automobiles and begin reducing the country's carbon footprint (Low, 2008). The public's desire to shift from road to rail transportation is apparent. A survey conducted in Melbourne showed that 27% of the people were choosing to use their cars less, and rail use increased at a rate of 8% per year between 2005 and 2008 (ibid). Unfortunately, the growth of demand cannot be met without the construction of a new infrastructure because the current network is insufficient (ibid).

3.1. Current State

[20] Carbon emissions depend on the energy intensity of a given mode, MJ/pk·m provides an amount of energy based upon the kilometer traveled by one passenger.
[21] Able to comply with environmental, economic, and societal standards
[22] Calculated from average number of passengers based on past ridership that is updated yearly (IFEU, 2010)

Figure 2 shows that the Australian rail network lacks a high speed rail line and is very disconnected, running latitudinally but not longitudinally. Travel between Sydney and Melbourne takes up to 12 hours and costs roughly $90 traveling via Country Link (RailCorp, 2005). This is far too slow considering it only costs between $60 and $175 (depending on the airline, time of day, and how far in advance you book the flight) for a 1.33 hour flight (I Want That Flight, 2011).

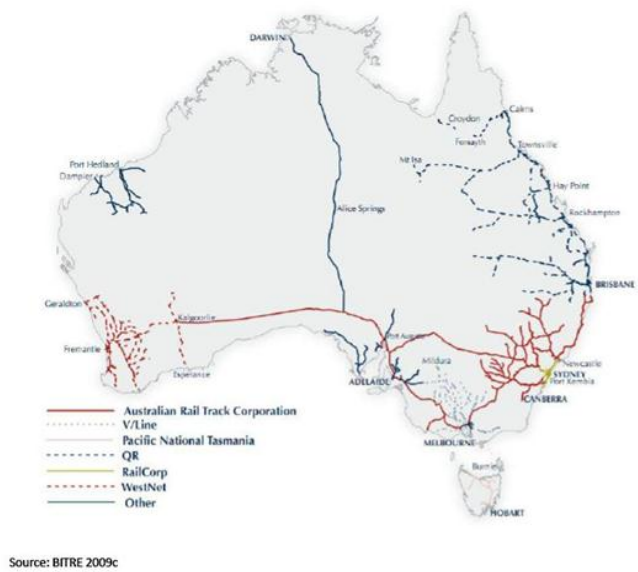

Figure 2 Current Rail Map of Australia (Nye, 2011)

The project group actually experienced how bad the Australian rail network is first hand. While visiting Brisbane, two of the project members traveled from the CBD of Brisbane to Surfers' Paradise (two popular destinations within Queensland). Traveling via train and then traveling by bus from the train station to the beach took roughly 2 hours (excluding the time spent waiting for the transportation); compared to the hour cab ride it took to return from the beach to the CBD. Furthermore, Australia's current rail network is comprised of several different *track gauges*[23], which creates problems switching between the different rail lines (Heidt, et al., 2010).

3.2. Desired Improvements

While it would be ideal to provide a rail network for 100% of the population of Australia, it is not feasible (BZE, 2011). Figure 3 shows 90% of Australia's population[24]; however, 82% is located within or surrounding its 5 major cities: Perth, Adelaide, Melbourne, Brisbane, and Sydney, with a few cities/towns of 5,000-30,000 people, and the last 10% (~2500 cities/towns of 5,000 people or fewer) scattered throughout the rest of the country (ibid). A high speed network connecting the 5 major cities is desirable (Rood, 2011). The country has been investigating the costs and routes of a high speed line linking Melbourne and Brisbane, with stops at Canberra

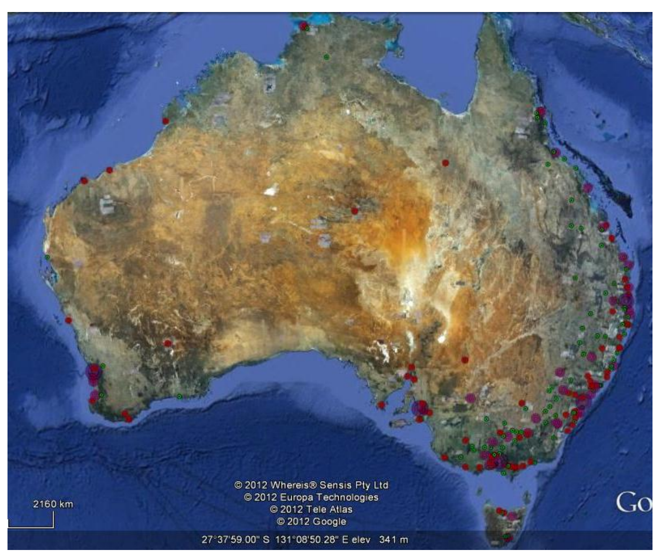

Figure 3 Australia's Population (Google Earth)

[23] Width of the rail

[24] the last 10% is registered as "rural balance", "no usual address", or "Off-shore areas & migratory"

and Sydney (ibid). Such a proposal could reduce travel time between Melbourne and Sydney, by train to as little as 3 hours (traveling at speeds of up to 350 km/h), all for as little as $100 to the passenger (ibid). Furthermore, with an increased public desire to use the rail, there comes a need to build a brand new infrastructure, or at least upgrade the current network, in order to allow for the capacity to provide for the growing demand (Low, 2008). Speeds of trains on the current lines need to be increased to provide for quicker travel times between destinations, and the extra capacity provided by a new/upgraded rail network will allow for faster rail services to avoid being caught behind slower trains that stop more frequently (ibid).

4. Building a Successful Rail Network

Multiple factors play a role in the planning of a successful rail network. The three main elements that are within the scope of this project are *cost of construction*[25], *network coverage*[26] and *consumer convenience*[27]. These factors were chosen to serve as further research to both the survey questions asked in regards to public transportation in England (Kamba, O.K. Rahmat, & Ismail, 2007), as well as the weighted-factor analysis on the rails in the US (Todorovich & Hagler, 2011). While it may certainly be argued that other points should receive as much if not more attention, the timeframe of this study and access to various sources and types of information were limited.

4.1. Cost

The cost of building a rail network must be viewed from many standpoints to fully understand how to apply it to any setting. These include a normalized cost per length, cost of different rail speeds, and cost of applying landscaping techniques to accommodate the rail.

4.1.1. Measure against Benefits

One way to look at the effect of costs is how they compare to benefits over a set period of time. This requires the consideration of more than just the monetary input/output, but also the time, labor and resources put in, as well as the social gain yielded (See Appendix B). More specifically, every input can be categorized as either initial investment, time-dependent fixed costs and time-dependent usage costs (the latter two generally involving maintenance and operation) (ibid). Furthermore, while the initial investment lacks the dependency of time, it still acts as a function of the plan, where the rail length, terrain type, necessary rolling stock and stations play a role (ibid).

4.1.2. External Costs

[25] Cost of building the rail lines which includes the planning and land costs, infrastructure building costs, and super structure costs

[26] The rail network's accessibility to its commuters and its ability to provide the options of high speed (250+ km/h), fast (200-250 km/h), or basic (<200 km/h) trains within the city of the station or an adjacent city

[27] The rail network's ability to provide services frequently throughout a daily operational period that is able to fulfill commuters' needs

External costs are crucial in deciding where to run certain rail lines within the network (See Appendix B). The world is not completely flat; terrain varies as you go from place to place; therefore, the price of building over different terrains varies as well (See Appendix G). While trying to connect point A with point B, there may be decisions such as whether to tunnel through a mountain or run the rail around it. For example, a metro line that is in the process of being built in Copenhagen, Denmark, costs almost $250 million/km because the whole rail network will be underground (Railway Finance, 2012), while a high speed line built in France costs about $11 million/km (Arduin & Ni, 2005). Which route is best depends in part on the cost of each method; however, without data on the cost of building on different terrains, an informed decision cannot be made.

4.2. Rail Network Coverage

In order for the Australian population to use the rail network, we use the criterion that it covers 80% of the population, as previously mentioned. The type of rail (high, fast, and basic speed) each line utilizes is crucial in providing its passengers with a time efficient means of transportation.

4.2.1. Accessibility

Travel to a large (in terms of development, population, etc.) city is beneficial for multiple reasons: work, sight-seeing, visiting family/friends, etc. Hence, larger cities should have more in/outbound connections than smaller cities. The relationship between city size and connectivity can easily go hand-in-hand towards defining how accessible a rail network is to the majority of a population (See Appendix C). Additionally, the more tracks a rail network has, the more likely it is to provide access to its passengers. Although more rail track can mean more access to passengers, it is not necessarily important when considering the location of a network's population. For example, Australia could have track that covered the entire continent; however, it doesn't need that much track considering the majority of its population is located on less than 50% of its land (See Appendix H). More than just accessibility needs to be accounted for when considering rail network coverage.

4.2.2. Type of Rail

The type of rail (high, fast or basic speed) utilized within the rail network is important to determine because the different types of track and trains have different limitations (Infrastructure, 2012). While all high speed tracks may be enticing, high speed trains make wider turns than slower trains and cannot travel along steep gradients, due to the high speeds in which they travel (ibid). Also, when a train travels at 250+ km/h and weighs as much as it does, it requires a longer time to accelerate to full velocity; and likewise, it needs more time to brake when coming to a stop (See Appendix E). If the train is to stop too frequently, it may undergo times at which it does not reach its maximum speed and thus, be rendered inefficient (ibid).

4.3. Convenience

Motivation of passengers to use public transportation plays a big role in the switch from road to rail (Kansas State University's Physical Activity and Public Health Laboratory, 2009). While most of what may fall under “motivation” deals with the outcome of private ownership of the network (consumer cost, advertising, etc.), there are some important components that are affected during the development stage of a rail proposal. These include the frequency of train stops, as well as the travel time between the connected cities.

4.3.1. Frequency

A train that runs once per day is of little use, and unappealing to the public (Kamba, O.K. Rahmat, & Ismail, 2007). The more frequently a train visits a station, the more convenient and appealing it is for its passengers (ibid). Of course, the frequency of a rail network has its limitations. Trains cannot run at 1 minute intervals, as the cost for all of the trains necessary throughout the network would far outweigh the social benefit to having flexibility and is unlikely to be economically sustainable (See Appendix B).

4.3.2. Travel Times

Why would a passenger bother taking a train to work, if they can travel faster by car? Whichever commute takes less time will surely be a major factor of choice, whether it means more time to have a good breakfast, finish up some last minute work, or get a few more minutes of sleep (Beesley, 1965). So everything time-related about taking the train must compare to the fewer nuances of taking the automobile (see Appendix F). It is not enough that the train has an overall higher speed than the automobile for the route, but that the train does not have too many stops, otherwise the total time of the trip will build up and become greater than that of the trip by automobile (ibid).

5. The Gap

Coverage, convenience and cost were considered and applied to our rail network proposal. Beyond Zero Emissions (BZE) also used this information to develop their proposal which works with upgrading the current rail network. As seen earlier, the current rail network is very disconnected and to fix this, new lines are being designed to connect more cities. In order to determine which rail lines are desirable and useful, information to make such informed decisions is required.

5.1. What Is Known

BZE has collected a considerable amount of data on Australia and its population. There are maps depicting the location of all cities and towns with the populations of each, and much more related info on them. Information on Australia’s population, its travel habits, employment, etc. can prove helpful in developing rail lines within a rail network.

5.2. What Is Missing

Information on international rail networks was needed to make informed decisions and provide models of successes and failures of rail networks. The information needed to be collected and compiled into an organized data base: enter, stage right, the project team. We assisted BZE with the collection and organization of international data and provided our own rail network proposal that, instead of using the figures and rail line ratings that BZE has used in its rail network proposal, decided to focus generating a rail network that provides coverage for 80% of the population of Australia.

III. Research Methods

This chapter will discuss the methods that were utilized during the project. The primary goal of this project was to design a rail network proposal that reaches 80% of the population by collecting statistics on other countries' rail network. The proposal will include connecting the 5 major cities (Adelaide, Brisbane, Melbourne, Perth and Sydney) via high speed rails and using fast and basic rails to connect the rest of the population. This was accomplished by:

- Gathering information on the entire[28] rail network of France, Germany, Great Britain, Italy, Japan, Spain, Switzerland, and US
- Analyzing these countries' rail network using the criteria of rail network *coverage, convenience, and cost*
- Proposing a feasible rail network that covers 80% of Australia's population

The following sections cover how each objective was completed including the specific methods that were used.

1. Examination of International Rail Networks

The acquisition of background information and statistics was necessary to create a foundation of rail knowledge. The examination of other countries allowed for a greater understanding of what helps make a rail network successful. Recently, many rail networks have either been upgraded or are in the process of being upgraded, making the information even more relevant and useful (Milmo, 2009).

Using online databases and archives, specific factors for each rail were researched, such as the coverage, convenience, and cost, so we could use them to create our own rail network proposal for Australia.

1.1. Why the Analysis of European Rail Networks

European rails were chosen for two reasons. First, railway travel is widely utilized due to the many areas of high population density throughout Europe (See Appendix H). This allows for observations of heavily used rail lines throughout specified nations in Europe. Second, Europe is the home to the most prominent rail networks in the world, such as the Swiss Federal Railways, which has been operating since 1901, currently runs 87% of its trains on time and serviced over 347 million passengers in 2004 (SBB, 2004). Europe currently contains over 5,000 km of total high speed track and many countries, such as Spain, France, and Germany, plan on doubling or tripling their amount by 2025 (Milmo, 2009). Furthermore, studies have shown that, since upgrading their rail networks, there has been a greater use of public railway (ibid). The latter of the reasons was particularly important in choosing which rail networks to analyze.

[28] Including all high speed, fast speed and basic rails throughout the country

1.2. Why the Analysis of US Rail

Unlike European rails, the US rails (Amtrak specifically) are lacking in many areas, including coverage and speed. The rails run mainly along the coast and do not extend into the middle of the country (See Appendix H). The current top speed for Amtrak trains is only 145 km/h (National Railroad Oassenger Corporation, 2012). The US has a high speed rail proposal in the works known as America 2050. We chose to research the US because their rail proposal addresses upgrades that are similar to the ones Australia seeks. For instance, the US is taking a country with no high speed rails and adding a whole new high speed rail network (High Speed Rail in America). The US proposal was also able to provide information on the costs of upgrading, building new rail lines, and why certain lines were chosen over others (ibid).

1.3. Why the Analysis of Japanese Rail

Japanese rails were chosen primarily for their superior high speed rail network. Other countries, such as China, have based their high speed train technology off of Japan's Shinkansen (bullet train) (Mong, 2010). As of 2008, Japan was the leader in total high speed lines, with 2,452 km (Milmo, 2009). Although Japan is more densely populated and smaller than Australia, the success of Japan's high speed rail network has become the pinnacle of quality rails (Mong, 2010).

1.4. Gathering the Information

As previously discussed, the type of information collected was coverage, convenience, and cost. Future plans of expansion were also researched in order to gather more up to date information on designing a rail network. By knowing the location of the train stations with respect to the population and understanding why stations were placed where they were (major cities, popular travel destinations, etc.), we were able to choose which cities/towns a station should be placed in.

1.4.1. Coverage

For rail network coverage, maps of up-to-date population densities were acquired to show how the countries related to Australia. It was important to see how other countries' population densities compare to Australia to justify the use of international rail data as the basis for the proposed rail network in Australia. The allocated data requires a specific use because of the disproportions of population densities throughout the countries (See Appendix D). For example, take into account the differences in localized population density; the feasibility of a rail network to cover 90% of Japan's population greatly differs from the feasibility of covering 80% of Australia's population. This is because Australia's population is more widely distributed than that of Japan as seen in the population density maps of Japan and Australia (See Appendix H).

Maps of the rail networks and location of rail stations were used in conjunction with the maps of population densities in each country. A list of cities containing a train station was generated from these station-route maps and available rail network specific information. The location of the rail stations in relation to each country population determined how each country deals with the accessibility of their rail network. We calculated the accessibility of each country's rail network; the sum of the populations of each city/town containing a rail station was divided by the total population of that country, in order to provide a percent population that resides in a city/town with a train station. For future reference, this equation will be referred to as the *Station Population Ratio (SPR)* (See Appendix H).

1.4.2. Infrastructure of Rails

Speeds at which each rail runs provided another factor. We acquired maps that provided the location of all existing and proposed “high speed” and “fast speed” rails in Europe, Japan and the US. Additional research was done on the individual train companies to show stations at which high speed trains stop.

1.4.3. Convenience of Rails

When addressing convenience, travel times between popular destinations (major city to major city) were acquired from each rail companies’ website. This method also proved useful for finding the availability and frequency of services. The frequency that each train stops at each train station was gathered straight from the rail proprietor’s website, generally by simply looking at a timetable or pretending to buy a ticket and looking at all the available times throughout the day. In some circumstances, the trains did not depart at set intervals, in which case an average was calculated. The hours of operation each station operates at were found in the same manner.

1.4.4. Cost of Rails

While coverage and convenience are important, cost plays a big role in all decision-making processes. To give an idea of how much the rail line may cost and to help determine the most feasible location of rail lines, the cost of building them was researched. We acquired the average price of rail construction per unit length in each country in order to calculate how the price may vary from country to country. There was limited information on cost available to us, but we gathered as much information as possible and normalized[29] it all in order to find the best average estimate for each country. This information was then used to provide an estimate for building a rail network in Australia. We also acquired different prices on the types of tracks because out rail network proposal contains a variety of track type. Also, we used the cost information in our proposal, in order to determine whether it is more economically viable to build a high speed line through or around mountainous terrain.

1.4.5. Future Expansion of Rails

Additionally, we researched any future expansion plans for each country. Many government sites or government reports contained their plans of rail network upgrades or expansions which had gone through feasibility studies and moved onto the design and construction stages. These future plans, along with the aforementioned international rail data, were considered when generating our rail network proposal for Australia.

[29] Currency and inflation were taken into account when looking at cost, via currency converters and inflation calculators found online (Coinnews Media Group LLC) (OANDA, 2012)

2. Analyzing the Collected Data

Once the international data were collected, it was organized into several Excel spreadsheets. These spreadsheets provided BZE with valuable information for its own use on projects, and allowed us to analyze international rail networks and compose a rail network suitable for Australia.

2.1. The Data

The researched data was categorized into several spreadsheets, based on rail network coverage, convenience, and cost. Disclaimers were included and noted when appropriate; for example, if the population data was from a different year. Each spreadsheet included a summary tab which highlighted the main statistics of each country, while each individual country had its own tab, with a detailed breakdown accompanied by the sources used.

2.2. The Data Analysis

We gathered data on international rail networks to provide individual analysis of each country. During analysis we looked at the rail networks of each country and learn where they locate the stations and where high speed lines were used over fast/basic speed lines. We learned that it is not about the length of track a country has, but rather the speed and frequency the track offers. Understanding the rail networks of other countries and transferring that knowledge onto Australia's rail network allowed us to make better decisions with regards to rail line and train station placement. Furthermore, we learned if it was effective to extend to a city/town that was a tourist attraction, but had a small population. The international data could only be used as guidelines and references, given the varying statistics of coverage, convenience and cost. Using the analysis of combining and comparing information of international rail networks, we formed a foundation of information to which the current Australian rail network could be compared. The data provided to us by BZE on Australia and its rail network also required analysis to provide us with insight on the current state of the rail network and where necessary improvements and/or installations could be added in the proposed rail network.

3. The Proposal

After all the data from the international rail networks had been collected and analyzed, the information was used to create a proposal for our rail network in Australia. The target was to reach 80% of the population with this proposal.

3.1. 80% Coverage

The main objective[30] of our rail network proposal was to achieve 80% coverage. This was concluded to mean that 80% of the population of Australia either resides in or is located within 10km of a city/town that contains a train station. Google Earth was used to view the most up to date census for the location of the most populous cities/towns that house 80% of Australia's population. The main objective to cover 80% of the population was to connect the 5 major cities with a high speed line

[30] See beginning of Methods for list of objectives

(Adelaide, Brisbane, Melbourne, Perth and Sydney). For many situations there were multiple different options, but using the knowledge attained from the international rail networks we were able to make decisions regarding our proposal. We also looked at the elevation profiles for different lines in order to determine if a line would need a tunnel or bridge. For our proposed rails we tried to minimize the use of tunnels and bridges to minimize the building cost (Appendix G).

3.2 Different Rail Lines

Cost influenced the chosen path of rail lines within our proposal to make it economically feasible. By avoiding high slope gradients, we minimized tunneling and kept costs low. We didn't have all the necessary resources to form precise cost estimates; therefore, we could not rely heavily on cost for our proposal. The cost estimates provided to use by BZE was used to help determine whether it is more reasonable to have a rail line run through a mountain (tunnel cost) or around it (no tunnel cost, but more track) (See Appendix G). Furthermore, all the information gathered and analyzed on international rail networks was used to make informed decisions throughout the creation of our proposed rail network. This was where future plans and estimates were very useful for us by giving us an idea of what a current rail network would cost with the new technologies that are being used.

4. Summary

Using comparative and data analysis, we were able to create a rail network proposal that covers 80% of Australia's population. Upon completion, we provided a database of international rail networks and a rail network proposal for Australia. BZE will be able to use this international information and the rail network proposal to make informed decisions regarding its own proposal.

IV. Findings/Results

1. International Rail Networks Information

Three different spreadsheets of the research were created: population of cities with stations, costs and frequency (See Appendix H.1). The sheets contain the raw data for each country, with which calculations, inferences and analogies to Australia's current state were made.

1.1. Station Location and Population

For our project, it was crucial to observe where stations were located relative to the population density and distribution. From a visual standpoint, it allowed us to see if each country followed suit with our definition of coverage and placed stations in highly populated areas. To further assess the utility of these graphics, we may suggest a relationship between the maps and our definition's characteristic quality of the population being in the city with a station, or in a city within 10km of a city/town with a station.

1.1.1. Overview

Table 1 displays the different information collected relating to the population of cities/towns with stations. As seen in the table, Japan covers the most people with their stations, but Great Britain has the greatest percentage of its population with a station in the city/town. For most countries, high speed stations are located in cities, on average, greater than 300,000 people.

Table 1 Coverage Summary Table for International Rails

	France	Germany	Great Britain	Italy	Japan	Spain	Switzerland	US*
Total Population of Cities/Towns with Stations	13,849,626	23,123,632	38,642,153	17,613,946	63,701,995	20,345,890	2,948,644	61,305,595
Total Population	64,876,618	81,702,309	59,000,000	60,600,000	127,450,460	46,081,574	7,825,243	307,006,550
Total Population of Cities/Towns with High Speed Station	3,781,062	22,532,807	7,287,845	11,333,944	41,190,338	8,221,381	2,948,644	46,049,442
% Population Located within Cities/Towns with Stations	21.35%	28.30%	65.50%	29.07%	49.98%	44.15%	37.68%	19.97%
% Population Residing in City/Town with High Speed Stop	0.58%	27.58%	12.35%	18.70%	32.32%	17.84%	37.68%	0.21%
Average Size of City/Town with High Speed Stop	378,106	229,927	45,143	404,784	441,707	483,611	15,853	639,576
Total Rail (km)	33,778	33,706	20,000	24,227	13,000	15,288	5,063	21,200

*US numbers are based of America2050 Proposal (Todorovich & Hagler, 2011)

1.1.2. France

France's rail network is made up of all three types of tracks, but is known for their high speed rails known as the TGV. There are currently only ten cities with high speed stations in France; with an average population of just under 200,000 people[31]. The high speed rail stations are in densely

[31] Paris was considered an outlier and not considered when determining the average size of the cities

populated areas so although there are limited stations, many smaller cities have access to them (See Appendix H.1.1). The populations of the other cities with fast and basic stations range from a few hundred to hundreds of thousands. The average population of the other 238 cities with stations is 41,230. Altogether, about 21% of the French population resides in a city/town with a train station. Most of the more densely settled areas are in close to a city/town with a station. As for the rest of the population, many people live in rural areas with less densely settled communities.

1.1.3. Germany

86% (98 stations) of the rail stations in Germany accommodate high speed rail. The population of each city containing a station ranges from 4,929 to 3,460,725, with an average of 229,927. There are three populations of under 10,000 (slightly over 0.01%), where there are high speed rail stops, but these stations are points of interest that are used for tourism, such as Binz, Germany, which contains an island resort in the northeastern part of the country (See Appendix H.1.1).

1.1.4. Great Britain

At first glance, Great Britain appears to reach a high percentage of its population with its rail network; however, almost every rail line is either traditional or fast speed. There is only one high speed rail line (109 km in length), consisting of 5 train stations: 3 of which are located within London (See Appendix H.1.1). Great Britain's high speed rail network reaches 12.35% of its population. Unfortunately, London accounts for 12.15% of this population; therefore, excluding London, Great Britain's high speed network only reaches .02% of its population. Fortunately, Great Britain's government has recently approved a new high speed rail proposal known as High Speed 2. This new high speed network will connect the major cities of Great Britain (Birmingham, Manchester, Liverpool, Leeds, and Glasgow) with London (Department for Transport, 2012). The lines connecting these cities are in the process of being researched and proposed to the government for approval. At the current moment, only the line between London and the West Midlands has been approved by the government (ibid). Assuming the High Speed 2 plan is completed, it will provide Great Britain with a high speed network that reaches 17.5% of the population (5.5% excluding London). Great Britain's rail network provides stations to roughly 500 towns that contain less than 20,000 people, and of those 500 towns, 400 contain less than 10,000 people. This is an alarming statistic that is vastly different from every other country observed, and may well be the reason why Great Britain is not considered to have a successful rail network.

1.1.5. Italy

Approximately 30% of its population resides in a city/town with a train station, with that number rising even higher when one considers the cities/towns within 10km (See Appendix H.1.1). Most stations are located within cities/towns of at least 20,000 people; however, there were roughly 10 towns of 20,000 people or less that contained a train station. Much of this reasoning was due to popular tourist attractions, such as Sibari, which is located on the coast in Calabria, or Limon (population 1572), which is located on Lake Garda, a popular destination (Rout).

Observation of Italy's rail map (See Appendix H.1.1) shows how Italy offers numerous paths and connections within its network. Italy focuses on concentrating its rail network within its high density areas, with virtually all of its rail network located within regions of at least 25-249 persons per km^2 (ibid). The network also offers travel in both longitudinal and latitudinal directions.

1.1.6. Japan

Japan provides a highly accessible rail network, and offers a plethora of options to its passengers. Japan is able to provide train stations in the cities/towns in which roughly 50% of its population resides and that percentage is even higher when considering the cities/towns within 10km (Appendix H.1.1). While most train stations are located in cities/towns of at least 10,000 or 20,000 people, some stations are located in towns with as few as 1,306 people. Low populated cities/towns that contain a station are usually site of high interest, such as ski resorts, summer vacation areas, etc. Ueno (Population of 1,306) is the smallest populated town with a high speed rail station, but it is the home of much of Tokyo's cultural sites and the Ueno Park, which is a prominent national park in Japan.

The rail network also contains a good number of line changes, allowing for both longitudinal and latitudinal travel. Observing the Population Density and Rail Network Map, not only do the rail lines connect the major cities, but there are several points of intersection allowing for travel in various directions. Japan also provides a variety of different types of trains along their rail network. Although much of their rail is high speed, they still manage to provide travel for the intermediate sized towns between the major cities.

1.1.7. Spain

Spain contains all three types of rails, but is best known for its advanced high speed rail network, AVE Alta Velocidad Española. Its high speed rail leads in distance in Europe and is the 2nd longest in the world with 2665 km of track. The Spanish population that resides within city with a train stations is roughly 44%, of which 17% reside within one of the 17 cities with a high speed station. Spain defines coverage as living within 50km of a station; therefore, 40% of the population is covered by the high speed network (Ministerio De Fomento, 2004). In 2004 the Spanish government approved PEIT, Plan Estratégico de Infrastruces y Transporte (Strategic plan for infrastructures and transport), an expansive infrastructure proposal which will then cover 90% of the Spanish population with a high speed station and have 10,000km total of high speed track (ibid).

1.1.8. Switzerland

All 185 of the rail stations in Switzerland accommodate high speed rail. The population of each city containing a station ranges from 30 to 372,857, with an average of 15,931. There are few populations of under 1,000 (See Appendix H.1.1), but they are generally points of interest that are used for tourism, such as Wasserauen, Switzerland, which contains a lake on a mountain for summer and winter travel respectively.

1.1.9. US

Only 19.14% of Americans live in a city with an Amtrak station. Amtrak only runs through 23 states and has limited stops because Amtrak is usually used for further travel (National Railroad Passenger Corporation, 2012). For short trips, many states have their own train networks that were not looked at for this study (See Appendix H.1.1).

1.2. Frequency and Time

Using online timetables, we were able to determine the frequency and travel times for the international rails. Not all information on routes could be found due to lack of resources.

1.2.1. France

From the timetables that were found, the TGV runs once or twice an hour to most destinations. During rush hour[32], the TGV runs at least twice an hour. Using the TGV, one can make the 427km trip from Paris to Lyons in just under two hours. The longest trip the TGV makes within France is from Paris to Marseille (749 km) in 3 hours flat (Arduin & Ni, 2005). The other noticeable fact about the frequency in France is that many fast and basic trains run every 45 minutes, but they do not always stop at all the stations. In many cases, a branch with 10 stations will stop at 6-8 of them during one passage and only run one train every couple of hours that stop at all the stations (See Appendix H.1.3).

1.2.2. Germany

Travel in the high speed rail network in Germany is divided into three main sectors by train, the *Intercity* (IC), the *InterCity Express* (ICE), and the *EuroCity*. Functionality-wise, there is little difference between the IC and ICE; both have very similar travel times on long stretches, to the point where the organization's informational website does not give discrepancies. These times include Berlin to Frankfurt in about 4 hours, Frankfurt to Munich in a little over 3 hours, and Berlin to Hamburg in about 1.5 hours. The main difference between the two trains is that the IC is often less available to make these long hauls, generally following a path that stops often to service passengers. The ICE was built for these journeys and makes more of these trips available. The *EuroCity* is an extensive high speed network that connects Germany with other European countries. The frequency of all three services is generally between 1-2 hours (See Appendix H.1.3).

1.2.3. Great Britain

Great Britain offers two different types of services along their rail network (excluding the high speed line). Many of their rail companies run basic speed trains that either stop at every station or alternate which stations they stop at, such as the First Great Western rail company, which operates the rail lines that contain about 25% of all of Great Britain's train stations (Railsaver, 2010). Great Britain provides frequent services between its major cities, offering fast speed trains that typically run on a semi-hourly or hourly schedule, with some trains running non-stop to their destinations (See Appendix H.1.3).

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1.2.4. Italy

Italy offers two main rail services: the Frecciarossa and the Frecciargento. The Frecciarossa is Italy's fastest train service, providing connections between: Milan and Rome, Milan and Naples, Bologna and Florence, and Rome and Naples. These trains reach speeds of up to 360km/h during their journey. Many of the lines offer non-stop train services once an hour, with other services making 1 or 2 stops running every hour or half hour as well. The Frecciargento offers connection between: Rome and Venice, Rome and Verona, Rome and Bari, and Rome and Reggio Calabria. These trains reach speeds of 250km/h. The Frecciargento offers 1 or 2 "Fast" (non-stop or limited stop) trains per line every day, and the rest of the trains that run hourly (on average) make more stops. Italy also offers high speed trains via Eurostar Italia. These trains run along lines that connect Rome to: Ancona, Genoa, Lamezia Terme, Reggio Calabria, Perugia, Ravenna, Rimmini, and Taranto (See Appendix H.1.3). While these trains run at speeds of over 300km/h, currently all Eurostar trains are being replaced by Frecciarossa trains (Gruppo Ferrovie, 2008).

1.2.5. Japan

Japan manages different types/speeds of trains for its passengers, allowing for travel that is available throughout the day at reasonable times, and provides services for a variety of passengers. For example, along the Tokaido Shinkansen line (Tokyo-Osaka) 3 different trains are run routinely throughout the day, all offering different services and making different stops. The Nozomi train, which reaches speeds of up to 270km/h, departs 4 times every hour (even more during rush hour) but only stops at Tokyo, Shinagawa, Shin-Yokohama, Nagoya, Kyoto, and Osaka, taking roughly 2.5 hours. The Hikari train also runs along the line, traveling slightly slower than the Nozomi and departing 2 times every hour, making 6 more stops along its route (Odawara, Atami, Mishima, Shizuoka, Hamamatsu, and Maibara) in roughly 3 hours. The Kodama is the final train that runs along the line, departing 2 times per hour and stopping at every station along the line, taking roughly 4 hours to travel from Tokyo to Osaka, or vice versa. This ability to incorporate different types of train on the same line allows Japan to provide services that run often, throughout the day and allow travel for a passenger who either desires to go straight from Tokyo to Osaka as fast as possible, or needs to stop at one of the less populated cities (whether going home or visiting a friend, etc.)(See Appendix H.1.3).

1.2.6. Spain

RENFE, Red Nacional de los Ferrocarriles Españoles (National Spanish Rail Network) has the responsibility of operating Spain's high speed rail, AVE Alta Velocidad. RENFE has a punctuality commitment for all of its lines; with the most exceptional being the Sevilla-Madrid Line which is sure to arrive within 5 minutes of scheduled arrival (Renfe-Operadora, 2010). AVE offers frequent services to and from major destinations particularly the Madrid-Barcelona, Madrid-Sevilla, and Barcelona- Sevilla lines running an average of 20 trains out of each station on a daily basis (See Appendix H.1.3).

The Sevilla-Madrid line departs with an average, daily interval of 45 minutes. This train line reaches speeds up to 300km/h and can make the 471km journey in 2 hours and 20 minutes (Ferropedia, 2011). The Madrid-Barcelona line departs, on average, every 37 minutes (See Appendix H.1.3) traveling the 621km between the two cities in 2 hours and 38 minutes in a one way train or 3 hours and 23 minutes if stopping at all the stations in between the two cities (Ferropedia, 2012). Due to AVE's ability to provide frequent services, AVE accounts for 65% of all passenger train travels (Madrid, 2009) (See Appendix H.1.3).

1.2.7. Switzerland

The rail network in Switzerland is governed by two main authorities, the *Zürich Verkehrsverbund* based in Zürich, and the *Tarifverbund Nordwestschweiz* based in Basel. Both organizations work together to create a very flexible system for anyone's travel. Open 24 hours a day, trains are available every 30-60 minutes depending on the length of travel. Long distances are travelled quickly, with trains making their way from either Basel or Zürich to Bern in a little over 1 hour, Zürich to Lausanne in over 2 hours, and Basel to Geneva in less than 3 hours. *Libero* is a third authority which offers a 15 minute frequency of travel. This fast speed service covers the cantons of Bern and Solothurn between 10PM and 2AM, to help local passengers get where they need to be at night (See Appendix H.1.3).

1.2.8. US

The Amtrak schedule varies from corridor to corridor. For highly travelled corridors (i.e. Northeast Regional), trains run almost once an hour during the week, but in other places (i.e. Chicago – Indianapolis) trains only run a few times a week. For this reason, most Amtrak trains are not used daily, but rather for trips (See Appendix H.1.3).

1.3. Cost per Kilometer of Rail

For the information that was collected, each number was normalized in a different manner. The currencies, years (inflation), regulations (wages) were different, giving us very different numbers for each country. These were all taken into consideration while we complied and compared the numbers we had for each country (See Appendix H.1.2). Unfortunately, with limited resources and construction prices confidential, in many cases, limited figures were found; therefore, only multiple, reliable figures were found for France, Germany, Spain and Switzerland.

1.3.1. France

France was one country with multiple different costs throughout the years. The oldest numbers that were obtained were from 1994. The cost of building a high speed rail in France in 1994 was $3.4 million/km ($5 million/km in 2010 due to inflation). In 2005, the cost was $10 million/km ($11.2 million/km in 2010). The final numbers that were found were from 2010 where it was said to cost $35 million/km for rail upgrades (See Appendix H.1.2).

1.3.2. Germany

A report released by the HM Treasury averaged the cost of high speed rail projects in Germany and gave an overall price of €57 million/km. As this average only incorporated 4 unspecified projects, further research was performed to acquire a more viable average with details on the type of situation in which the rail was placed. An underground rail in Copenhagen extended 16 km at a rate of about $15 million/km, while a massive project called Stuttgart21, which extended to many areas around Stuttgart, extended 60 km at a rate of over $105 million/km.

1.3.3. Spain

Spain has a lot of relevant information due to the recent and ongoing construction of high speed rail lines. Given Spain's rough and mountainous terrain the information gathered gave us insight on the production costs. The most recent and under construction costs for Spain would be the Basque Y network, with a cost of €22.57 million/km(See Appendix H.1.2) and a total projected cost being €3,882,040,000 (Ferropedia, 2011). The most expensive and longest corridor in total project cost, built in Spain to date is the Madrid-Zaragoza-Barcelona line, completed in 2008 at €15.88 million/km with a total cost of €9,861,480,000 (Ferropedia, 2011). The least expensive line built was the Madrid-Sevilla completed in 1992 at €4.88 million/km with a total cost of €2,298,480,000 (adjusted for inflation 2001) (ibid).

1.3.4. Switzerland

Averaging many rail projects in Switzerland over the years, the per km cost of Swiss rail comes to over $36 million. Costs ranged between 164 million CHF[33]/km for the Alp Transit Gotthard Project and 6.5 million CHF/km for the line which extended from Rhine, Switzerland to Rhone, France. Twin tunnels are planned for construction in Bremmer to upgrade their current rail at a rate of €109 million/km.

2. Australia vs. international rails

Using the information on the international rails, we compared Australia with each individual country. Some countries proved to be more similar or useful than others, but we were able to benefit from all the international rails.

2.1. France

Although very little is similar between Australia and France, but France's TGV is still a good comparison of a high speed network. There are currently only 10 high speed stations in France that are strategically placed so one can travel from one side of France to the other in a timely fashion. There are very few, if any, stops on many high speed lines and this was taken into consideration for our proposal. France shows the importance of straight high speed rails with limited stops. France used these high speed stations for longer travel and then branches out and reaches other places with fast and basic trains. This creates the ideal rail network that we sought since most of the population in Australia is found in and around large cities.

[33] Swiss Franc

2.2. Germany

There is a geographic analogy between Germany and Australia. All along the west coast of Germany lie major cities (Dusseldorf, Frankfort, Köln, etc.), while Berlin (which contains the most population by almost twice as much as the second highest) is located on the east side. There is a large area of low populated cities, likely due to the Hartz Mountains which are located along the longitudal center; similar to Australia's low populated cities within the center of the country, where there is more desert.

2.3. Great Britain

Great Britain is not very similar to Australia, but its lack of a high speed rail network and its current high speed 2 proposal makes it a good case study to explore. Great Britain plans on connecting its major cities with high speed rail lines, which is exactly what Australia desires and is researching. Upon completion of the proposal, the rail lines and maps can provide useful information for the Australian high speed proposal Furthermore, Great Britain provides the numerous stations (many of which contain fewer than 20,000 people) demonstrating how having more stops, does not necessarily make a rail network successful (See Appendix H).

2.4. Italy

Italy is much more densely populated than Australia; however, similarities can be seen between the two countries. Italy is very densely populated in and around its major cities (Rome, Venice, Milan, Naples, etc.), similar to Australia (See Appendix H.1.2). For this reason, the high speed rails in Italy can be an excellent study for the creation of Australia's high speed rail line.

2.5. Japan

At first glance, Japan appears to offers little similarity in terms of population density versus train stations to Australia; however, a closer look proves otherwise. Japan is far more densely populated than Australia, but what truly brings both countries on a similar playing field is the location of the populated areas. Australia is a much bigger country than Japan, but much of its population is located along the outer edges of the country, depicted in the population maps located in Appendix H. When comparing this corridor of populations and disregarding the rest of the country that is unpopulated, Australia becomes comparable to Japan. Once the mindset that Japan can be used to resemble the outer coast of Australia, the methods the country uses to connect its populations with a mix of high speed and fast speed trains can be analyzed and help form the basis of knowledge for the Australian rail network proposal.

2.6. Spain

Spain, though a small country, has many similarities to Australia when looking at the southeastern corridor of cities in Australia. When comparing Spain (504,030 km^2) to Australia (7,617,930 km^2) as a whole, Spain only has 6.5% of the total area of Australia. However, when comparing

Spain to the populated states of Victoria (504,030 km^2) and New South Wales (39,273 km^2), Spain is 60% of the combined areas, making it more comparable. Additionally, looking at Spain's longest high speed line, Madrid-Zaragoza-Barcelona (621 km), compares with the direct distance of Melbourne to Sydney (700 km) and Brisbane to Sydney (731). Conversely, looking at shorter distances such as, Madrid-Valladolid (179 km) and Madrid-Toledo (20.8 km) becomes comparable with other shorter distances in Australia such as, Canberra to Sydney (240 km) or Melbourne to Geelong (80 km). Similarities exist between the Spain's population distributions and Australia's when focusing on southeastern coast. Spain is populated throughout its coastal regions, where Australia also has similar dense populations. After the completion of Spain's first high speed rail line, Madrid-Sevilla (471km), a modal shift for transportation occurred. Before the high speed rail line, travel between Madrid and Sevilla could be broken down into airplane (33%), conventional train (14%), bus (15%), and automobile (60%) transportation. After the completion of the Madrid-Sevilla AVE corridor, transportation percentages drastically changed to airplane (4%), high speed train (52%), conventional train (2%), bus (8%) and automobile (34%). Considering the modal shift of transportation after the implementation of high speed rail (AVE) in Spain, Australia can expect to see a similar increase. Based off of this analysis we could expect high speed rail to become the optimum choice of transportation for short and long distance travels in Australia.

2.7. Switzerland

A visual comparison of the population density between Switzerland and Australia shows locational similarities. Australia's eastern coast holds many highly populated areas, from Cairns to Melbourne, with well-populated Perth on the western coast, separated by near barren land. Switzerland has a very densely populated northern side, from Neuchatel to St. Gallen, with Luçano in the south, separated by the Alps. There are still many cities that reside throughout the Alps, whereas Australia's outback contains very few cities. In both cases, these cities help connect the two areas of heavy population, with some Swiss cities' residency as low as 12,467 (Brig) having 4 direct-route inbound/outbound connections.

2.8. US

The US is in a very similar situation as Australia. There are no high speed rails in the country, but people are trying to fix this through the America2050 plan. The US and Australia both have a large amount of land with people settled in only a few areas. It is said that the US has 11 "megaregions" in which 70% of the total population resides and Australia has 5 major cities with about 55% of the population (Todorovich & Hagler, 2011). Finally a helpful discovery that was made while making the US proposal was that the most successful corridors are those that run from about 160-1000km while connecting major employment centers with large population hubs (ibid).

3. Possible Upgrades/proposals

We created many different rail lines, but not all were used in our final proposal. After creating different lines based on the information we had gathered from the international rails and Australia, we began to look at the best possible rail network. For some connections there were not many options. As seen in Figure 4, we designed 4 different routes between Melbourne and Adelaide, 3 between Melbourne and Sydney and 2 between Sydney and Brisbane. Tables in Appendix H are charts containing the total length of each track, the total population that is reached by each rail and the number of stations/stops that would be needed. Using this information and the cost estimation (See Appendix H), we were able to design the most desirable high speed rail for Australia.

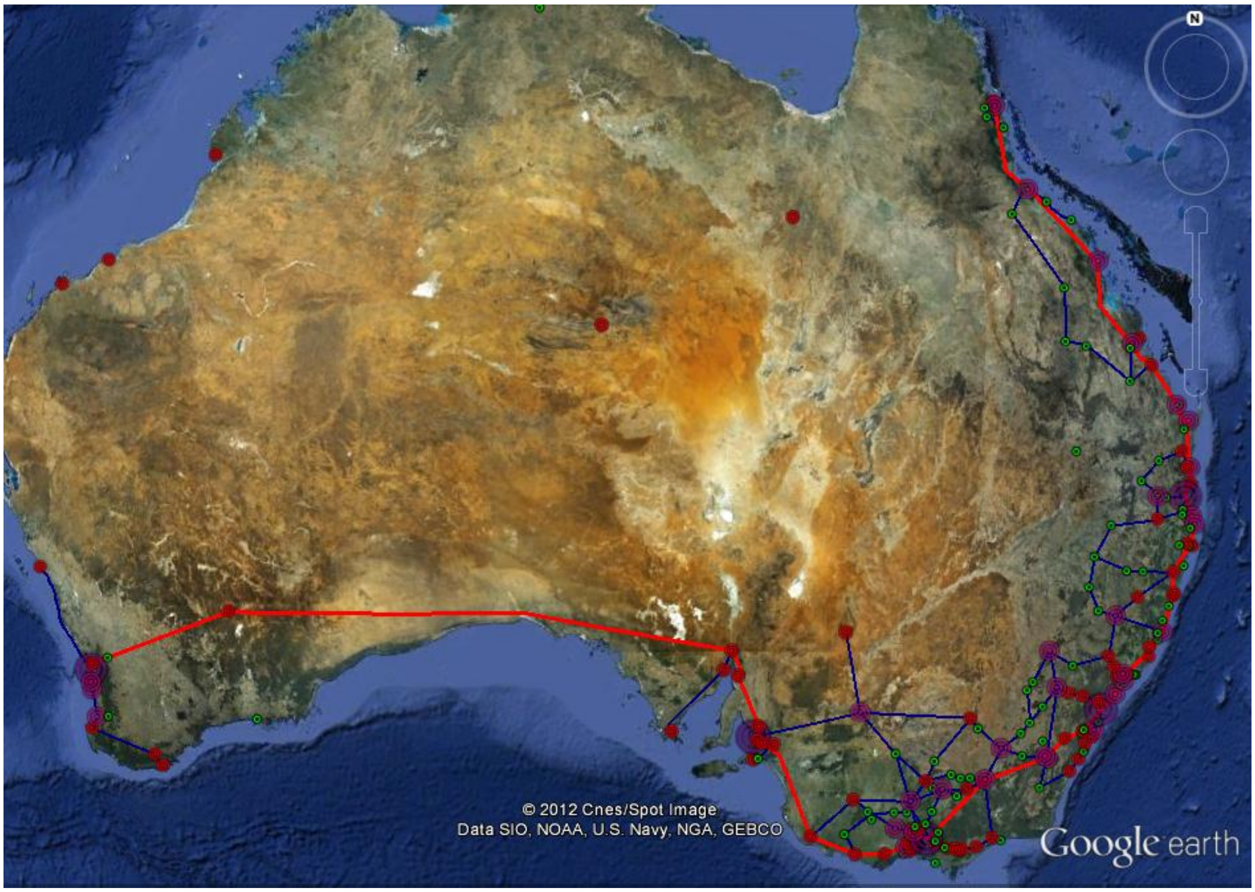

Figure 4 High Speed Rail Proposal (Google Earth)

Once the high speed rail was finalized, we began to connect other cities to reach 80% of the population. Following Japan's lead, we create a rail network with a high connectivity (See Appendix C).

4. Limitations of Research

As with any project there are limitations and restrictions that need to be considered. Also, with a time sensitive project some questions were not fully explored.

4.1. Information Acquisition

Most of the information we acquired or used in our project was obtained from the internet or information BZE had given us. The information from the web was mainly from government websites, but in some cases other websites were used. There is always a possibility that the information was not sufficiently accurate. Also, some information was taken from work BZE had done, so there were no other studies to support or reject its findings.

When it came to analyzing the information we had gathered, there were many factors that could have been overlooked. For example, when we compared cost we had to take into consideration inflation and currency conversions, but we also did not know if the cost of the materials had changed from year to year and country to country.

4.2. Biases

In many studies, there lies a bias that must be overcome. The major bias that we had to overcome in this study was being pro-rails. In our study we promoted the use of rails over all other methods of transportation, but we could not overlook data claiming that rail use contains negative effects or that other methods of transportation were better. Another bias was our focus on reaching 80% of the population. If we were not working to reach 80% of the population, our results could have been different depending on what our main focus was.

V. Conclusions and Recommendations

The information gathered on the international rail networks enabled us to construct a rail network proposal for Australia. The proposal incorporated many of the aspects that other countries' rail networks contained: station location, high speed rail versus fast/basic rail, and how each rail line operated trains of various speeds. Upon completion of the rail network, we were able to comprise a list of recommendations to help provide a successful rail network for Australia.

A successful Australian rail network would look like the one in Figure 4. The common theme found in every country with a high speed rail network was that all major cities should be linked with a high speed rail, minimizing stops between major cities. Limiting the amount of stops along a high speed line is important because the main purpose of a high speed train is to get its passengers from point A to point B as quickly as possible; more stops will increase the travel time. The more popular travel destinations in other countries were also given a high speed station, such as Ueno, Japan (home of much of Tokyo's cultural museums). This concept justified the allocation of a high speed line running up to Cairns, a popular point of access to the Great Barrier Reef; thus, the main 6 cities for the high speed line of our proposal were Perth, Adelaide, Melbourne, Sydney, Brisbane, and Cairns. Several lines could then be drawn, connecting city to city, creating the high speed line.

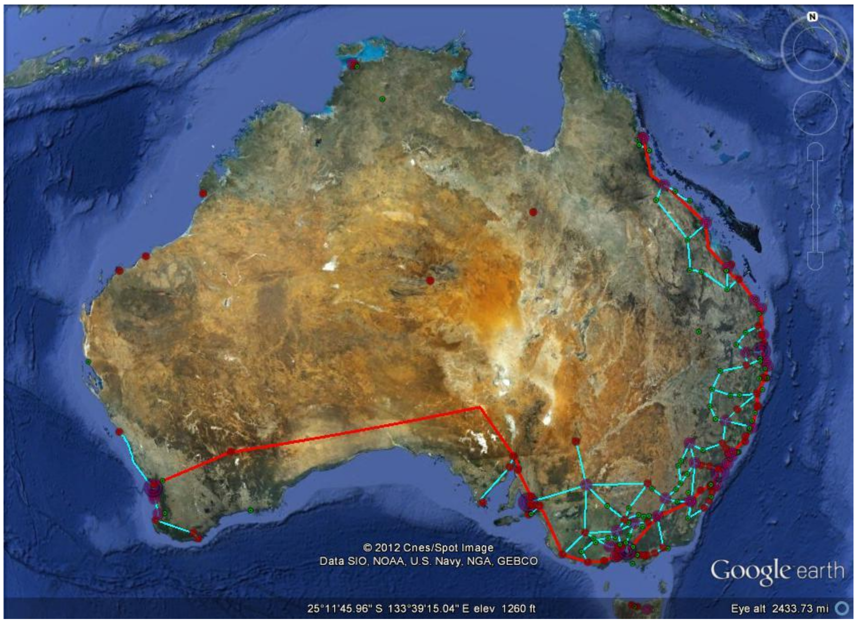

Figure 5 Australian Rail Network Proposal

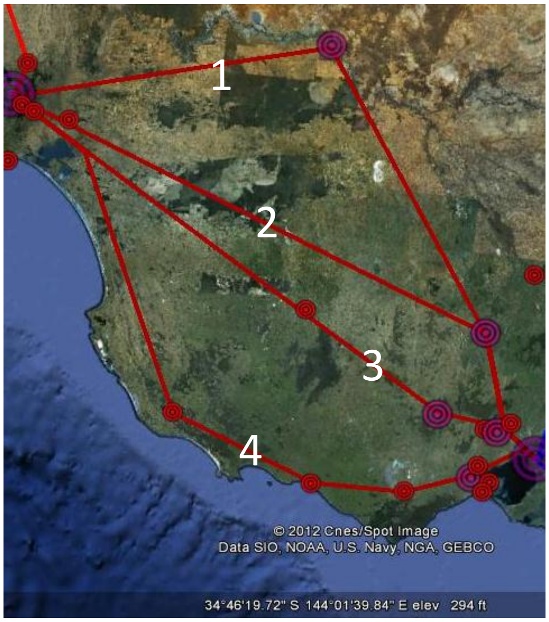

Figure 6 Adelaide to Melbourne Corridor

There were not many options for high speed lines from Perth to Adelaide, Sydney to Brisbane, and Brisbane to Cairns; however, from Adelaide to Melbourne and from Melbourne to Sydney, several options arose. We looked at different routes between two major cities, looking for a path that reached not only a large amount of the population, but had limited stops, was relatively direct, and avoided elevation peaks, due to mountains or lakes (more costly than building over a flat surface). Once multiple routes were mapped out, all of the aforementioned factors were considered while applying an estimated cost analysis. Weighing the different options, we decided on the chosen routes seen in Figure 4. The path between Perth and Adelaide was adjusted to avoid a reserve on the southern coast. Although, there was an option with one fewer stop for the route between Adelaide and Melbourne (Figure 5), route 4, with 6 stops, was chosen over the other 3 options because, although it cost an estimated $16 million more than any of the other 3 options (See Appendix G), it reached the highest amount of population, provided access to tourist attractions such as the various beaches in Victoria and the Great Ocean Road, and had the least grade of slope[34].

The route between Melbourne and Sydney (Figure 6) was more complex; we made three different possible routes and then had two combination routes. The most direct route that reached the highest amount of the population and had the best elevation was routes 1^L and 1^R which was chosen to connect Melbourne and Sydney[35]. The final corridor with different options was from Sydney to Brisbane. Of the two options (which can be observed in Appendix H.2.2) route 1 was the best because, it was a shorter more direct, reached a greater amount of the population, and had the least grade of slope.

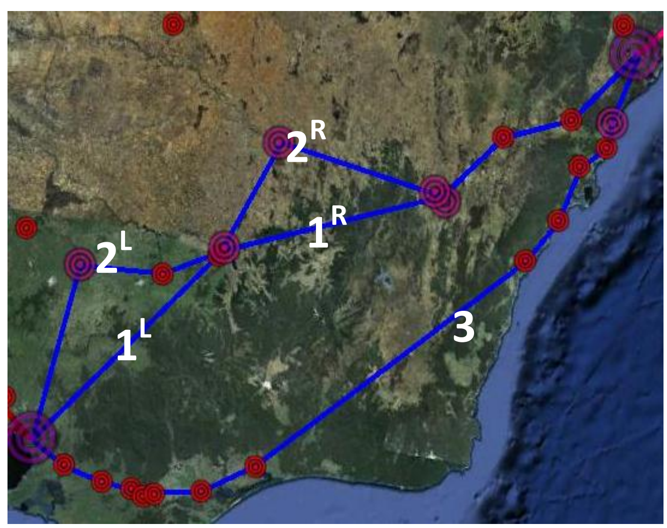

Figure 7 Melbourne – Sydney Corridor

After implementation of the high speed

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[34] The grade of slope was calculated in GoogleEarth along every rail line to determine the $\frac{rise}{run}$

[35] 1^L and 1^R run through national reserves and will need to modified slightly

line, the fast/basic speed lines were added to link up the towns surrounding the major cities[36], and provide the final 25% of Australia's population with rail access. The rail maps of the other countries provided insight on the paths of these other rail lines. Not only was it important to run rail lines radially out of the major cities, but it was also important to provide rail lines perpendicular to these radial lines, to form a grid within the rail network. These "crossing" lines were important to allow for the rail network to provide better connectivity and allow for more options while traveling, especially for the larger cities (50,000+ people).

The approximate cost of the high speed line was analyzed for several alternative paths. Appendix G depicts 4 optimized pathways in terms of maximum coverage, minimum cost, minimum stations and maximum distance. There was no one path that was best in all 4 qualities. These individual paths were not chosen because a numerical optimization was not concluded to be the most effective path; rather, an average was used in order to more effectively agree with the qualitative factors, such as the reaching of tourist attractions.

The denser populated countries, such as Japan and Italy, proved useful in the creation of the section of the rail network located between Melbourne and Brisbane, while the other less densely populated countries helped for the creation of other corridors of the Australian rail network. Many populated cities and towns are located between the Melbourne-Brisbane Corridor. With cities and towns so centrally located, the rail network turned into a grid, as opposed to having a radial pattern. Due to the numerous towns located within a small area, the grid patterns observed in the rail networks of Italy and Japan (the more densely populated countries) acted as useful analogies. When a rail network branches out from one city to reach 20+ towns, crossing lines between some of the further out towns should be added to the network to allow for travel between the towns further away from the city. The calculated connectivity of the other countries showed the importance of offering more connections along the rail line. These, as well as that of the proposed network can be seen below in Figure 7.

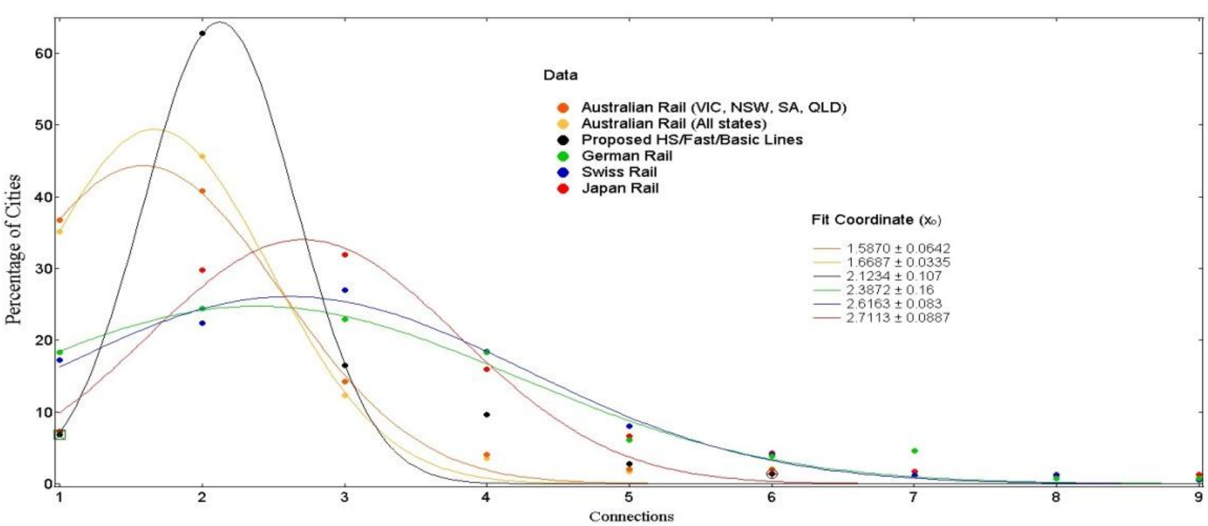

Figure 8 Rail Network Connectivity

[36] ~55% of the population

Originally, the network had an average number of direct connections of approximately 1.5, meaning (on average) every other station in Australia had one or two direct connections. Similarly, with Switzerland's current network, the 2.6 signifies the same situation but with two to three direct connections. With our proposal, the new value is about 2.1, thus the average station has at least 2 direct connections. The higher the connectivity of a rail network, the more destinations it can provide for its passengers, and the more likely the rail network's target population is to use the rail network (Kamba, O.K. Rahmat, & Ismail, 2007).

The rail network that we created requires further study and evaluation. Better software, in addition to more time spent analyzing local topography, can be used to determine the actual paths for the various rail lines. Additionally, the current rail lines throughout Australia can be compared with our rail network to determine if there is any overlap or if there is a path already along or close to one of our rail lines. This is especially important because it is cheaper to upgrade a rail line instead of building a new one altogether, and, if there is already a rail line that cuts through a mountain, it could potentially save more money to upgrade that rail line, instead of tunneling a new line (AECOM, 2011).

While the foundation of the rail network is important to its success (location of stations, type of track, etc.), it is also important to consider the types of services provided along the rail lines. Studies should be conducted to determine how often travel between the cities is required/desired. This information is essential in determining how often to run trains along the rail lines. Regardless of how often the trains run, we would recommend that the rail lines between the major cities run both high speed and fast speed trains. Based on the methods of other countries, it may be extremely beneficial to run a non-stop high speed train once per hour along the Melbourne-Sydney line, with another high speed train and a fast speed train running semi-hourly, making stops at select stations and at all the train stations along the line, respectively. This technique is utilized by Japan along its rail lines, and it is a very efficient method of accommodating passengers who want to travel longer distances more quickly, and those who desire to travel shorter distances. This method can be utilized along the fast/basic lines as well, having a fast speed train run and stop at select stations, and a basic speed train running behind it, stopping at all stations. The "select stops" that the fast speed train stops at can be determined by further study of the travel patterns of Australians; identifying the most popular destinations along a given line, and having those locations be the "select stops." It is also important, if this method is used, that the train that stops more frequently does not interfere with the high speed trains running behind them or the high speed train will have to slow down and will lose its effectiveness.

With our proposal and our recommendations, Australia can have a well-developed rail network that is accessible and successful, providing useful travel for both short and long distances. With a better rail network, Australia can expect to see a shift from road to rail. This shift will lower the amount of carbon emissions released by the transportation sector and in turn lower Australia's carbon footprint, reducing the effects of global warming.

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Appendix A: Glossary

Accessibility	The rail network's ability to provide its passengers with access points and destinations that fulfill their needs.
Carbon emissions	Refers to carbon dioxide emissions. Carbon dioxide released into the atmosphere due to the use of energy, and absorbs and emits radiation (EPA).
Connections	The different directions one can go from a given station.
Connectivity	The average number of direct connections a station provides (See Appendix C for further detail).
Convenience	The rail network's ability to provide services frequently throughout a daily operational period that is able to fulfill passengers' needs.
Cost	Cost of building the rail lines which includes the planning and land costs, infrastructure building costs, and super structure costs.
Coverage	The rail network's accessibility to its passengers and its ability to provide the options of high speed (250+ km/h), fast (200-250 km/h), or basic (<200 km/h) trains within the city of the station or an adjacent city.
Frequency	The interval at which a train departs from a train station.
Track gauges	The distance between the rails (inside rail to inside rail).

Appendix B: Cost-Benefit Analysis

In a recent study on high-speed rail investment, a relation between costs and profitability was found to be represented by the following:

$$\int_0^T B(H)\, e^{-(r-g)t} dt > I + \int_0^T C_f\, e^{-rt} dt + \int_0^T C_q(Q) e^{-(r-g)t}\, dt$$

Where:

- B(H) is the annual social benefits of the project. This may be economic or consumer convenience (availability, etc.).
- *Q* is the number of annual passenger-trips.
- *r* is the social discount rate, which may be representative of changing living cost values or depreciation due to age.
- *g* is the annual growth of benefits and cost which depend on the level of real wages and Q.
- *I* is the investment cost (construction, etc.).
- C_f is the annual fixed maintenance and operations costs.
- $C_q(Q)$ is the annual maintenance & operating costs depending on Q (usage costs).
- *T* is the total time of the high-speed rail project. For a permanent installment, we allow $T \to \infty$.

The equation has cleverly adopted the use of integrals and exponential functions instead of a summation of yearly functions to allow for the incorporation of any instantaneous changes throughout the functions.

The idea behind this equation should be straightforward; revenue should outweigh costs. It should be noted that the investment costs seems to be a constant, but from an urban planning standpoint, it is a complicated function in terms of track length, used land area and the type of track being used. It can be written as shown below:

$$I = C_l \cdot l + T(l, type) + M(l)$$

Where

- *l* is the rail length.
- C_l is the cost-per-length of rail.
- *T(l,type)* is the cost of landscaping the local terrain, as a function of the rail length and type of terrain (mountain, etc.)
- *M(l)* is other miscellaneous expenses as a function of track length, including train costs, station establishment costs, etc.

The *M(l)* function was used to shorthand the many other possible time-independent expenses that exist in establishing a high-speed rail. It should be noted that the terrain landscaping cost function is *not* *necessarily* a linear function of length. For a quick reassuring example, it is easy to dig a hole, but it is not easy to keep a larger hole from collapsing; this addition of length requires more work.

Appendix C: Connectivity

Background

The singular point in proving disconnectivity in the rail network, purely from a graph theory standpoint, is that not every station connects to every other station. From a more practical side, this is perfectly fine, as having every station do so would result in an unnecessarily large number of lines required to be constructed. The following equation shows the number of connections *N* resulting from a connected graph of *n* components.

$$N = \sum_{i=1}^{n-1} i$$

A rail network with 50 stations would have over 1200 lines! It would become the most ideal state of a rail for accessibility, but it would be financially impossible. Therefore, any feasible network proposition will require *some* stops for travelers. At this point, the question is raised as to *how* disconnected can it be to still be successful?

Method

To begin, the connectivity of the Australian, German, Swiss and Japanese (the latter three as a control [of "successful" networks]) rail networks are assessed. This is done by categorizing the number of connections in/outbound *direct* connections of a station with the number of stations that have such number. A single connection refers to a "dead-end" of a track, two being a station that may serve as a stop along a singular path, and so forth. The previously mentioned idealization is that each of the ***n*** stations have ***n-1*** connections (connect to all but itself). There is nothing wrong with having many stations with a lower number of connections: this is because, in general, most cities will have a low population. As the population increases, so should the number of connections to/from the city.

A Gaussian distribution equation can be found for the data set. The peak represents the average number of connections of all the cities. Figure 9 shows the result for each case.

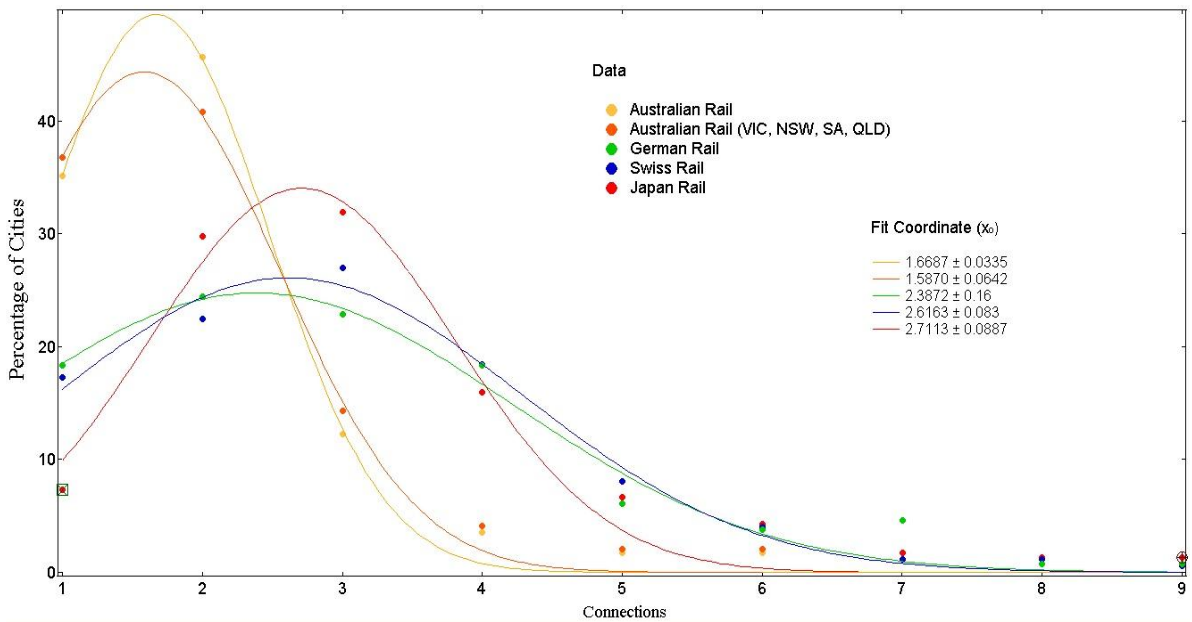

Figure 9 Initial Rail Network Connectivity

Limitations

There were two pitfalls throughout the development of this method.

- The magnitudes of these curves cannot be the same unless the numbers of stations are the same for all countries.

To fix this, percentages were used in either case. The dependent variable is therefore "The percent of cities with said connections", bringing the total integral of each case to 100.

- This method assumes a somewhat even distribution of population distribution.

This is true; graph theory fails to acknowledge the effects of one or more components having a very large distance from the larger portion of components. Such effects include issues of cost, or overall efficiency or even worth of creating these connections. This can very readily be observed in Australia, where most of the stations lie along the east coast, with Perth and Darwin (west and north coast) having one to two connections. The outlying cities do have somewhat comparable populations, but the fact remains that some of the stations lie in very sparse cities.

To remedy the latter issue, a second sample of Australia was taken, this time excluding Western Australia and Northern Territory, the lesser populated areas. Figure 10 shows the percent total population by city-station connection, a relation which depicts evenness of population density by number of connections. Switzerland has a relatively "nice" distribution, with less total population on each end (least and most connections), with growing and decaying population from the average of ~4.8 connections. As can be seen by Figure 10, the secondary Australian sample was just as lacking in average connections.

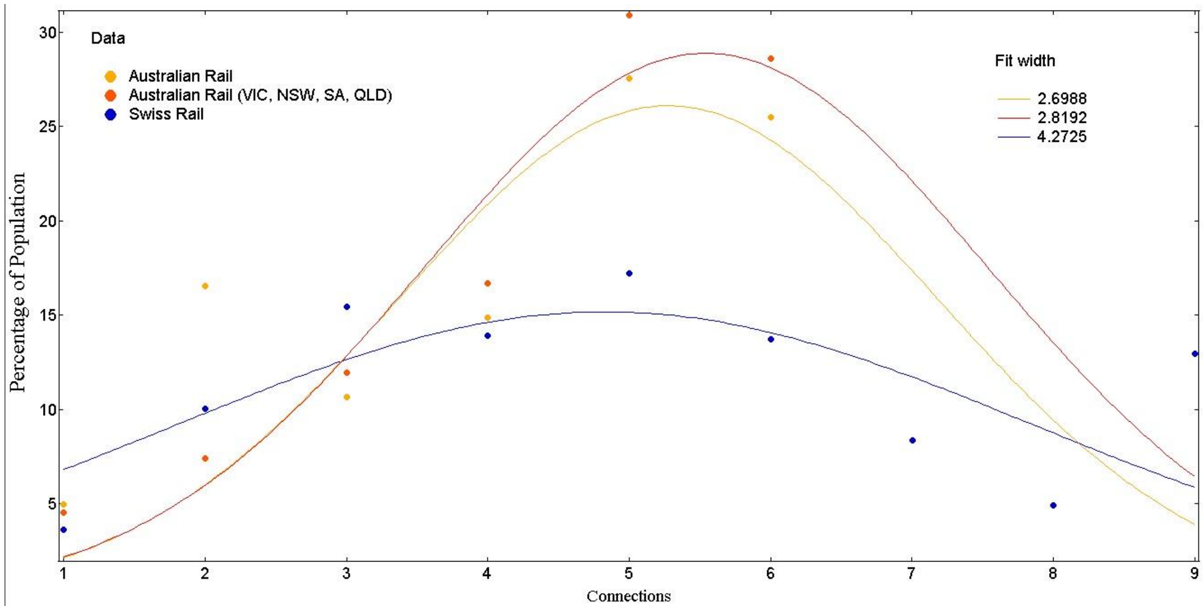

Figure 10 Population Distribution by Connectivity

The *width*, as shown in Figure 10, is the best fit for the quantity $\sqrt{2} \cdot \sigma$, where σ is the standard deviation of the Gaussian curve. Given that Switzerland can be agreed to have a much more even population distribution than Australia, we can therefore attribute its larger *width* to such. The smaller Australian sample has a larger *width* than the original and therefore has a more even population distribution.

This secondary analysis is restricted by means of statistical theory. There was no data of cities with seven or more connections in Australia, but the fit curves use the data and that side of the Gaussian anyway. This "ghost" data is generated by nothing more than the idea that the Gaussian curve is movable, as though one can figuratively translate the x_o coordinate back and forth across the connections axis, with each position its own relative population distribution correlation. The idea is based off of the original relation seen in Figure 9, where the x_o coordinate has more meaning.

Conclusion

The stations in Australia (both overall and within the more populated region), Germany, Switzerland and Japan (chosen due to their renowned success) were inventoried according to number of in/outbound direct connections. It was shown that, on average, Australian stations have one less connection than the other countries. Improvements made to this rail in regards to accessibility should ideally move this average towards the right, implying that, on average, Australians will have less of a hassle in getting from some points A to B, without making too many intermediate stops.

Appendix D: Population Distribution Weighting

Australia's population distribution is very unique, in that a very large amount of the population lies within few cities. Sydney and Melbourne alone make up over 35% of the total population. In order to have appropriately weighted comparisons of countries, a graphical analysis of all population distributions must be made. While certainly all of the case studies will be considered for what they have to offer, the more similar a countries distribution to Australia, the more its rail network can apply.

There are two ways to show population distribution. One way is to use a *cumulative percentage of population* vs. *number of cities* graph. What this does, assuming cities are ordered from most to least populated, is give a nice curve along the number of cities as it approaches total population. This is shown by Figure 11.

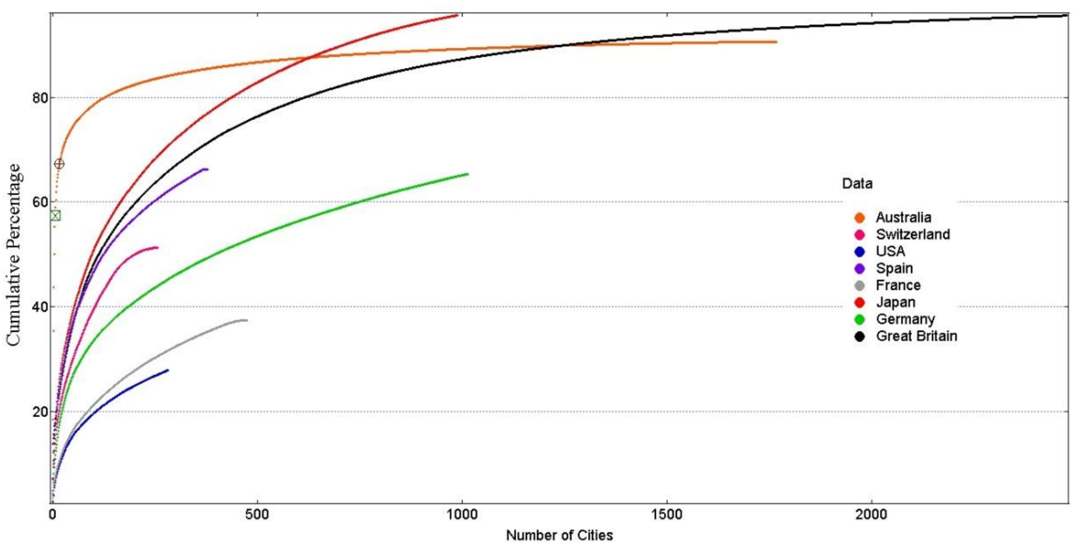

Figure 11 Cumulative Population by Cumulative Cities

At first glance, the graph seems like it will prove to be very useful. Unfortunately, there are multiple downfalls to this method. Clearly, there is not enough available info on all of the cities in other countries. Many places will generally have large cities (capitols, metropolitan areas, etc.), cities/townships and a great deal of small/near-uninhabited cities. Such latter cities are often only known due to tourism, such as Wasserauen, Switzerland, which has a population of 30, but is connected to a major high speed rail line due to its proximity to a mountain and lake, which serve as tourist attractions. Aside from this missing information, it is also quite difficult to make a numeric analysis on these graphs. Undoubtedly, exponential functions may be used as a best fit to the curves in this graph, but they vary far too much to be an accurate fit for too long (along the x-axis). Even with multiple exponential functions in place, there is still too much variation. Furthermore, there is no good combinatoric explanation for the use of the exponential argument(s).

The other way to display population distributions is to assign each city to belong to a particular category of population. These categories must be carefully chosen to allow for an optimum representation of the distribution; a logarithmic scale can be deceiving, and anything else non-linear (such as an arbitrary list [10,000, 20,000, 50,000, etc.]) can misrepresent the population. Thus, the ideal representation is to use percentiles for the categories.

The total population is divided into 1000 equal partitions. Each city is categorized into a particular percentile, given by the ratio of the city's population to the total. The populations of multiple cities within a particular percentile are summed and a bar graph is created. Figures 12 and 13 show the results for Australia and Great Britain.

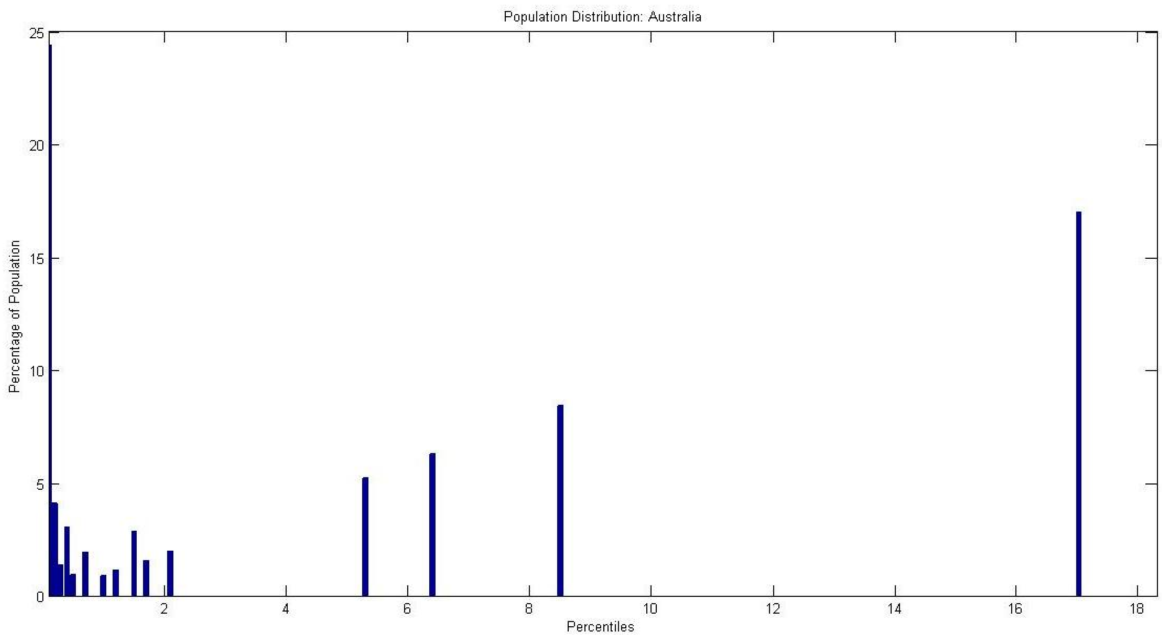

Figure 12 Population Distribution by Percentiles - Australia

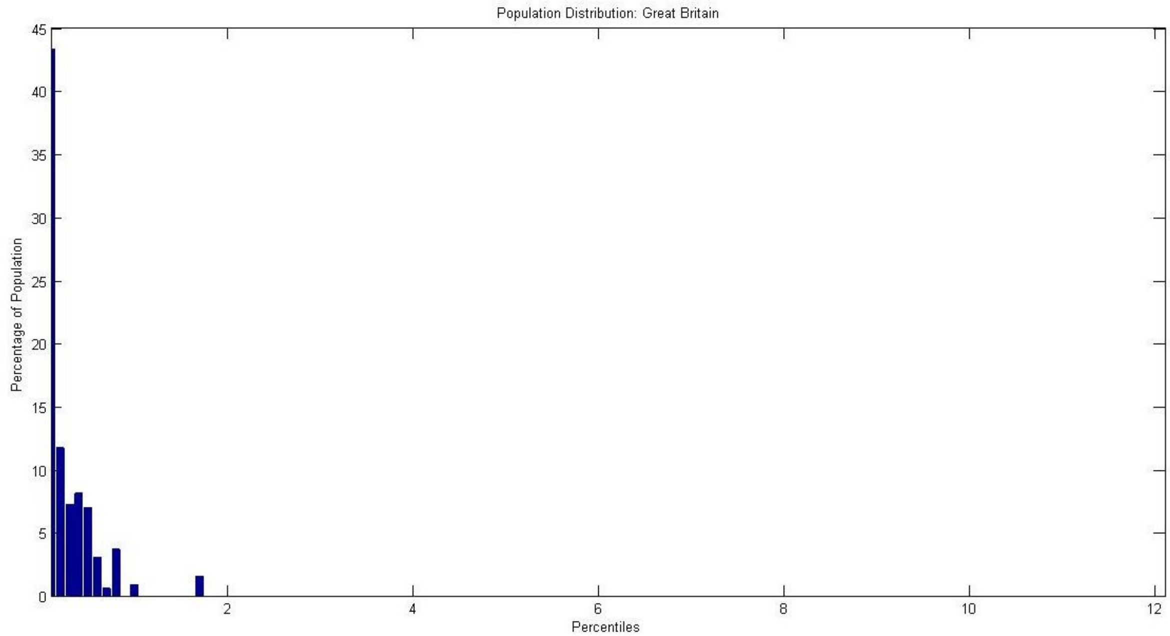

Figure 13 Population Distribution by Percentiles – Great Britain

Obviously, there is *very* little in common between Australia's and Great Britain's population distribution. These two were chosen as the weighted average of all cities and their percentage of population was closest, Australia at the 7.6757th percentile of its population and Great Britain at the 1.3151th percentile. All other cases' weighted average remain underneath the first percentile. It is with this numeric conclusion that one can justify by ratios of populations that Great Britain proves most useful for comparison.

However, these percentiles do no justice for the corresponding populations. The 7.6757th percentile of Australia is 1,523,883, meaning the average Australian lives in a city of said population. The closest case study to this population is Japan, whose weighted average percentile of 0.94501th corresponded to a population of 1,204,420. Interestingly enough, Japan was second to Great Britain in average percentile, but vice versa in population (GB at 775,909). This allows for a more robust conclusion that Great Britain and Japan are equally (if not somewhat more so Japan) suitable for population-based comparisons. Table 1 below shows the weighting results for all of the cases.

Table 1 Comparison of International Population Distributions

Country	Average Percentile	Population	Weighted Average Population
Australia	7.6757th	19853342	1,523,883
Great Britain	1.3151th	59000000	775,909
Japan	0.94501th	127450460	1,204,420
Spain	0.92018th	46081574	424,033
Switzerland	0.57042th	7825243	44,637
Italy	0.45691th	60600000	276,887
Germany	0.44580th	81702309	364,229
France	0.26662th	64876618	172,974

Appendix E: Locomotive Dynamics

The location of stations along the pathway of a rail network requires knowledge of what type of train is being used. High speed trains would be inefficient if they cannot reach their maximum speed, which will occur of the length of track between the stations is too short to allow the train to accelerate enough.

The dynamics of train acceleration and deceleration can be derived from Newton's Laws, given a few experimental constants. Considering an accelerating train, the sum of all of the forces acting upon it governs its inertia as a whole:

$$ma = F_T + F_g - F_d - F_f$$

In this equation, *m* signifies the total mass of the train (hull, engine, crew, patrons, everything), a is the acceleration, F_g is the gravitational force acting upon the train (which affects the acceleration positively on downward slopes, and vice versa), F_d is the aerodynamic drag force of the train, F_f is the friction force between the train and track, and F_T is the tractive force of the engine pulling on the cars. These parameters can be expanded given a couple of assumptions: the train is powered with an electric current, and the velocity is high enough to use the *high Reynold's number* interpretation of drag force (this means the momentum transfer effect of the internal system [inside the train] is negligible compared to the momentum of the external system [the train itself]).

$$ma(t) = 1976900\frac{\epsilon P}{v(t)} + mgSin(\theta) - \frac{1}{2}\rho v(t)^2 C_d A - \mu mgCos(\theta)$$

From here we make the following exemplary numeric assumptions (followed by sources of assumptions):

- P (power of train) is $9{\cdot}10^6$ W (http://irsme.nic.in/files/FACT_RLY_ELC.pdf)
- ϵ (efficiency coefficient) is 90% (http://www.easts.info/on-line/journal_06/278.pdf)
- m (mass) is $2.358{\cdot}10^6$ kg (http://www.irfca.org/docs/stats/stats-goods-train-load.html)
- g is 9.8067 $\frac{m}{s^2}$
- ρ (air density at 20°C and 1 atm) is $1.2041\frac{kg}{m^3}$
- C_d (unitless Drag coefficient of train) is 1.8 (http://www.engineeringtoolbox.com/drag-coefficient-d_627.html)
- A (reference frontal area) is 11.5 m^2 (http://www.scientificbulletin.upb.ro/rev_docs/arhiva/rez86368.pdf)
- μ (unitless coefficient of friction) is $2.312{\cdot}10^{-3}$ (http://www.inrets.fr/ur/lte/publi-autresactions/fichesresultats/ficheartemis/non_road4/Artemis_del7b_rail.pdf)
- θ (angle of slope) can be assumed to be zero (flat land). This only removes the basic F_g term.

Assuming the initial state of the train to be at rest, this creates the following first order non-linear initial value problem for velocity:

$$(2.797 \cdot 10^6)\frac{dv}{dt} = (\frac{8.0065 \cdot 10^{12}}{v} - 6.3417 \cdot 10^4 - 10.837v^2), \text{ v(0) = 0}$$

From this IVP, we can infer the trivial solution of $v(t) = 0$; as the train will start at remain at rest, which nothing provoking the need for friction and drag forces. From here, we may apply Euler's method of linear approximation, which can be incorporated into a computer coded *for*-loop of iteration *i*.

$$v(i+1) = v(i) + \frac{(dt)}{(2.797 \cdot 10^6)}\left(\frac{8.0065 \cdot 10^{12}}{v(i)} - 6.3417 \cdot 10^4 - 10.837v(i)^2\right)$$

We can approximate the velocity of this model train recursively, point-by-point. Figure 14 shows the result of the previously mentioned code.

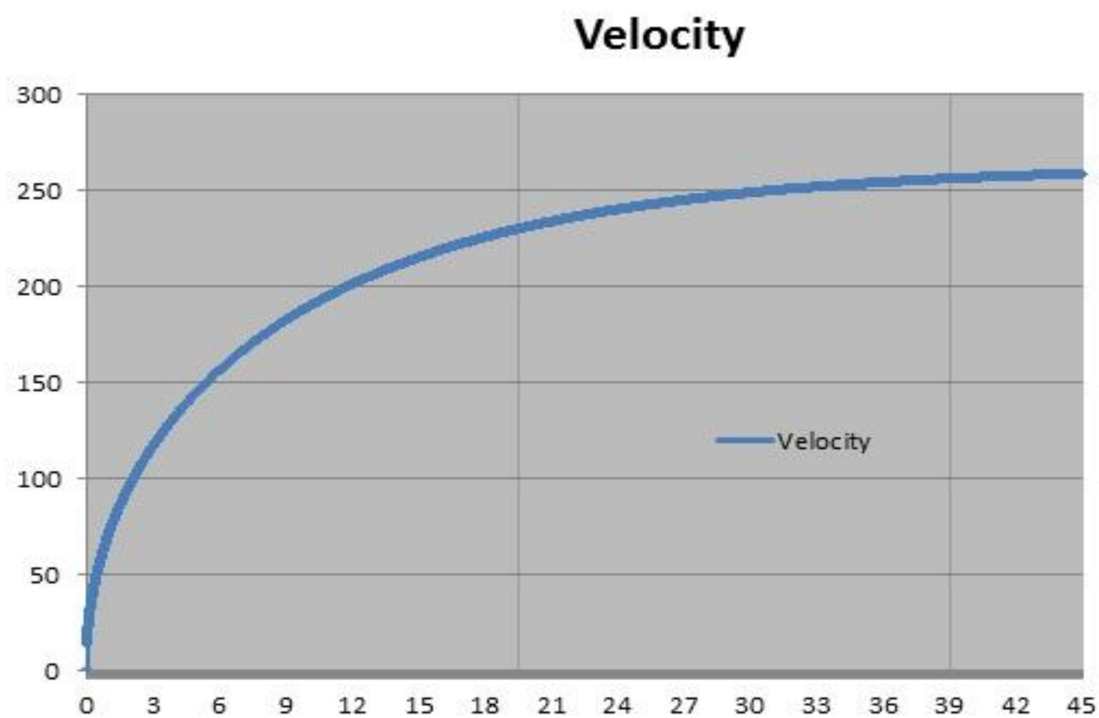

Figure 14 Approximate Acceleration of Locomotive

This exemplary motion of a high speed rail was calculated every 0.1 seconds for 45 minutes (shown on x-axis). To avoid the error of dividing by zero, the initial velocity was adjusted to 0.1 m/s (shown on y-axis converted to km/h).

This velocity curve not only gives a fine example of locomotive inertia based off of simple Newtonian principles, but also depicts a valuable piece of information. Around 31 minutes is where the train achieves the predefined "high speed" of 250 km/h. For a train with similar characteristics to this example, it would be vital that the travel time is at least 31 minutes in order for the use of the train to be worthwhile. Otherwise, it would be more cost effective to implement a basic or fast speed rail system.

The deceleration of a locomotive undergoes identical forces with the exception of the tractive force. It is not assumed that the self-propulsion force simply goes to zero, as this would imply that the train simply allows itself to slow to a halt. This is by far not the case as emergencies would not be capable of being evaded (such as applying more brake in order to avoid a collision). Thus, we assume that a constant brake force F_{br} is applied. The extrema magnitudes of this force would be zero (representing the previous situation) and that which is the limit of comfort to passengers, which we shall assume to have a value of 0.09 times the weight of the train ("*Tractive Effort, Acceleration and braking*". *The Mathematical Association 2004.*). This changes our differential equation in the following way.

$$ma(t) = -0.09mg + mgSin(\theta) - \frac{1}{2}\rho v(t)^2 C_d A - \mu mgCos(\theta)$$

If we assume all previous experimental quantities, we acquire a new initial value problem, this time with the boundary of v(0) = $\frac{250}{3}$ (assuming the 300 km/h top speed of a high speed train [for longer timespan of experiment] [given in m/s for the equation]). Figure 15 below is the result of the same approximation method.

Figure 15 Approximate Deceleration of Locomotive

The graph shows the limits of possibility for the train, signifying the lack of any brakes (red line) and the brakes with specified force (blue line). Certainly, with a stronger brake force, the lower limit decreases further, which on the scale of minutes approaches zero. With a more massive train and a smaller area of incidence, the upper limit increases variably. From a calculus standpoint, we know that the distance covered is equal to the integral of the velocity function over time, or:

$$d = \int_0^T v(t) \cdot dt$$

As the distance between the two stations certainly remain the same, the time will vary depending on how effective the velocity function is, which will essentially be a piecewise function. If T is the total time of the trip, T_{top} is the time to achieve top speed from zero (let us assume 250 km/h), and T_{dec} is the time required for a safe, adequate deceleration to zero, then the velocity function throughout the trip will be as follows:

$$v(t) = \begin{cases} v_{accel}(t), \quad 0 < t < T_{top} \\ 250, \quad T_{top} < t < (T - T_{dec}) \\ v_{decel}(t), \quad (T - T_{decel}) < t < T \end{cases}$$

The velocity function becomes more effective when T_{top} and T_{decel} approach zero, allowing for the train to travel at its top speed for as long as possible during the journey.

Appendix F: Travel Time Assessment

A study was made on local and non-stop (i.e. high speed) rail times for passengers between Los Angeles and San Francisco. Its purpose is to relate factors which cause passengers to take the local service rather than the non-stop service. This was achieved when the following equation was satisfied:

$$TT_{ns} + \delta\left(\frac{A}{2} + x(S)\right) \geq TT_{loc} + \delta\left(\frac{A}{2} - x(S)\right)$$

Where

- $TT_{ns, loc}$ are the travel times for each service
- δ is the schedule delay weighting coefficient (unitless constant denoting a circumstantial delay)
- A is the average time between the services
- $x(S)$ is the difference between the literal clock time of the previous train of a service + $\frac{A}{2}$, and the consumer's target clock time S.

An oversimplification of this would be to use just travel times, $TT_{loc} \leq TT_{ns}$ which of course is impossible as it would defeat the purpose of having a high-speed rail. Instead, the circumstance relies upon how much of a delay the trains are accumulating.

Bearing this in mind, we immediately notice an issue with the equation: that there is ambiguity between δ and $x(S)$ of either side of the equation. Certainly they must differ as they relate to the delay and train times of a *single* service.

While this relation may seem somewhat bare in terms of *everything* that adds to train time, it is vague enough to allow for interpretation, as can be seen by the δ coefficient. Such interpretation may even permit for the introduction of other modes of travel. For the purpose of the relation to our study, we may rewrite parts of this equation, and arrive at the following.

$$TT_{car} + \delta_{car}(S) \geq TT_{hs} + \delta_{hs}x(S)$$

What is being observed with the satisfying of this equation is that the travel time by car, along with any delay as a function of the car's departure time S, $\delta_{car}(S)$ (construction, traffic, etc.) is greater than the travel time by high-speed rail, along with any delays as a function of the coordination between multiple trains (train coordination, ticket purchase of the individual [assuming prepaid options are unavailable], etc.), which relies on the departure time S, $\delta_{hs}x(S)$.

Appendix G: **Optimization of Parameters**

The cost of construction for rail will vary depending on the type of terrain along the rail path. The total cost per kilometer of Australian rail has been found for *urban, tunneling, mountainous, elevated, undulating* and *flat farmland* implementation. For a general case for a path that may pass through one or more of these area types, the cost (in millions of AUD $) equation would be as follows:

$$C = 51.583205x_1 + 152.531345x_2 + 67.032318x_3 + 92.601045x_4 + 26.202367x_5 + 12.795889x_6,$$

In this equation:

- x_1 denotes the length of track in the *urban* setting, where there is a clear sky-view of residential and commercial blocks, and the existence of a population for the area.
- x_2 is the length of *tunneling* track, utilized for rail segments that approach mountainous areas that vary in elevation with respect to distance too quickly to apply a gradient to the track, most especially for high speed rail.
- x_3 is the length of track upon *mountainous* terrain, which vary in elevation with respect to distance too quickly to apply slight (approximately zero) changes in track gradient, as seen in flat terrain.
- x_4 is the length of *elevated* track, used over distances containing large water bodies, and in some cases parks, and other sociopolitical boundaries that must be crossed over carefully.
- x_5 is the length of *undulating* track, defined as track that has an overall curve to it. As this does not apply directly to high speed (as high speed track should be as straightforward as possible when planning to be built), it is assumed this value will be low.
- x_6 is the length of track upon *flat farmland*, which has very small changes in elevation with relation to distance, and does not cross any body of water or park/urban boundaries.

Thus, for a non-zero route length, l:

$l = x_1 + x_2 + x_3 + x_4 + x_5 + x_6$, and *at least* one of the components does not equal zero.

With no other boundary conditions, the trivial solution is to incorporate solely the *flat farmland* setting in order to minimize cost. Unfortunately, this amount of ease implies that there is only *flat farmland* everywhere between and around endpoints A and B of the path. This is simply untrue, as there are indeed mountains within Australia, as well as heavily populated cities, rivers and areas which are simply a hassle to build directly through. To apply the condition of reality to this problem, we introduce the area function:

$$A(X, Y) = F(E, T, P)$$

Where *X* is the global longitude, *Y* is the latitude, *E* is the elevation of the location, *T* is the type of geographical feature of the location (water, somewhat level land, mountain, etc.), and *P* is the population of the area. What this relation implies is that for every global position, there is a determining function of population, elevation and land-type that will govern the required area-type of track for that location. This function is applied continuously throughout the path between the two points (generally cities), and with thorough calculations, the magnitudes of x_{1-6} can be found. From here a total cost is acquired by using these magnitudes in the original cost equation; though this is simply one possible path. A second path may be created by "tweaking" this path, perhaps simply applying a distortion in a single direction, much like pulling back on a string of a guitar. Clearly this increases the magnitude of *l*, which in turn will change x_{1-6}, but this can be beneficial for reducing the total cost.

For example, let's assume the path from City A to City B is 100 km, with mountain area between 30 and 60 km along the path. For simplicity, all other path will be flat farmland. This gives us a total cost of $2906.68 million. However, if there exists a path around the mountain, such that it adds 50 km to the path but causes the whole path to be farmland, the total cost becomes $1919.38 million for the rail. This example is an extreme oversimplification of the topology in Australia; to the point where coding is required to arrive at the same basic solution.

This brings us to the limitation of this method. The defined boundary function $A(X, Y)$ currently does not exist in archival form for Australia, in a way that does not involve extensive budget options surpassing that of the ability of the group, or programs which require a great deal of time-consuming training.

Alternatives for routes were found during the creation of the high speed network to give a discrete set of comparisons as seen in Figure 16. Four alternatives were made to connect Melbourne and Adelaide, three between Sydney and Melbourne, and two between Brisbane and Sydney. The alternatives were labeled in numerical order descending in global latitude.

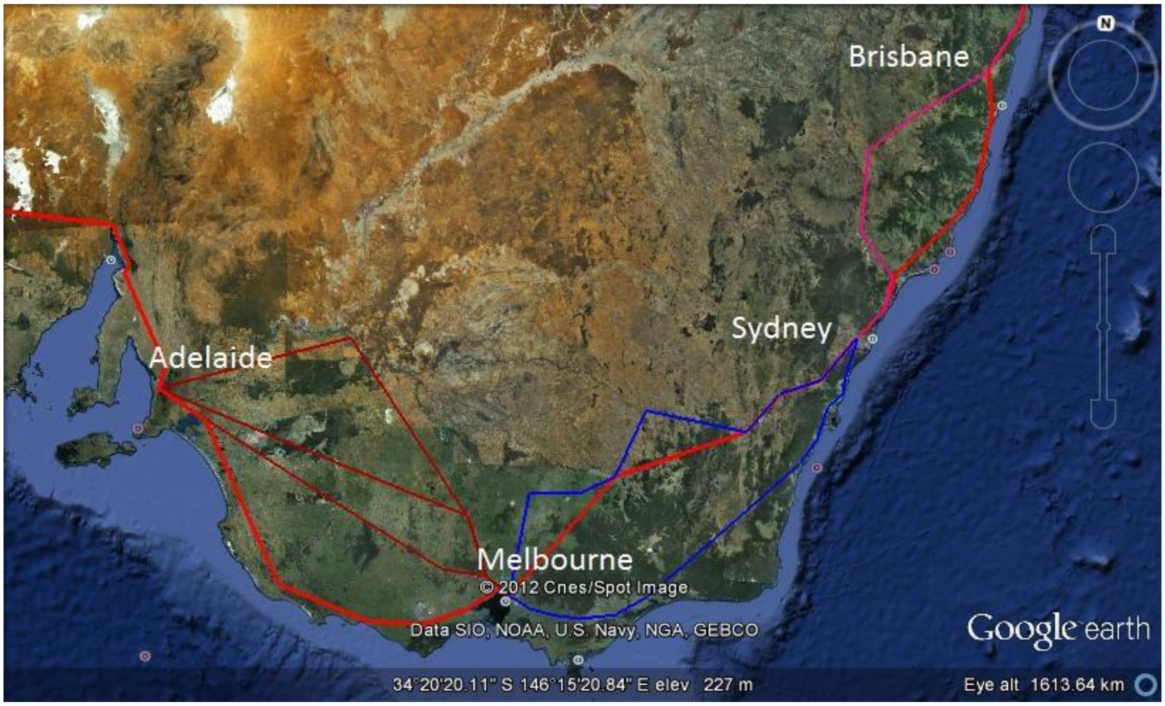

Figure 16 Depiction of All Possibile Alternative High Speed Rail Lines

Table 2 below shows the analysis for coverage (the sum of the populations of cities expecting to have a station in them throughout the line, as well adjacent cities to simulate proximity to the station), the expected cost (roughly calculated by categorizing segments of the line to acquire the total x_{1-6}), the number of expected stations throughout the line, and the total length of the line.

Table 2 Comparison of Optimized High Speed Lines

Path A: Highest Coverage	**Distance (km)**	**69.73%**	Stations:	**43**
Route	**Distance**	**Cumulative Pop**	**Cost (millions)**	**Cost/km (millions)**
Brisbane - Cairns	1,528	699,817	29236.26959	19.13368429
Sydney - Brisbane 2	789	2,983,789	29070.79193	36.70554537
Melbourne - Sydney 1	836	4,205,020	31343.00664	37.44684186
Melbourne - Adelaide 4	795	3,571,610	20838.01724	26.21134244
Adelaide - Perth	2,425	2,383,281	53519.6924	22.06997625
Total	*6,373*	*13,843,517*	164007.7778	*25.734784*
Path B: Lowest Cost	Coverage:	**68.77%**	Stations:	**45**
Route	**Distance (km)**	**Cumulative Pop**	**Cost (millions)**	**Cost/km (millions)**
Brisbane - Cairns	1,528	699,817	29236.26959	19.13368429
Sydney - Brisbane 2	789	2,983,789	29070.79193	36.70554537

Melbourne - Sydney 3	791	4,042,691	29837.14147	37.62565129
Melbourne - Adelaide 1	820	3,543,018	15081.08407	18.36916452
Adelaide - Perth	2,425	2,383,281	53519.6924	22.06997625
Total	*6,353*	*13,652,596*	156744.9795	*24.672592*
Path C: Least Stops	Coverage:	**69.07%**	Stations:	**39**
Route	**Distance (km)**	**Cumulative Pop**	**Cost (millions)**	**Cost/km (millions)**
Brisbane - Cairns	1,528	699,817	29236.26959	19.13368429
Sydney - Brisbane 2	789	2,983,789	29070.79193	36.70554537
Melbourne - Sydney 2	721	4,102,667	40160.17853	55.62351597
Melbourne - Adelaide 1	820	3,543,018	15081.08407	18.36916452
Adelaide - Perth	2,425	2,383,281	53519.6924	22.06997625
Total	*6,283*	*13,712,572*	167068.0165	*26.590485*
Path D: Most Distance	Coverage:	**69.39%**	Stations:	**43**
Route	**Distance (km)**	**Cumulative Pop**	**Cost (millions)**	**Cost/km (millions)**
Brisbane - Cairns	1,528	699,817	29236.26959	19.13368429

Sydney - Brisbane 1	861	2,945,168	54718.10552	63.33114065
Melbourne - Sydney 1	836	4,205,020	31343.00664	37.44684186
Melbourne - Adelaide 1	820	3,543,018	15081.08407	18.36916452
Adelaide - Perth	2,425	2,383,281	53519.6924	22.06997625
Total	*6,470*	*13,776,304*	183898.1582	*28.423208*

Appendix H: Findings

H.1. International Rails

H.1.1. Populations and Station Locations

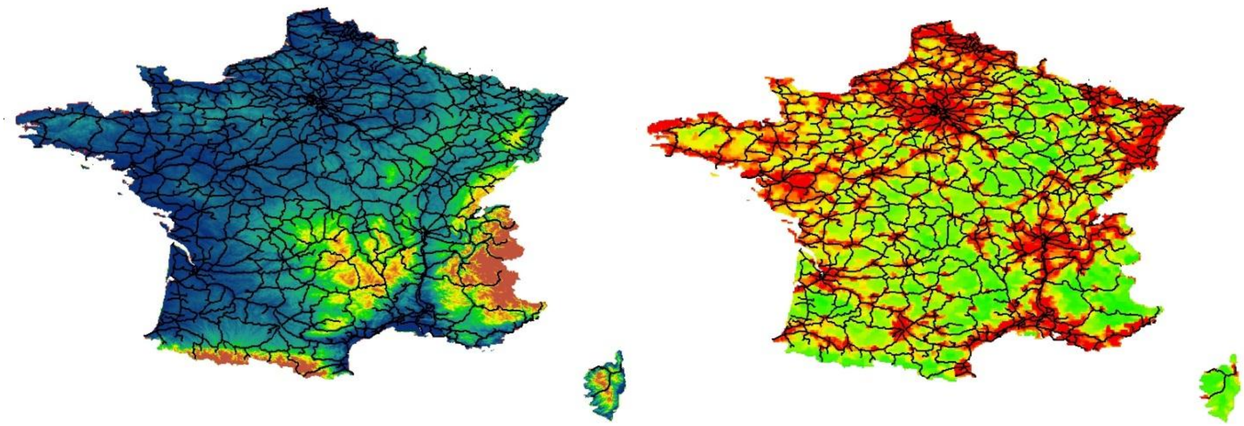

Figure 17 Elevation Profile (left) and Population Density (right) for France with Rail Map

Table 3 Population of Cities/Towns in France with Stations

City	Population 1/1/09	Track Type
Mont Saint Michel*	42	Non-Electrified
Chantes*	106	Non-Electrified
Merrey*	134	Normal Speed
Blesme*	178	Normal Speed
Fos*	253	Normal Speed
Lapeyrouse*	295	Non-Electrified
Lison*	475	Normal Speed
Peyraud*	504	Normal Speed
Hombourg Budange*	508	Normal Speed
Monterolier*	517	Normal Speed
Saint Exupery*		Normal Speed

	537	
Courtalain*	595	Normal Speed
Chemilly*	630	Non-Electrified
Abancourt*	653	Normal Speed
Amagne-Lucquy*	689	Normal Speed
Motteville*	730	Normal Speed
Aspres-sur-Buëch *	752	Non-Electrified
Saint Maixent*	754	Normal Speed
Folligny*	941	Non-Electrified
Apach*	943	Normal Speed
Siorac-en-Périgord*	994	Non-Electrified
Estivareilles*	1,008	Non-Electrified
Serqueux*	1,061	Normal Speed
Puyoo*	1,150	Normal Speed
Mouchard*	1,188	Normal Speed
Béning-lès-Saint-Avold*	1,226	Normal Speed
Bréauté *	1,236	Normal Speed
Lérouville *	1,473	Normal Speed
Rothau*	1,582	Non-Electrified
Briouze*	1,600	Non-Electrified
Longueville*	1,625	Non-Electrified
Saint Florent*	1,635	Non-Electrified
Aillevillers-et-Lyaumont *	1,653	Non-Electrified
Arches*	1,726	Normal Speed

Crépy *	1,832	Normal Speed
Gièvres*	2,189	Normal Speed
Serquigny*	2,204	Normal Speed
Lauterbourg*	2,216	Non-Electrified
Saint Amour*	2,247	Normal Speed
Volgelsheim*	2,322	Non-Electrified
Saint-André-le-Gaz*	2,327	Normal Speed
Saint Germain*	2,351	Normal Speed
Nexon*	2,412	Non-Electrified
Conflans-en-Jarnisy*	2,446	Normal Speed
Lusignan*	2,637	Normal Speed
Chalindrey*	2,706	Normal Speed
Montréjeau *	2,722	Normal Speed
Gilly-sur-Isère*	2,798	Non-Electrified
Connerré*	2,872	Normal Speed
Aunay-sur-Odon*	2,944	Non-Electrified
Culoz*	2,957	Normal Speed
Carnoules*	3,162	Normal Speed
Veynes*	3,168	Non-Electrified
Modane*	3,472	Fast Speed
Contrexéville*	3,526	Non-Electrified
Saint-Germain-des-Fossés*	3,672	Normal Speed
Montmélian*	3,933	Normal Speed
Pontorson*		Non-Electrified

	4,094	
Bouzonville*	4,178	Normal Speed
Villars Les Dombes*	4,317	Non-Electrified
Moret-sur-Loing*	4,472	Normal Speed
Morcenx*	4,586	Normal Speed
Volvic*	4,606	Non-Electrified
Mézidon-Canon*	4,683	Normal Speed
Dol-de-Bretagne*	4,807	Normal Speed
La Voulte-sur-Rhône*	4,993	Normal Speed
Santes*	5,036	Non-Electrified
Saint Rambert d'Albon*	5,198	Normal Speed
Flers-en-Escrebieux*	5,342	Non-Electrified
Chagny*	5,391	Normal Speed
Montchanin*	5,505	Non-Electrified
Montbard*	5,554	Fast Speed
Vendenheim*	5,646	Normal Speed
Longuyon*	5,711	Normal Speed
Salbris*	5,766	Normal Speed
Gannat*	5,881	Non-Electrified
Mirecourt*	5,956	Non-Electrified
Malesherbes*	6,015	Normal Speed
Bellegarde*	6,202	Normal Speed
Carentan*	6,340	Normal Speed
Givet*	6,777	Non-Electrified

Savenay*	7,039	Normal Speed
Elne*	7,452	Normal Speed
Saint Sulpice-Lauriere*	7,612	Normal Speed
Guingamp*	7,661	Fast Speed
Saint Marcellin*	7,794	Non-Electrified
Moirans*	7,804	Normal Speed
Coutras*	7,815	Normal Speed
Avranches*	8,226	Non-Electrified
Lure*	8,263	Non-Electrified
Rivesaltes*	8,625	Normal Speed
Livron-sur-Drôme*	8,945	Normal Speed
Paray-le-Monial *	9,138	Non-Electrified
Hagondange*	9,212	Normal Speed
Molsheim*	9,331	Non-Electrified
Dourdan*	9,435	Normal Speed
Hirson*	9,473	Normal Speed
Redon*	9,493	Fast Speed
Saint Gaudens*	11,152	Normal Speed
Lamballe*	11,261	Normal Speed
Gisors*	11,677	Normal Speed
Arachon*	11,679	Fast Speed
Auray*	12,435	Normal Speed
Ambérieu-en-Bugey*	12,696	Normal Speed
Granville*		Non-Electrified

	13,100	
Tarascon*	13,177	Normal Speed
Bayeux*	13,478	Normal Speed
Argentan*	14,642	Non-Electrified
Tergnier*	14,722	Normal Speed
Les Herbiers*	14,893	Non-Electrified
Landerneau*	14,902	Normal Speed
Lourdes*	15,254	Fast Speed
Saint Pierre-des-Corps*	15,370	Normal Speed
Gien*	15,447	Normal Speed
Morlaix*	15,605	Normal Speed
Montargis*	15,755	Normal Speed
Vesoul*	15,920	Non-Electrified
Toul*	16,230	Normal Speed
La Baule*	16,719	Fast Speed
Montereau-Fault-Yonne*	16,802	Normal Speed
Firminy*	17,569	Normal Speed
Selestat*	19,303	Normal Speed
Givors*	19,345	Normal Speed
Montceau-les-Mines*	19,548	Non-Electrified
Moulins*	19,837	Normal Speed
Lunéville*	19,937	Normal Speed
Cahors*	19,948	Normal Speed
Dax	21,003	Fast Speed

Forbach	21,595	High Speed
Lisieux	21,826	Normal Speed
Sainte Foy lès Lyon	22,015	Non-Electrified
Beaune	22,516	Fast Speed
Le Creusot	22,840	High Speed
Chaumont	23,411	Non-Electrified
Libourne	23,830	Fast Speed
Agde	24,031	Normal Speed
Épernay	24,317	Normal Speed
Dole	24,906	Fast Speed
Vichy	25,090	Normal Speed
Biarritz	25,397	Normal Speed
Miramas	25,440	Normal Speed
Laon	26,094	Non-Electrified
Saint Dizier	26,112	Normal Speed
Saintes	26,335	Non-Electrified
Aix-les-Bains	26,819	Fast Speed
Vierzon	27,020	Normal Speed
Alençon	27,325	Non-Electrified
Saumur	28,070	Normal Speed
Soissons	28,471	Non-Electrified
Orange	28,990	Fast Speed
Périgueux	29,273	Non-Electrified
Périgueux		Non-Electrified

	29,416	
Dreux	30,690	Normal Speed
Épinal	32,845	Normal Speed
Romans-sur-Isère	33,664	Non-Electrified
Agen	33,920	Fast Speed
Mâcon	34,136	High Speed
Saint Raphaël	34,269	Normal Speed
Creil	34,327	Normal Speed
Haguenau	34,648	Non-Electrified
Montélimar	35,495	Fast Speed
Roanne	36,866	Non-Electrified
Nevers	37,470	Normal Speed
Montluçon	38,978	Non-Electrified
Cherbourg-Octeville	39,003	Normal Speed
Chartres	39,122	High Speed
Melun	39,400	Normal Speed
Bourg-en-Bresse	39,586	Normal Speed
Cherbourg-Octeville	40,288	Normal Speed
Compiègne	40,860	Normal Speed
Alès	41,432	Non-Electrified
Thionville	41,564	Normal Speed
Angoulême	42,242	Fast Speed
Corbeil-Essonnes	42,456	Normal Speed
Sète	42,496	Normal Speed

Mantes-la-Jolie	43,128	Normal Speed
Boulogne-sur-Mer	43,310	Normal Speed
Tarbes	43,686	Fast Speed
Bayonne	44,900	Fast Speed
Chalon-sur-Saône	45,504	Fast Speed
Saint-Brieuc	46,013	Fast Speed
Blois	46,013	Normal Speed
Châlons-en-Champagne(Châlons-sur-Marne)	46,236	Normal Speed
Saint Malo	47,045	Normal Speed
Carcassonne	47,854	Normal Speed
Brive-la-Gaillarde	49,231	Normal Speed
Charleville-Mézières	49,975	Normal Speed
Belfort	50,199	Normal Speed
Laval	51,182	Fast Speed
Évreux	51,193	Normal Speed
Narbonne	51,227	Fast Speed
La Roche-sur-Yon	52,234	Normal Speed
Vannes	52,683	Fast Speed
Arles	52,979	Fast Speed
Beauvais	54,461	Normal Speed
Saint Quentin	55,971	Normal Speed
Montauban	56,126	Fast Speed
Chambéry	56,476	Fast Speed
Niort		Fast Speed

	56,878	
Lorient	57,812	Fast Speed
Troyes	61,188	Non-Electrified
Quimper	63,387	Fast Speed
Valence	64,364	Normal Speed
Saint Nazaire	66,348	Normal Speed
Bourges	66,786	Normal Speed
Colmar	67,214	Normal Speed
Béziers	70,957	Fast Speed
Cannes	73,372	Normal Speed
Calais	74,336	High Speed
La Rochelle	74,707	Normal Speed
Pau	82,763	Fast Speed
Poitiers	88,795	Fast Speed
Avignon	89,592	Fast Speed
Tourcoing	92,389	Normal Speed
Nancy	106,318	Fast Speed
Caen	109,312	Normal Speed
Rouen	110,688	Fast Speed
Mulhouse	111,156	Normal Speed
Orléans	113,224	Normal Speed
Besançon	117,392	Normal Speed
Perpignan	117,905	Normal Speed
Metz	121,841	Normal Speed

Amiens	133,998	Normal Speed
Tours	135,218	High Speed
Clermont-Ferrand	138,588	Normal Speed
Limoges	139,216	Normal Speed
Nîmes	140,747	Fast Speed
Brest	141,315	Fast Speed
Aix-en-Provence	141,895	Non-Electrified
Le Mans	142,281	High Speed
Angers	147,305	Fast Speed
Dijon	152,110	Fast Speed
Grenoble	155,632	Fast Speed
Toulon	165,514	Normal Speed
Saint Étienne	171,961	Fast Speed
Le Havre	177,259	Normal Speed
Reims	180,842	Non-Electrified
Rennes	206,604	Fast Speed
Lille	226,827	High Speed
Bordeaux	236,725	Fast Speed
Montpellier	255,080	Fast Speed
Annecy	255,771	Fast Speed
Strasbourg	271,708	Fast Speed
Nantes	282,047	Fast Speed
Nice	340,735	Normal Speed
Toullouse		Fast Speed

	440,204	
Lyon	479,803	Fast Speed
Marseille	850,602	High Speed
Paris	2,234,105	High Speed

Table 4 Summary of Coverage for France

Population With Station in City	13,593,855
Total Population of France*	64,876,618
% Population in city of station	20.95%
Total Rail (km) (Trading Economics, 2012)	33,778

* Population from 2007 (Map of France)

(Brinkhoff, 2012)

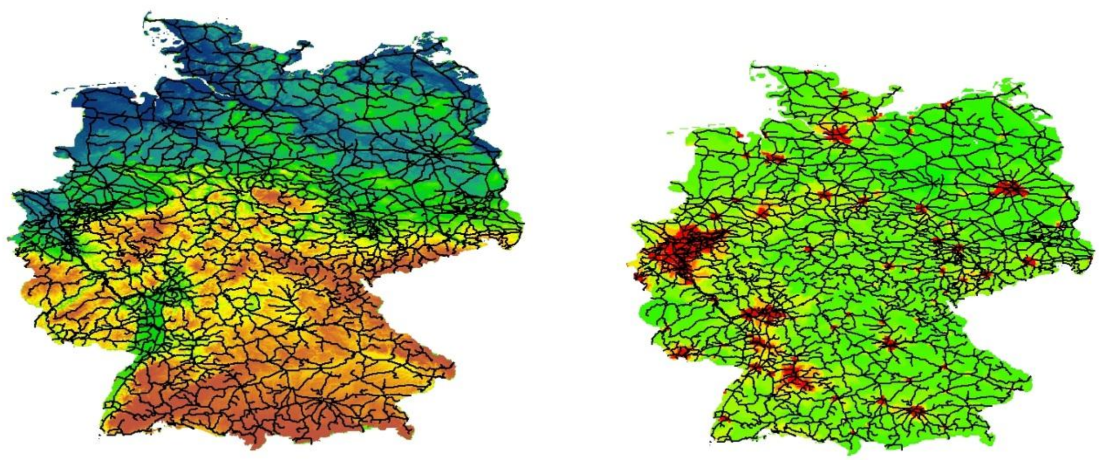

Figure 18 Elevation Profile (left) and Population Density (right) for Germany with Rail Map

Table 5 Population of Cities/Towns in Germany with Stations

Station-Cities	**Pop. 12-31-2010**	**Rail Speed(s)**
Cochem	4,929	High

Station-Cities	**Pop. 12-31-2010**	**Rail Speed(s)**
Binz	5,407	High
Berchtesgaden	7,597	High
Barth	8,733	Non-Ev
Sassnitz	10,366	High
Pasewalk	11,319	High/Non-Ev
Buchloe	12,104	Non-Ev
Ludwigslust	12,319	High/Non-Ev
Plattling	12,746	High/Non-Ev
Treuchtlingen	12,778	High
Bebra	13,789	High
Füssen	14,213	Non-Ev
Angermünde	14,360	High
Sylt	15,169	Non-Ev
Bad Bentheim	15,567	High
Wittenberge	18,571	High/Non-Ev
Heide	20,886	Non-Ev
Neustrelitz	21,207	High/Non-Ev
Meiningen	21,590	Non-Ev
Husum	22,084	Non-Ev
Schleswig	24,058	High
Lindau (Bodensee)	24,772	High/Non-Ev
Norden	25,116	High/Non-Ev

Station-Cities	**Pop. 12-31-2010**	**Rail Speed(s)**
Garmisch-Partenkirchen	26,068	High
Zittau	28,212	Non-Ev
Emmerich	29,571	High
Riesa	34,013	High
Uelzen	34,250	High/Non-Ev
Naumburg (Saale)	34,294	High/Non-Ev
Leer (Ostfriesland)	34,301	High
Kehl	34,789	High
Siegburg	39,746	High
Ansbach	40,253	High
Bautzen (Budyšin)	40,573	Non-Ev
Freiberg	41,342	High/Non-Ev
Stendal	42,435	High/Non-Ev
Rottenburg (am Neckar)	42,501	Non-Ev
Halberstadt	42,605	Non-Ev
Singen (Hohentwiel)	45,826	High
Hof	46,286	High/Non-Ev
Cuxhaven	50,492	Non-Ev
Passau	50,594	High/Non-Ev
Emden	51,616	High
Görlitz	55,596	Non-Ev
Stralsund	57,670	High

Station-Cities	Pop. 12-31-2010	Rail Speed(s)
Offenburg	59,215	High
Rosenheim	61,299	High/Non-Ev
Kempten (Allgäu)	62,060	Non-Ev
Landshut	63,258	High/Non-Ev
Fulda	64,349	High/Non-Ev
Neubrandenburg	65,282	High/Non-Ev
Celle	70,242	High/Non-Ev
Bayreuth	72,683	Non-Ev
Lüneburg	72,983	High/Non-Ev
Rheine	76,530	High
Neumünster	76,830	High/Non-Ev
Gießen	77,366	High/Non-Ev
Marburg	80,656	High
Wilhelmshaven	81,324	Non-Ev
Dessau (-Roßlau)	86,906	High/Non-Ev
Flensburg	88,759	High/Non-Ev
Zwickau	93,750	High/Non-Ev
Schwerin	95,220	High/Non-Ev
Cottbus (Chóśebuz)	102,091	High/Non-Ev
Jena	105,129	High/Non-Ev
Trier	105,260	High
Koblenz	106,417	High

Station-Cities	**Pop. 12-31-2010**	**Rail Speed(s)**
Bremerhaven	113,366	High/Non-Ev
Fürth	114,628	High/Non-Ev
Göttingen	121,060	High/Non-Ev
Wolfsburg	121,451	High
Ulm	122,801	High/Non-Ev
Ingolstadt	125,088	High/Non-Ev
Würzburg	133,799	High
Regensburg	135,520	High/Non-Ev
Darmstadt	144,402	High/Non-Ev
Heidelberg	147,312	High
Potsdam	156,906	High
Oldenburg (Oldenburg)	162,173	High/Non-Ev
Osnabrück	164,119	High/Non-Ev
Saarbrücken	175,741	High
Hagen	188,529	High/Non-Ev
Kassel	195,530	High/Non-Ev
Mainz	199,237	High/Non-Ev
Rostock	202,735	High/Non-Ev
Erfurt	204,994	High
Lübeck	210,232	High/Non-Ev
Magdeburg	231,525	High/Non-Ev
Halle (Saale)	232,963	High/Non-Ev

Station-Cities	Pop. 12-31-2010	Rail Speed(s)
Kiel	239,526	High/Non-Ev
Chemnitz	243,248	High/Non-Ev
Braunschweig [Brunswick]	248,867	High/Non-Ev
Mönchengladbach	257,993	High
Aachen [Aix-la-Chapelle]	258,664	High
Augsburg	264,708	High/Non-Ev
Münster	279,803	High/Non-Ev
Karlsruhe	294,761	High
Mannheim	313,174	High
Wuppertal	349,721	High
Duisburg	489,559	High
Nürnberg [Nuremberg]	505,664	High/Non-Ev
Hannover [Hanover]	522,686	High
Leipzig	522,883	High
Dresden	523,058	High
Bremen	547,340	High
Essen	574,635	High
Dortmund	580,444	High/Non-Ev
Düsseldorf [Dusseldorf]	588,735	High
Stuttgart	606,588	High/Non-Ev
Frankfurt (am Main)	679,664	High

Station-Cities	Pop. 12-31-2010	Rail Speed(s)
Köln [Cologne]	1,007,119	High/Non-Ev
München [Munich]	1,353,186	High
Hamburg	1,786,448	High/Non-Ev
Berlin	3,460,725	High

Table 6 Summary of Coverage for Germany

Total Population of Cities/Towns with Stations	**23,123,632**
Total Population	**81,702,309**
% Population Located within Cities/Towns with Stations	**28.30%**
Total Rail (km)	**33,706**

(Brinkhoff, 2012)

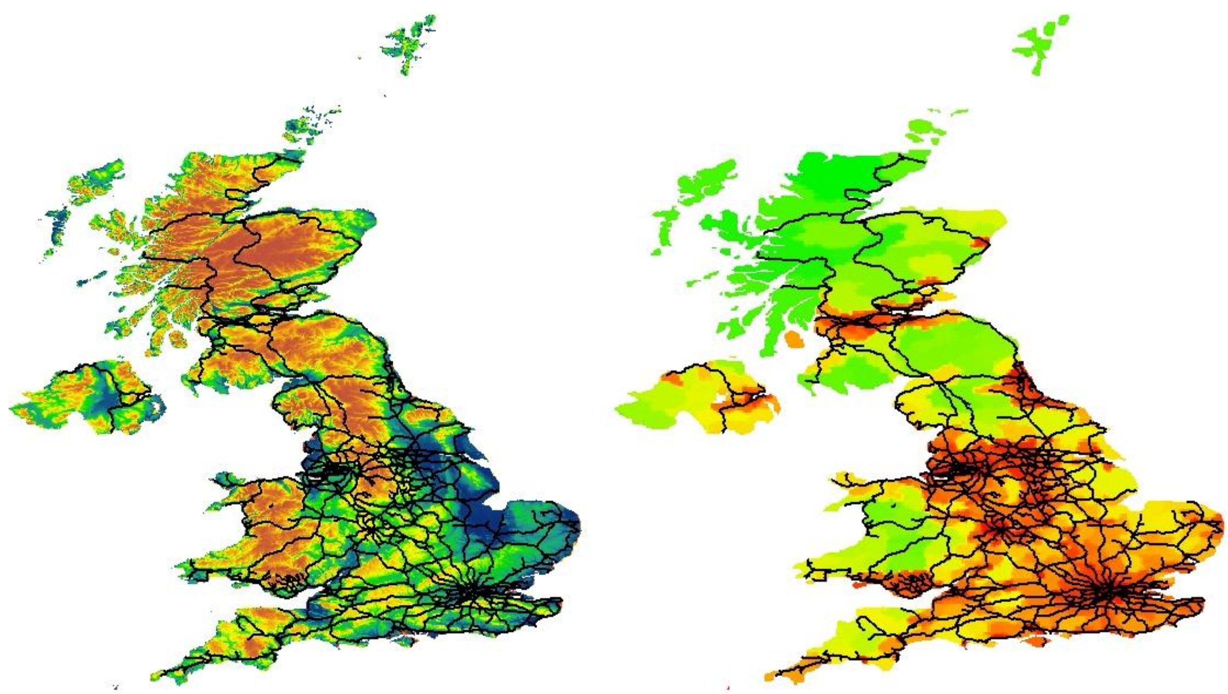

Figure 19 Elevation Profile (left) and Population Density (right) for Great Britain with Rail Map

Table 7 Population of Cities/Towns in Great Britain with Stations

Cities/Towns with Stations	Population	Rail Type
Kyle of Lochalsh	660	ScotRail
Chapelton	760	First Great Western
Mallaig	760	ScotRail
Bridgend	790	Arriva Trains Wales/First Great Western
Carstairs	820	ScotRail
Dunlop	920	ScotRail
Langbank	930	ScotRail
Springfield	940	ScotRail
Newtonmore	1,060	ScotRail/East Coast
Hillside	1,140	Merseyrail
North Queensferry	1,150	ScotRail
Garelochhead	1,170	ScotRail
Brora	1,180	ScotRail
Dunkeld and Birnam	1,220	ScotRail/East Coast
Beauly	1,250	ScotRail
Croy	1,280	ScotRail
Kingussie	1,340	ScotRail/East Coast
Golspie	1,380	ScotRail
Balloch	1,430	ScotRail
Fairlie	1,530	ScotRail
Wylam	1,549	ScotRail/Northern

Cities/Towns with Stations	Population	Rail Type
Busby	1,550	ScotRail
Ladybank	1,560	ScotRail/Cross Country
Feniton	1,567	South West Trains
East Dean	1,578	South West Trains
Manea	1,579	East Midlands/Cnational Express East Anglia
Barnetby le Wold	1,593	Northern/East Midlands Trains
Great Bentley	1,613	National Express East Anglia
Howwood	1,620	ScotRail
Acton	1,635	First Great Western
Flimby	1,636	Northern
Meldreth	1,641	First Capital Connect
Hampton in Arden	1,655	London Midland
Ashwell	1,660	First Capital Connect
Blackridge	1,680	ScotRail
Ambergate / Crich	1,682	East Midlands Trains
Mistley	1,684	National Express East Anglia
Roche	1,685	First Great Western
Brompton (nr Northallerton)	1,690	Southern/London Overground
Aberdour	1,700	ScotRail
Llandeilo	1,731	Arriva Trains Wales
Seascale	1,747	Northern
Johnston	1,778	Arriva Trains Wales

Cities/Towns with Stations	Population	Rail Type
Starcross	1,780	First Great Western/CrossCountry
Brading	1,794	South West Trains
Barlaston	1,805	East Midlands Trains
Criccieth	1,826	Arriva Trains Wales
Kirkby Stephen	1,832	Northern
Thornton Dale	1,845	Northern
Swineshead	1,849	East Midlands
Narberth	1,869	Arriva Trains Wales
Kirknewton	1,880	ScotRail
Radley	1,906	First Great Western
Gartcosh	1,950	ScotRail
Wainfleet All Saints	1,965	East Midlands
Insch	1,970	ScotRail
Robertsbridge	1,987	Southeastern
Goxhill	1,994	Northern
Sleights	1,995	Northern
Hutton Cranswick	2,015	Northern
Goostrey	2,029	Northern
Sanquhar	2,030	ScotRail
Penrhyndeudraeth	2,031	Arriva Trains Wales
Watlington (King's Lynn and West Norfolk)	2,031	First Capital Connect/National Express East Anglia

Cities/Towns with Stations	Population	Rail Type
Betws	2,034	Arriva Trains Wales
Invergowrie	2,040	ScotRail
Tisbury	2,041	South West Trains
Seamer(Scarborough)	2,048	Northern/First Transpennine Express
Westham	2,061	Southern
Wye	2,066	Southeastern
King's Sutton	2,069	First Great Western/Chiltern Railways
Kintbury	2,086	First Great Western
Lowdham	2,089	East Midlands Trains
Kirkconnel	2,090	ScotRail
Caldercruix	2,140	ScotRail
Machynlleth	2,147	Arriva Trains Wales
Cardross	2,170	ScotRail
Nafferton	2,184	Northern
Muir of Ord	2,190	ScotRail
Widdrington Station	2,197	Northern
Cromford / Matlock Bath	2,202	East Midlands Trains
Wickham Market	2,204	National Express East Anglia
Newport (Uttlesford)	2,208	National Express Anglia
Acle	2,230	National Express East Anglia
Wool	2,234	South West Trains
Llandovery	2,235	Arriva Trains Wales

Cities/Towns with Stations	Population	Rail Type
Bugle / Stenalees	2,243	First Great Western
Hightown	2,247	Merseyrail
Barmouth	2,251	Arriva Trains Wales
Elsenham	2,252	National Express Anglia
Watton-at-Stone	2,272	First Capital Connect
Sway	2,294	South West Trains
Arnside	2,301	Northern/First Transpennine Express
Carfin	2,310	ScotRail
Harlington	2,322	First Great Western
Renton	2,350	ScotRail
Lingwood	2,374	National Express East Anglia
Aspatria	2,376	Northern
Penmaenmawr	2,403	Arriva Trains Wales/Virgin Trains
Long Hanborough	2,404	First Great Western
Marden	2,412	Southeastern
Valley	2,413	Arriva Trains Wales/Virgin Trains
Greenfield	2,419	Northern
Markinch	2,420	ScotRail/Cross Country
Markinch	2,420	ScotRail/Cross Country
Laurencekirk	2,440	ScotRail
Longniddry	2,450	ScotRail
Shipton-under-Wychwood	2,480	First Great Western

Cities/Towns with Stations	Population	Rail Type
Gilfach Goch	2,504	Arriva Trains Wales
St Columb Road	2,510	First Great Western
Rolleston	2,545	East Midlands Trains
Wemyss Bay	2,550	ScotRail
Barrow upon Humber	2,554	Nothern
Wareham	2,568	South West Trains
Collingham(Nottinghamshire)	2,580	East Midlands Trains/East Coast
Lostwithiel	2,602	First Great Western
Bosham	2,604	Southern
Willington (South Derbyshire)	2,604	CrossCountry
Healing	2,606	Northern/East Midlands Trains
Llandybie	2,635	Arriva Trains Wales
Aviemore	2,660	ScotRail/East Coast
Pitlochry	2,690	ScotRail/East Coast
Kidwelly	2,691	Arriva Trains Wales/First Great Western
Cleland	2,700	ScotRail
Parbold	2,702	Northern
Pevensey Bay	2,708	Southern
Bargeddie	2,710	ScotRail
Saxmundham	2,712	National Express East Anglia
Teynham	2,725	Southeastern
Gilberdyke	2,727	Northern

Cities/Towns with Stations	Population	Rail Type
Inverkip	2,760	ScotRail
Theale	2,771	First Great Western
Henley-in-Arden	2,797	London Midland
Corbridge	2,800	ScotRail/Northern
Kilmaurs	2,810	ScotRail
Seer Green	2,843	Chiltern Railways
Appleby	2,862	Northern
Brockenhurst	2,865	South West Trains/CrossCountry
Thurston	2,898	National Express East Anglia
Kinghorn	2,930	ScotRail
Lochwinnoch	2,940	ScotRail
Saundersfoot	2,946	Arriva Trains Wales
Gunnislake	2,959	First Great Western
New Cumnock	2,970	ScotRail
Bruton	2,982	First Great Western
Charlbury	2,984	First Great Western
Llanhilleth	3,002	Arriva Trains Wales
Bottesford	3,008	East Midlands Trains
Cholsey	3,034	First Great Western
Gretna	3,040	ScotRail
Llanfairpwllgwyngyll	3,040	Arriva Trains Wales/Virgin Trains
Castle Cary	3,056	First Great Western

Cities/Towns with Stations	Population	Rail Type
Ruabon	3,057	Arriva Trains Wales
Old Kilpatrick	3,060	ScotRail
Perranporth	3,066	First Great Western
Tywyn	3,085	Arriva Trains Wales
Disley	3,090	Northern
Ashurst / Netley Marsh	3,116	South West Trains
Wroxham / Hoveton	3,128	National Express East Anglia
Elmswell	3,168	National Express East Anglia
Pegswood	3,174	Northern
Fishguard	3,193	Arriva Trains Wales
Moreton-in-Marsh	3,198	First Great Western
West Calder	3,220	ScotRail
Gobowen	3,230	Arriva Trains Wales
Whalley	3,230	Northern
Crowle	3,268	First Transpennine Express/Northern
Prestbury	3,269	Northern
Hunmanby	3,279	Northern
Arundel	3,297	Southern
Overton(Basingstoke and Deane)	3,318	South West Trains/CrossCountry/First Great Western
Metheringham	3,384	East Midlands
Heckington	3,391	East Midlands
Tain	3,420	ScotRail

Cities/Towns with Stations	Population	Rail Type
Askam in Furness	3,423	Northern
Poppleton	3,428	Northern
Market Rasen	3,491	East Midlands
Marsden	3,499	Northern
Topsham	3,545	First Great Western
Alvechurch	3,568	London Midland
Water Orton	3,573	CrossCountry
Settle	3,621	Northern
Clapham (Bedford)	3,643	Northern
Llanfairfechan	3,653	Arriva Trains Wales/Virgin Trains
Llanbradach	3,658	Arriva Trains Wales
Saxilby	3,660	Northern/East Midlands Trains
Wadhurst	3,686	Southeastern
Auchinleck	3,720	ScotRail
Mytholmroyd	3,730	Northern
Burton Joyce	3,731	East Midlands Trains
Pangbourne / Whitchurch	3,739	Arriva Trains Wales
Whitwell (Bolsover)	3,762	East Midlands Trains
Higham(Gravesham)	3,791	Southeastern
Howden	3,810	First Hull Trains/Northern/First Transpennine Express
Haltwhistle	3,811	ScotRail/Northern
Pwllheli	3,861	Arriva Trains Wales

Cities/Towns with Stations	Population	Rail Type
Chirk	3,883	Arriva Trains Wales
Pulborough	3,906	Southern
Invergordon	3,920	ScotRail
Merthyr Vale	3,925	Arriva Trains Wales
Goring / Streatley	3,934	First Great Western
Blaenau Ffestiniog	3,961	Arriva Trains Wales
Brampton(Carlisle)	3,965	ScotRail/Northern
Hebden Bridge	4,086	Northern
Waterbeach	4,205	First Capital Connect/National Express East Anglia
Cwmbach	4,283	Arriva Trains Wales
Cuffley	4,306	First Capital Connect
Sandwich	4,398	Southeastern
Great Ayton	4,451	Northern
Huntly	4,480	ScotRail
Keith	4,540	ScotRail
Needham Market	4,574	National Express East Anglia
Duffield	4,585	Northern/East Midlands Trains
Kelvedon	4,593	National Express East Anglia
Hope / Caergwrle	4,622	Arriva Trains Wales
Creswell	4,645	East Midlands Trains
Datchet	4,646	South West Trains
Whaley Bridge	4,650	Northern

Cities/Towns with Stations	Population	Rail Type
Radyr	4,658	Arriva Trains Wales
Maybole	4,690	ScotRail
West Kilbride	4,710	ScotRail
Haddenham(Aylesbury Vale)	4,720	Chiltern Railways
Sturry	4,737	Southeastern
Arlesey	4,741	First Capital Connect
Preesall	4,782	Arriva Trains Wales
Bishopton	4,810	ScotRail
Grange-over-Sands	4,835	Northern/First Transpennine Express
Fauldhouse	4,920	ScotRail
Tenby	4,934	Arriva Trains Wales
Hungerford	4,938	First Great Western
Ruskington	4,950	East Midlands
Dingwall	4,970	ScotRail
Abercanaid / Troedyrhiw	5,005	Arriva Trains Wales
Malton	5,023	First Transpennine/East Midlands
Llandrindod Wells	5,024	Arriva Trains Wales
Brampton(Huntingdonshire)	5,030	National Express East Anglia
Barrow upon Soar	5,083	East Midlands Trains
Alresford(Winchester)	5,102	National Express East Anglia
Staplehurst	5,103	Southeastern
Bridge of Allan	5,120	ScotRail

Cities/Towns with Stations	Population	Rail Type
Wem	5,142	Arriva Trains Wales
Appley Bridge	5,155	Northern
Inverkeithing	5,180	ScotRail
Battle	5,190	Southeastern
Shepley / Shelley	5,242	Northern
Barnt Green	5,249	London Midland
Cardenden	5,270	ScotRail
Holytown	5,270	ScotRail
Looe	5,280	First Great Western
Crofton	5,299	Southeastern
Stansted Mountfitchet	5,311	National Express Anglia/CrossCountry/Stanstead Express
Alness	5,340	ScotRail
Carnforth	5,350	Northern/First Transpennine Express
Wigton	5,360	Northern
Dyce	5,430	ScotRail
Neilston	5,440	ScotRail
Halesworth	5,454	National Express East Anglia
Billingshurst	5,465	Southern
Welshpool	5,539	Arriva Trains Wales
Manningtree	5,628	National Express East Anglia
Dalry	5,700	ScotRail
Hagley	5,723	London Midland/Chiltern Railways

Cities/Towns with Stations	Population	Rail Type
Dodworth	5,742	Northern
Uddingston	5,810	ScotRail
Brundall	5,832	National Express East Anglia
Okehampton	5,846	First Great Western
Brigg	5,860	Northern
Saltburn-by-the-Sea	5,912	Northern
Shifnal	5,925	London Midland/Arriva Trains Wales
Burntisland	5,940	ScotRail
Liphook	6,031	South West Trains
Milford / Witley	6,084	South West Trains
Millom	6,103	Northern
Netley	6,150	South West Trains/Southern/First Great Western
Narborough	6,183	CrossCountry
Stepps	6,200	ScotRail
Heighington / Washingborough	6,274	Northern
Great Shelford	6,352	National Express Anglia
Norton Canes	6,394	London Midland
Liss	6,441	South West Trains
Filey	6,468	Northern
North Berwick	6,530	ScotRail
Pickering	6,616	Northern
Littleport	6,727	First Capital Connect/National Express East Anglia

Cities/Towns with Stations	Population	Rail Type
Downham Market	6,730	First Capital Connect/National Express East Anglia
Portlethen	6,740	ScotRail
Bursledon	6,744	South West Trains/Southern/First Great Western
Stewarton	6,750	ScotRail
Hook (Hart)	6,869	South West Trains
Girvan	6,890	ScotRail
Wick	6,960	ScotRail
Rhymney	7,011	Arriva Trains Wales
Twyford	7,035	First Great Western
Great Missenden / Prestwood	7,070	Chiltern Railways
Crediton	7,092	First Great Western
Sileby	7,103	East Midlands Trains
Pershore	7,104	First Great Western
Edenbridge	7,123	Southern
Sheringham	7,143	National Express East Anglia
Penryn	7,166	First Great Western
Yatton	7,196	First Great Western
Pembroke	7,214	Arriva Trains Wales
Wivenhoe	7,221	National Express East Anglia
North Ferriby / Swanland	7,254	Northern
Stonehouse	7,318	First Great Western
Iver / Iver Heath	7,329	First Great Western

Cities/Towns with Stations	Population	Rail Type
Wendover	7,385	Chiltern Railways
Diss	7,444	National Express East Anglia
Thurso	7,470	ScotRail
Crewkerne	7,520	South West Trains
Burnham-on-Crouch	7,636	National Express East Anglia
Dinas Powys	7,653	Arriva Trains Wales
Euxton	7,692	Northern
Albrighton (Bridgnorth)	7,713	London Midland/Arriva Trains Wales
Alnwick	7,767	Northern/East Coast/CrossCountry
Adlington	7,791	Northern
Paddock Wood	7,841	Southeastern
Hayle	7,844	First Great Western/CrossCountry
Prestonpans	7,910	ScotRail
Totnes	7,929	First Great Western/CrossCountry
Windermere	7,941	First Transpennine Express
Dunbar	7,960	ScotRail/East Coast/CrossCountry
Radlett	8,034	First Capital Connect
Dalton-in-Furness	8,057	Northern/First Transpennine Express
Cefn-Mawr	8,098	Arriva Trains Wales
Oban	8,120	ScotRail
Princes Risborough	8,121	Chiltern Railways
Monifieth	8,220	ScotRail

Cities/Towns with Stations	Population	Rail Type
Brandon (Forest Heath)	8,256	National Express East Anglia
Lanark	8,400	ScotRail
Lakenheath	8,403	National Express East Anglia
Annan	8,450	ScotRail
Liskeard	8,478	First Great Western/CrossCountry
Ledbury	8,491	First Great Western/London Midland
Lenzie	8,500	ScotRail
Burscough Bridge	8,536	Northern
Shotts	8,560	ScotRail
Brough	8,573	Northern/First Transpennine Express/East Coast/ First Hull Trains
Bingham	8,685	East Midlands Trains
Cromer	8,836	National Express East Anglia
Frodsham	8,908	London Midland
Marske-by-the-Sea	8,921	Northern
Dunblane	8,940	ScotRail/East Coast
Lydney	8,960	Arriva Trains Wales/CrossCountry
Cupar	8,980	ScotRail
Nairn	8,990	ScotRail
Stevenston	9,020	ScotRail
Bradford-on-Avon	9,072	First Great Western/South West Trains
Thirsk	9,099	First Transpennine/Grand Central

Cities/Towns with Stations	Population	Rail Type
St Blazey / Par	9,256	First Great Western/CrossCountry
Durrington / Bulford	9,312	Southern
Barton-upon-Humber	9,334	Northern
Sherborne	9,350	South West Trains
Royston (South Yorkshire)	9,375	First Capital Connect
Forres	9,540	ScotRail
Ludlow	9,548	Arriva Trains Wales
Attleborough	9,603	National Express East Anglia
Oakham	9,620	East Midlands Trains
Maryport	9,639	Northern
Fort William	9,680	ScotRail
Mossley	9,713	Northern
Baldock	9,866	First Capital Connect
St Ives (Cornwall)	9,866	First Great Western
Shepperton	9,886	South West Trains
Tewkesbury	9,978	First Great Western/CrossCountry
Abercarn / Newbridge	10,007	Arriva Trains Wales
Brierfield	10,047	Northern
Shildon	10,075	Northern
Dalgety Bay	10,090	ScotRail
Newtown	10,358	Arriva Trains Wales
Kirkham	10,372	Northern/First Transpennine Express

Cities/Towns with Stations	Population	Rail Type
Stranraer	10,380	ScotRail
Market Drayton	10,407	First Great Western
Prudhoe	10,437	ScotRail/Northern
Leominster	10,440	Arriva Trains Wales
Dawlish	10,443	First Great Western
Ardrossan	10,620	ScotRail
Hexham	10,682	ScotRail/Northern
Stonehaven	10,760	ScotRail/East Coast/CrossCountry
Carnoustie	10,780	ScotRail
Chepstow	10,821	Arriva Trains Wales/CrossCountry
Llantrisant / Pontyclun	10,880	Arriva Trains Wales
Sandy	10,887	First Capital Connect
Woodbridge	10,956	National Express East Anglia
Inverurie	11,030	ScotRail
Montrose	11,050	ScotRail/East Coast/CrossCountry
Atherstone	11,058	London Midland
Ulverston	11,210	Northern/First Transpennine Express
Orrell	11,212	Northern/Merseyrail
Honiton	11,213	South West Trains
Holyhead	11,237	Arriva Trains Wales/Virgin Trains
Great Driffield	11,245	Northern
Caldicot	11,248	Arriva Trains Wales/CrossCountry

Cities/Towns with Stations	Population	Rail Type
Matlock	11,265	East Midlands Trains
Southwick	11,281	Southern
Codsall	11,296	London Midland/Arriva Trains Wales
Largs	11,420	ScotRail
Wymondham	11,420	National Express East Anglia
Todmorden	11,555	Northern
Cowdenbeath	11,640	ScotRail
Chorleywood	11,657	Chiltern Railways
Haslemere	11,663	South West Trains
Gourock	11,680	ScotRail
Rickmansworth	11,781	Chiltern Railways
North Walsham	11,845	National Express East Anglia
Saltcoats	11,920	ScotRail
Flint	11,936	Arriva Trains Wales/Virgin Trains
Uttoxeter	12,023	East Midlands Trains
Ivybridge	12,056	First Great Western
Newhaven	12,276	Southern
Beaconsfield	12,292	Chiltern Railways
Pyle	12,466	Arriva Trains Wales
Longton	12,515	East Midlands Trains
Oxted	12,576	Southern
Ammanford	12,615	Arriva Trains Wales

Cities/Towns with Stations	Population	Rail Type
Flitwick	12,700	First Capital Connect
Bodmin	12,778	First Great Western/CrossCountry
Rosyth	12,790	ScorRail
Milford Haven	12,830	Arriva Trains Wales
Berwick-upon-Tweed	12,870	East Coast/CrossCountry
Beccles	12,917	National Express East Anglia
Milngavie	13,070	ScotRail
Petersfield	13,092	South West Trains
Alexandria	13,210	ScotRail
Westbury	13,257	First Great Western/South West Trains
Dursley	13,355	First Great Western
Linlithgow	13,360	ScotRail
Llantwit Major	13,366	Arriva Trains Wales
Haverfordwest	13,367	Arriva Trains Wales
Nantwich	13,447	Arriva Trains Wales
Morpeth	13,555	Northern/East Coast/CrossCountry
Whitby	13,594	Northern
Hockley	13,616	National Express East Anglia
Carluke	13,620	ScotRail
Bargoed	13,721	Arriva Trains Wales
Helensburgh	13,770	ScotRail
Littleborough	13,807	Northern

Cities/Towns with Stations	Population	Rail Type
Ely	13,954	CrossCountry/East Midlands Trains/First Capital Connect/National Express East Anglia
Saltash	14,124	First Great Western
Alsager	14,178	East Midlands/London Midland
Lymington	14,227	South West Trains
Melksham	14,372	First Great Western
Penrith	14,471	Northern
Troon	14,500	ScotRail
Hadley	14,506	First Capital Connect
Stone (Stafford)	14,555	London Midland
Swinton	14,643	Northern
Blaydon	14,648	ScotRail/Northern
Carmarthen	14,648	Arriva Trains Wales/First Great Western
Addlestone	14,652	South West Trains
Hythe	14,766	National Express East Anglia
Teignmouth	14,799	First Great Western/CrossCountry
Prestwick	14,810	ScotRail
St Neots	14,937	First Capital Connect
Neston	15,018	Arriva Trains Wales
Stowmarket	15,059	National Express East Anglia
Wombwell	15,180	Northern
Sleaford	15,219	East Midlands

Cities/Towns with Stations	Population	Rail Type
Bangor	15,280	Arriva Trains Wales/Virgin Trains
Uckfield	15,374	Southern
Biggleswade	15,383	First Capital Connect
Garforth	15,394	Northern/First Transpennine Express
Larkhall	15,420	ScotRail
Northallerton	15,517	East Coast/First Transpennine Express/Grand Central
Keynsham	15,533	South West Trains/First Great Western
Johnstone	15,680	ScotRail
Selby	15,807	First Hull Trains/Northern/First Transpennine Express/East Coast
Aberystwyth	15,935	Arriva Trains Wales
Lewes	15,988	Southern
Alton	16,051	South West Trains
Dorking	16,071	First Great Western
Giffnock	16,090	ScotRail
Dorchester	16,171	First Great Western/South West Trains
Cobham / Oxshott	16,360	South West Trains
Rochford	16,374	National Express East Anglia
Kilwinning	16,380	ScotRail
Tiverton	16,772	First Great Western/CrossCountry
Skegness	16,806	East Midlands
Barrhead	16,990	ScotRail

Cities/Towns with Stations	Population	Rail Type
Bishopstoke	17,282	Southern
Romsey	17,386	South West Trains/First Great Western
Warminster	17,486	First Great Western/South West Trains
Shoreham	17,537	Southern/First Great Western
Sandbach	17,630	Northern
Nailsea	17,649	First Great Western
March	18,040	East Midlands/Cnational Express East Anglia
Emsworth / Southbourne	18,139	Southern
Buckley	18,268	Arriva Trains Wales
Bathgate	18,270	ScotRail
Eaglescliffe	18,335	Northern/First Transpennine Express
Mirfield	18,390	Northern
Maesteg	18,395	Arriva Trains Wales
Marple	18,475	Northern
Prestatyn	18,496	Arriva Trains Wales/Virgin Trains
Ebbw Vale	18,558	Arriva Trains Wales
Goole	18,741	Northern
Horsforth	18,928	Northern
Clarkston	18,980	ScotRail
Gainsborough	19,110	Northern/East Midlands Trains
Poulton-le-Fylde	19,480	Northern/First Transpennine Express
Stamford	19,525	East Midlands Trains

Cities/Towns with Stations	Population	Rail Type
Newquay	19,562	First Great Western
Portslade	19,564	Southern
Chalfont St Peter / Gerrards Cross	19,622	Chiltern Railways
Sandown / Shanklin	19,716	South West Trains
Dumbarton	19,860	ScotRail
Blantyre	19,870	ScotRail
Alloa	20,040	ScotRail
Mountain Ash / Abercynon	20,053	Arriva Trains Wales
Bellshill	20,090	ScotRail
Colne	20,118	Northern
Market Harborough	20,127	East Midlands Trains
Harwich	20,130	National Express East Anglia
Sudbury	20,188	Chiltern Railways
Risca	20,219	Arriva Trains Wales
Penzance	20,255	First Great Western/CrossCountry
Huntingdon	20,600	First Capital Connect
Buxton	20,836	Northern
Truro	20,920	First Great Western/CrossCountry
Elgin	21,040	ScotRail
Polmont	21,070	ScotRail
Seaham	21,153	Northern
Hedge End	21,174	South West Trains

Cities/Towns with Stations	Population	Rail Type
East Retford	21,314	East Coast/First Hull Trains
Amersham	21,470	Chiltern Railways
Burnham-on-Sea / Highbridge	21,476	First Great Western
Godalming	21,514	South West Trains
Workington	21,514	Northern
Falmouth	21,635	First Great Western
Thetford	21,760	East Midlands/National Express East Anglia
Seaford	21,851	Southern
Belper	21,938	Northern/East Midlands Trains
Potters Bar	22,008	First Capital Connect
Spalding	22,081	East Midlands
Arbroath	22,110	ScotRail/East Coast/CrossCountry
Evesham	22,179	First Great Western
Stratford-upon-Avon	22,187	London Midland/Chiltern Railways
Alfreton	22,302	Northern/East Midlands Trains
Clifton	22,312	Northern
Wellington	22,319	Arriva Trains Wales/London Midland
Musselburgh	22,380	ScotRail
Droitwich	22,585	London Midland
Thornaby	22,620	Northern/First Transpennine Express
Witham	22,631	National Express East Anglia
St Austell	22,658	First Great Western/CrossCountry

Cities/Towns with Stations	Population	Rail Type
Chapeltown	22,665	Northern
Holmfirth / Honley	22,690	Northern
Rugeley	22,724	London Midland
Rugeley	22,724	London Midland
Bromley Cross / Bradshaw	22,747	Northern
Ryde	22,806	South West Trains
Bishopbriggs	22,940	ScotRail
Thatcham	22,989	First Great Western
Penarth	23,245	Arriva Trains Wales
Warwick	23,350	London Midland/Chiltern Railways
Northfleet	23,457	Southeastern
Newton Mearns	23,610	ScotRail
Frome	24,171	First Great Western
Formby	24,478	Merseyrail
Shotton / Hawarden	24,751	Arriva Trains Wales/Virgin Trains
Bishop Auckland	24,764	Northern
Newton Abbot	24,855	First Great Western/CrossCountry
Whitehaven	24,978	Northern
Didcot	25,231	First Great Western
Congleton	25,400	CrossCountry/Northern
Hoylake / West Kirby	25,524	Merseyrail
Melton Mowbray	25,554	East Midlands Trains

Cities/Towns with Stations	Population	Rail Type
Cambuslang	25,630	ScotRail
Newton Aycliffe	25,655	Northern
Staveley	25,763	First Transpennine Express
East Grinstead	26,222	Southern
New Milton / Barton-on-Sea	26,681	South West Trains
Kirkby in Ashfield	27,067	East Midlands Trains
Bearsden	27,220	ScotRail
Chichester	27,477	Southern/First Great Western
Egham	27,666	South West Trains
Totton	27,986	South West Trains
Kendal	28,030	First Transpennine Express
Bredbury and Romiley	28,167	Northern
Lichfield	28,435	London Midland/Virgin Trains
Harpenden	28,452	First Capital Connect
Cramlington	28,653	Northern
Kidsgrove	28,724	Northern/London Midland/East Midlands Trains
Maghull / Lydiate	28,848	Merseyrail
Nelson	28,998	Northern
Clydebank	29,020	ScotRail
Wishaw	29,040	ScotRail
Beverley	29,110	Northern
Haywards Heath	29,110	Southern/First Capital Connect

Cities/Towns with Stations	Population	Rail Type
Hucknall	29,188	East Midlands Trains
Deal	29,248	Southeastern
Burgess Hill	29,388	Southern/First Capital Connect
Winsford	29,440	London Midland
Pontypridd	29,781	Arriva Trains Wales
Whitstable	30,195	Southeastern
Sompting / Lancing	30,360	Southern
Merthyr Tydfil	30,483	Arriva Trains Wales
Windsor / Eton	30,568	First Great Western
Rayleigh	30,629	National Express East Anglia
Wickford	30,751	National Express East Anglia
Barnstaple	30,765	First Great Western
Caerphilly	31,060	Arriva Trains Wales
Caerphilly	31,060	Arriva Trains Wales
Bicester	31,113	Chiltern Railways
Borehamwood	31,172	First Capital Connect
Motherwell	31,180	ScotRail
Oakengates / Donnington	31,246	Arriva Trains Wales/London Midland
Hyde	31,253	Northern
Darwen	31,570	Northern
Dumfries	31,610	ScotRail
Rutherglen	31,700	ScotRail

Cities/Towns with Stations	Population	Rail Type
Aberdare	31,705	Arriva Trains Wales
Cleethorpes	31,853	Northern/First Transpennine Express/East Midlands Trains
Stroud	32,052	First Great Western
Hatfield	32,281	First Capital Connect
Strood	32,663	Southeastern
Newbury	32,675	First Great Western
Fleet (Hart)	32,726	South West Trains
Eston and South Bank	32,788	Northern
Irvine	32,920	ScotRail
Letchworth	32,932	First Capital Connect
Exmouth	32,972	First Great Western
Wigston	33,116	CrossCountry
Chippenham	33,189	First Great Western
Hitchin	33,352	First Capital Connect
Bridlington	33,589	Northern
Stirling	33,710	ScotRail/East Coast
Bentley	33,968	Northern
Dover	34,087	Southeastern
Wilmslow / Alderley Edge	34,087	Northern/Virgin Trains/CrossCountry/Arriva Trains Wales
Felling	34,196	Northern
Radcliffe	34,239	East Midlands Trains
Trowbridge	34,401	First Great Western/South West Trains

Cities/Towns with Stations	Population	Rail Type
Falkirk	34,570	ScotRail/East Coast
Grantham	34,592	East Midlands Trains/East Coast/First Hull Trains/Grand Central
Herne Bay	34,747	Southeastern
Boston	35,124	East Midlands
Bishop's Stortford	35,325	Stanstead Express/National Express East Anglia
Pontypool	35,447	Arriva Trains Wales
Newark-on-Trent	35,454	East Midlands Trains/East Coast/First Hull Trains/Grand Central
Airdrie	35,500	ScotRail
Great Malvern	35,588	First Great Western/London Midland
Billingham	35,592	Norhtern/Grand Central
Port Talbot	35,633	Arriva Trains Wales
Tonbridge	35,833	Southern/Southeastern
Farnham	36,298	South West Trains
Redcar	36,443	Northern
Bridgwater	36,563	First Great Western/CrossCountry
Leyland	37,103	Northern
Andover	37,955	South West Trains
Ramsgate	37,967	Southeastern
Scarborough	38,364	Northern/First Transpennine Express
Banstead / Tadworth	38,664	Southern
Hazel Grove and Bramhall	38,724	Northern/East Midlands Trains

Cities/Towns with Stations	Population	Rail Type
Glenrothes	38,750	ScotRail
Worksop	39,072	Northern/East Midlands Trains
Bexhill	39,451	Southern
Wokingham	39,544	First Great Western/South West Trains
Camborne / Redruth	39,937	First Great Western/CrossCountry
Sittingbourne	39,974	Southeastern
Kirkby	40,006	Northern
Christchurch	40,208	South West Trains
Telford Dawley	40,437	Arriva Trains Wales/London Midland
King's Lynn	40,921	First Capital Connect/National Express East Anglia
Lytham St Anne's	41,327	Northern
Winchester	41,420	South West Trains/CrossCountry
Yeovil	41,871	First Great Western/South West Trains
Coatbridge	42,000	ScotRail
Braintree	42,393	National Express East Anglia
Wrexham	42,576	Arriva Trains Wales/Virgin Trains
Leatherhead	42,885	Southern/South West Trains
Durham	42,939	Northern/East Coast/CrossCountry/First Transpennine Express
Leigh	43,006	Southern
Greenock	43,130	ScotRail
Hinckley	43,246	CrossCountry

Cities/Towns with Stations	Population	Rail Type
Salisbury	43,355	First Great Western/South West Trains
Welwyn Garden City	43,512	First Capital Connect
Canterbury	43,552	Southeastern
Burton Upon Trent	43,784	CrossCountry
Banbury	43,867	First Great Western/CrossCountry/Chiltern Railways
Inverness	44,220	ScotRail/East Coast
Kilmarnock	44,390	ScotRail
Perth	44,820	ScotRail/East Coast
Folkestone	45,273	Southeastern/Eurostar
Neath	45,898	Arriva Trains Wales/First Great Western
Lancaster	45,952	Northern/First Transpennine Express/Virgin Trains
Ayr	46,070	ScotRail
Llanelli	46,357	Arriva Trains Wales/First Great Western
Dunfermline	46,430	ScotRail
Long Eaton	46,490	Northern/East Midlands Trains/CrossCountry
Wellingborough	46,959	East Midlands Trains
Barrow-in-Furness	47,194	Northern/First Transpennine Express
Cwmbran	47,254	Arriva Trains Wales
Paignton	47,398	First Great Western/CrossCountry
Horsham	47,804	Southern
Weymouth	48,279	First Great Western/South West Trains
Carlton	48,493	East Midlands Trains

Cities/Towns with Stations	Population	Rail Type
Kirkcaldy	48,630	ScotRail/East Coast/CrossCountry
Hamilton	48,900	ScotRail
Batley	49,448	Northern
Morecambe	49,569	Northern/First Transpennine Express
Esher / Molesey	50,344	South West Trains
Reigate / Redhill	50,436	Southern/First Great Western/First Capital Connect
Cumbernauld	50,480	ScotRail
Staines	50,538	South West Trains
Barry	50,661	Arriva Trains Wales
Macclesfield	50,688	CrossCountry/Virgin Trains/Northern
Kettering	51,063	East Midlands Trains
Clacton-on-Sea	51,284	National Express East Anglia
Walton and Weybridge	52,890	South West Trains
Eastleigh	52,894	South West Trains
Gravesend	53,045	Southeastern
Greasby / Moreton	53,905	South West Trains
Morley	54,051	Northern
Dewsbury	54,341	Northern/First Transpennine Express
Livingston	54,740	ScotRail
Loughborough	55,258	East Midlands Trains
Kidderminster	55,348	London Midland/Chiltern Railways
Stourbridge	55,480	London Midland/Chiltern Railways

Cities/Towns with Stations	Population	Rail Type
Littlehampton	55,716	Southern
Fareham / Portchester	56,160	South West Trains/Southern/First Great Western
Hereford	56,373	Arriva Trains Wales/London Midland/First Great Western
Dartford	56,818	Southeastern
Farnborough	57,147	South West Trains
Great Yarmouth	58,032	National Express East Anglia
Aldershot	58,170	South West Trains
Taunton	58,241	First Great Western/CrossCountry
Margate	58,465	Southeastern
Wallasey	58,710	Merseyrail
Maidenhead	58,848	First Great Western
Ashford	58,936	Southeastern/Eurostar
Bootle	59,123	Northern
Royal Tunbridge Wells	60,095	Southeastern
Wolverton / Stony Stratford	60,359	National Express East Anglia/London Overground/Southeastern
Royal Leamington Spa	61,595	London Midland/Chiltern Railways/CrossCountry
Bognor Regis	62,141	Southern
Kingswood	62,679	Southern
Torquay	62,968	First Great Western/CrossCountry
Stafford	63,681	CrossCountry/Virgin Trains/Arriva Trains Wales/London Midland
Epsom and Ewell	64,493	Southern

Cities/Towns with Stations	Population	Rail Type
Cannock	65,022	London Midland
Beeston and Stapleford	66,683	Northern/East Midlands Trains/CrossCountry
Shrewsbury	67,126	Arriva Trains Wales/London Midland
Crewe	67,683	Virgin Trains/East Midlands Trains/Northern/Arriva Trains Wales/London Midland
Doncaster	67,977	CrossCoutry/East Midlands Trains/First Transpennine Express/Grand Central
Lowestoft	68,340	National Express East Anglia
Aylesbury	69,021	Chiltern Railways
Guildford	69,400	First Great Western/CrossCountry/South West Trains/Southern
Nuneaton	70,721	CrossCountry/Virgin Trains
Bracknell	70,795	South West Trains
Barnsley	71,599	Northern
Carlisle	71,773	ScotRail/Northern/East Coast/First Transpennine Express/Virgin Trains
Hove	72,335	Southern/First Great Western
Scunthorpe	72,660	First Transpennine Express/Northern
East Kilbride	73,200	ScotRail
Chatham	73,468	Southeastern
Paisley	74,100	ScotRail
Redditch	74,803	London Midland
Wakefield	76,886	Grand Central/East Coast/Northern/CrossCountry/East Midlands Trains

Cities/Towns with Stations	Population	Rail Type
High Wycombe	77,178	Chiltern Railways
Weston-Super-Mare	78,044	First Great Western/CrossCountry
Gateshead	78,403	Northern
Stockton-on-Tees	80,060	Norhtern/Grand Central
Chester	80,121	Arriva Trains Wales/Virgin Trains/Merseyrail
Stevenage	81,482	First Capital Connect/First Hull Trains/East Coast
St Albans	82,429	First Capital Connect
Bedford	82,488	East Midlands Trains/First Capital Connect/London Midland
Halifax	83,570	Northern/Grand Central
Harrogate / Knaresborough	85,128	East Coast/Northern
Hastings	85,828	Southereastn/Southern
Lincoln	85,963	Northern/East Coast/ East Midlands Trains
Hartlepool	86,075	Norhtern/Grand Central
Darlington	86,082	Northern/East Coast/CrossCountry/First Transpennine Express
Grimsby	87,574	Northern/First Transpennine Express/East Midlands Trains
Harlow / Sawbridgeworth	88,296	Stanstead Express/National Express East Anglia
Bath	90,144	South West Trains/First Great Western
Basingstoke	90,171	South West Trains/First Great Western/CrossCountry
Southport	91,404	Northern/Merseyrail
Worcester	94,029	First Great Western/London Midland
Rochdale	95,796	Northern

Cities/Towns with Stations	Population	Rail Type
Worthing	96,964	Southern/First Great Western
Gillingham	98,403	South West Trains
Cheltenham	98,875	First Great Western/CrossCountry/Arriva Trains Wales
Chelmsford	99,962	National Express East Anglia
Crawley	100,547	Southern
Woking / Byfleet	101,127	South West Trains
Colchester	104,390	National Express East Anglia
Blackburn	105,085	Northern
Eastbourne	106,562	Southern
Exeter	106,772	First Great Western/CrossCountry/South West Trains
Newport	116,143	Arriva Trains Wales/CrossCountry/First Great Western
Rotherham	117,262	Northern
Cambridge (/ Milton)	117,717	National Express East Anglia/First Capital Connect/CrossCountry
Gloucester	123,205	First Great Western/CrossCountry/Arriva Trains Wales
Slough	126,276	First Great Western
Brighton	134,293	Southern/First Great Western/First Capital Connect
Stockport	136,082	Northern/Virgin Trains/CrossCountry/Arriva Trains Wales/East Midlands Trains
Peterborough	136,292	East Midlands/CrossCountri/First Capital Connect/First Hull Trains/ Grand Central
York	137,505	Grand Central/East Coast/East Midlands Trains/First Transpennine Express/Northern/CrossCountry

Cities/Towns with Stations	Population	Rail Type
Ipswich	138,718	National Express East Anglia
Bolton	139,403	First Transpennine Express/Northern
Dundee	142,070	ScotRail/East Coast/CrossCountry
Blackpool	142,283	Northern/First Transpennine Express
Middlesbrough	142,691	Northern/First Transpennine Express
Oxford	143,016	First Great Western/CrossCountry/Chiltern Railways
Poole	144,800	South West Trains
Huddersfield	146,234	Northern/First Transpennine Express
Kingston upon Thames	146,873	South West Trains
Swindon	155,432	First Great Western
Kensington and Chelsea	158,439	Southern/London Overground
Barking and Dagenham	163,944	London Overground/CrossCountry
Bournemouth	167,527	South West Trains/CrossCountry
Swansea	169,880	Arriva Trains Wales/First Great Western
Walsall	170,994	London Midland
Richmond upon Thames	172,335	South West Trains/London Overground
Norwich	174,047	East Midlands/National Express East Anglia
Sunderland	177,739	Norhtern/Grand Central
Sutton	177,796	Southern/First Capital Connect
Aberdeen	183,030	ScotRail/East Coast/CrossCountry
Preston	184,836	First Great Western/First Transpennine Express/Virgin Trains/ScotRail (Sleeper)

Cities/Towns with Stations	Population	Rail Type
Luton	185,543	First Capital Connect/East Midlands Trains
Portsmouth	187,056	Southern/First Great Western/South West Trains
Merton	187,908	First Capital Connect
Newcastle upon Tyne	189,863	Northern/East Coast/CrossCountry
Dudley	194,919	London Midlands
Hackney	202,824	London Overground/Southeastern
Harrow	206,643	Chiltern Railways
Bexley	211,802	Southeastern
Greenwich	219,263	Southeastern
Derby	229,407	Northern/East Midlands Trains/CrossCountry
Reading	232,662	First Great Western/CrossCountry/South West Trains
Southampton	234,224	South West Trains/First Great Western/CrossCountry/Southern
Redbridge	240,796	South West Trains/First Great Western
Plymouth	243,795	First Great Western/CrossCountry
Lewisham	248,922	Southeastern
Nottingham	249,584	Northern/East Midlands Trains/CrossCountry
Wolverhampton	251,462	London Midland/CrossCountry/Virgin Trains/Arriva Trains Wales
Stoke-on-Trent	259,252	London Midland/Virgin Trains/East Midlands Trains/Northern
Enfield	273,203	National Express East Anglia/First Capital Connect
Bromley	280,305	Southeastern

Cities/Towns with Stations	Population	Rail Type
Cardiff	292,150	CrossCountry/First Great Western/Arriva Trains Wales
Bradford	293,717	Grand Central/East Coast/Northern
Ealing	300,948	First Great Western/Heathrow Express
Kingston upon Hull	301,416	Northern/First Transpennine Express/East Coast/ First Hull Trains
Coventry	303,475	CrossCountry/London Midland/Virgin Trains
Croydon	316,283	Southern/First Capital Connect
Leicester	330,574	East Midlands Trains/CrossCountry
Manchester	394,269	Northern/First Transpennine Express/East Midlands Trains/Virgin Trains/CrossCountry/Arriva Trains Wales
Bristol	420,556	First Great Western/South West Trains/CrossCountry
Sheffield	439,866	First Transpennine Express/Northern/East Midlands Express/CrossCountry
Leeds	443,247	Northern/East Coast/First Transpennine Express/CrossCountry
Edinburgh	454,280	ScotRail/East Coast/CrossCountry/Virgin Trains/First TransPennine Express
Liverpool	469,017	Merseyrail/Virgin Trains/East Midlands Trains/First Transpennine Express/Northern
Glasgow	581,320	ScotRail/East Coast/CrossCountry/Virgin Trains/First TransPennine Express
Birmingham	970,892	London Midland/Virgin Trains/CrossCountry/Chiltern Railways/Arriva Trains Wales
London	7,172,091	Everything

* London, Birmingham, Manchester, Liverpool, South Yorkshire, Leeds, Glasgow are proposed High Speed 2 stations

Table 8 Summary of Coverage for Great Britain

Total Population Residing in City/Town with Train Station	38,642,153
Total Population of GB	59,000,000
% Population	65.50%
Total Rail (km)	20,000
Total Population Residing in City/Town with High Speed Train Station	7,287,845
% Population Residing in City/Town with High Speed Station	12.35%
% Population Residing in City/Town with High Speed Station	0.20%
Average Size of City/Town with Train Station	45,143
Average Size of City/Town with Train Station	45,195

(Brinkhoff, 2012)

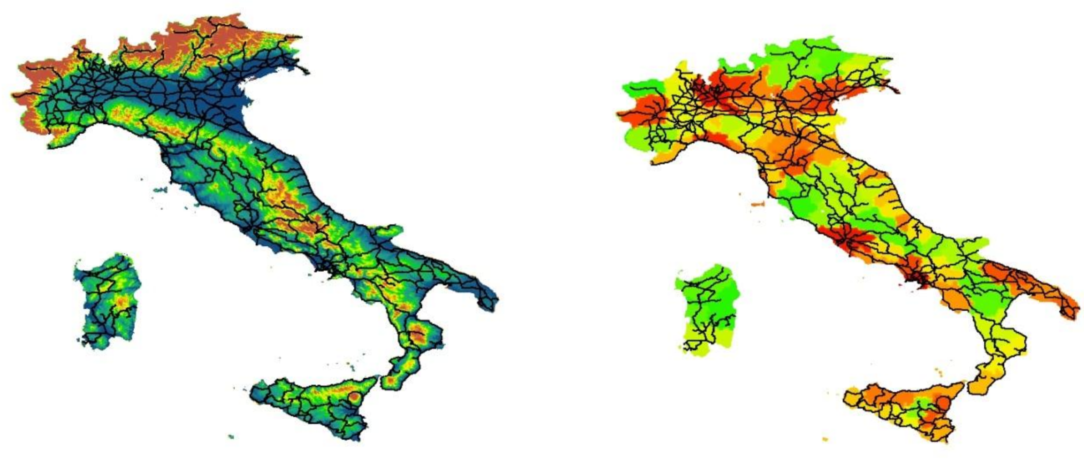

Figure 20 Elevation Profile (left) and Population Density (right) for Italy with Rail Map

Table 9 Population of Cities/Towns in Italy with Stations

Cities/Towns with High Speed Stations	Population 2011
Gioia Tauro*****	18,663
Lamezia Terme (Nicastro)	71,286

Lecce	95,520
Ancona	102,997
Bolzano (Bozen)	104,029
Rimini	143,321
Foggia	152,747
Ravenna	158,739
Livorno	161,131
Perugia	168,169
Reggio di Calabria	186,547
Taranto	191,810
Trieste	205,535
Padova [Padua]	214,198
Messina	242,503
Verona	263,964
Venezia [Venice]	270,884
Catania	293,458
Bari	320,475
Firenze [Florence]	371,282
Bologna	380,181
Genova [Genoa]	607,906
Palermo	655,875
Torino [Turin]	907,563
Napoli [Naples]	959,574

Milano [Milan]	1,324,110
Roma [Rome]	2,761,477

Table 10 Summary of Coverage for Italy

Total Population of Cities/Towns with Stations	17,613,946
Total Population of Italy* **	60,600,000
% Population Located within Cities/Towns with Stations	29.07%
% Population Residing in City/Town with High Speed Stop	18.70%
Average Size of City/Town with High Speed Stop	404,784
Total Rail (km)	24,227

(Brinkhoff, 2012)

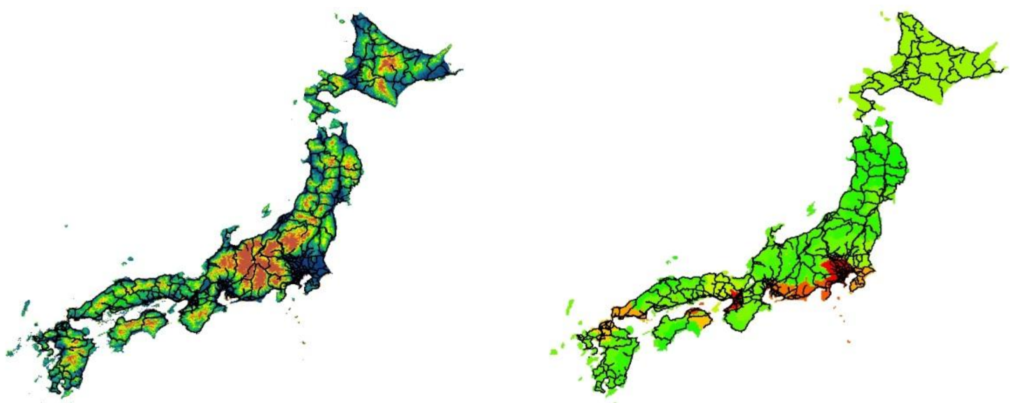

Figure 21 Elevation Profile (left) and Population Density (right) for Japan with Rail Map

Table 11 Population of Cities/Towns in Japan with Stations

Cities w/ Stations (High Speed Only)	**Population**
Ueno (上野村)***	1,306
Yuzawa (湯沢町)****	8,396

Cities w/ Stations (High Speed Only)	**Population**
Esashi (江差町)	9,004
Iwate**	18,264
Karuizawa (軽井沢町)*****	19,018
Minakami (みなかみ町) [Jomo-Kogen]	21,345
Minamata (水俣市)	26,978
Ninohe (二戸市)	29,702
Aioi (相生市)	31,158
Atami (熱海市)	39,611
Maibara (米原市)	40,060
Chikugo [Chikugo-Funagoya]	48,512
Izumi (出水市)	55,621
Annaka (安中市)	61,077
Minamiuonuma (南魚沼市)	61,624
San'yō-Onoda (山陽小野田市) [Asa]	64,550
Towada (十和田市)	66,110
Tosu (鳥栖市)	69,074
Tamana	69,541
Kurihara (栗原市) [Kurikoma-Kogen]	74,932
Tsubame (燕市)	81,876
Honjō (本庄市) [Honjo-Waseda]	81,889
Kitakami (北上市)	93,138
Mihara (三原市)	100,509

Cities w/ Stations (High Speed Only)	Population
Saku (佐久市) [Sakudaira]	100,552
Mishima (三島市)	111,838
Kakegawa (掛川市)	116,363
Ichinoseki (一関市)	118,578
Ōmuta	123,638
Yatsushiro (八代市)	132,266
Iwakuni (岩国市)	143,857
Onomichi (尾道市)	145,202
Shūnan (周南市) [Tokuyama]	149,487
Ueda (上田市)	159,597
Anjō (安城市)	178,691
Higashihiroshima (東広島市)	190,135
Yamaguchi (山口市)	196,628
Odawara (小田原市)	198,327
Kumagaya (熊谷市)	203,180
Minato*	217,335
Hachinohe (八戸市)	237,615
Fuji (富士市)	254,027
Shimonoseki (下関市)	280,947
Nagaoka (長岡市)	282,674
Akashi (明石市)	290,959
Morioka (盛岡市)	298,348

Cities w/ Stations (High Speed Only)	Population
Aomori (青森市)	299,520
Kurume (久留米市)	302,402
Takasaki (高崎市)	371,302
Toyohashi (豊橋市)	376,665
Nagano (長野市)	381,511
Gifu (岐阜市)	413,136
Fukuyama (福山市)	461,357
Kurashiki (倉敷市)	475,513
Himeji (姫路市)	536,270
Kagoshima (鹿児島市)	605,846
Okayama (岡山市)	709,584
Shizuoka (静岡市)	716,197
Kumamoto (熊本市)	734,474
Hamamatsu (浜松市)	800,866
Niigata (新潟市)	811,901
Kitakyūshū (北九州市) [Kokura]	976,846
Sendai (仙台市)	1,045,986
Hiroshima (広島市)	1,173,843
Saitama (さいたま市)	1,222,434
Kawasaki [Furukawa]	1,425,512
Fukuoka (福岡市) [Hakata]	1,463,743
Kyōto (京都市)	1,474,015

Cities w/ Stations (High Speed Only)	Population
Kōbe (神戸市)	1,544,200
Nagoya (名古屋市)	2,263,894
Ōsaka (大阪市)	2,665,314
Yokohama (横浜市)	3,688,773
Tōkyō	8,945,695

Table 12 Summary of Coverage for Japan

Total Population residing in Cities/Towns with Stations	63,701,995
Total Population of Japan	127,450,460
% Population residing in Cities/Towns with Stations	49.98%
% Population Residing in City/Town with High Speed Stop	32.32%
Average Size of City/Town with High Speed Stop	441,707
Total Rail (km) (Climate Avenue, 2011)	13,000

(Brinkhoff, 2012)

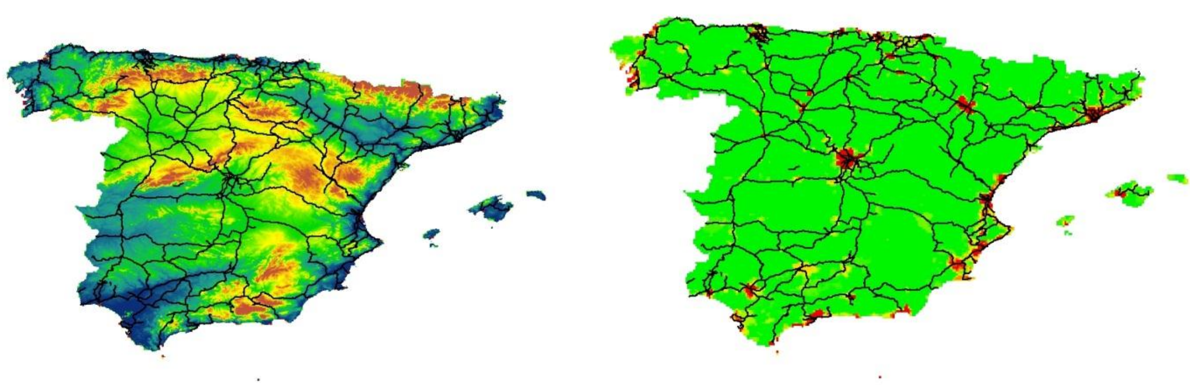

Figure 22 Elevation Profile (left) and Population Density (right) for Spain with Rail Map

Table 13 Population of Cities/Towns in Spain with Stations

City	Population	Type of Track
Castillejo de Mesleón	158	Fast Speed
Canfranc	454	Non-Electrified
L'Alqueria d'Asnar	455	Non-Electrified
Fuentes de Oñoro	1,436	Non-Electrified
Ribes de Freser	2,001	Fast Speed
Pobla de Segur	3,237	Non-Electrified
Castejon	4,235	Fast Speed
Valencia de Alcántara	6,178	Non-Electrified
Puigcerdà	9,022	Fast Speed
Astorga	12,078	Non-Electrified
Zafra	16,424	Non-Electrified
Tui	17,262	Fast Speed
Manzanares	19,126	Non-Electrified
Monforte de Lemos	19,486	Fast Speed
Calatayud	20,837	High Speed
Riba-roja de Túria	21,094	Non-Electrified
Amposta	21,445	Fast Speed
Medina del Campo	21,607	High Speed
Cullera	23,304	Fast Speed
Olesa de Montserrat	23,924	Non-Electrified
Santa Perpètua de Mogoda	25,331	High Speed
Martorell	27,457	Fast Speed

Sant Vicenç dels Horts	28,137	Fast Speed
Sitges	28,617	Fast Speed
Mahon	29,125	Non-Electrified
Xàtiva	29,469	Non-Electrified
Redondela	30,006	Non-Electrified
Alcázar de San Juan	31,652	Fast Speed
Cambrils	33,008	Fast Speed
Aranda de Duero	33,229	Non-Electrified
Tortosa	34,432	Fast Speed
Águilas	34,990	Non-Electrified
Teruel	35,288	
Vilagarcía (de Arousa)	37,903	Non-Electrified
Vilafranca (del Penedès)	38,785	Fast Speed
Miranda de Ebro	38,930	Fast Speed
Igualada	39,191	
Soria	39,987	Non-Electrified
Vic	40,900	Fast Speed
Tres Cantos	41,065	Fast Speed
Plasencia	41,392	Non-Electrified
Alcantarilla	41,568	Non-Electrified
Antequera	41,854	Non-Electrified
Basauri	42,166	Fast Speed
Dénia	44,726	Non-Electrified

Figueres	44,765	Fast Speed
Colmenar Viejo	45,468	Fast Speed
Pinto	45,643	Fast Speed
Boadilla del Monte	46,151	Fast Speed
Santurtzi (Santurce-Antiguo)	47,076	Fast Speed
Eivissa (Ibiza)	49,388	Non-Electrified
Utrera	51,630	Fast Speed
Puertollano	52,200	High Speed
Mollet (del Vallès)	52,409	High Speed
Huesca	52,443	Non-Electrified
Segovia	55,220	High Speed
Aranjuez	55,755	Fast Speed
Cuenca	56,703	
Mérida	57,797	Non-Electrified
Cerdanyola (del Vallès)	58,247	Fast Speed
Ávila	59,270	Fast Speed
Collado Villalba	60,998	Fast Speed
Irun (Irún)	61,006	Fast Speed
Alcoy (Alcoi)	61,093	
Linares	61,110	Fast Speed
Castelldefels	63,139	Fast Speed
El Prat (de Llobregat)	63,499	Fast Speed
Zamora	65,525	Non-Electrified

Sagunto (Sagunt)	65,595	Fast Speed
Vilanova i la Geltrú	66,905	Fast Speed
Ponferrada	68,508	Fast Speed
Ferrol (El Ferrol)	72,963	Non-Electrified
Fuengirola	74,054	Fast Speed
Ciudad Real	74,798	High Speed
Manresa	76,589	Fast Speed
Gandía	78,704	
San Sebastián de los Reyes	79,825	Fast Speed
Palencia	81,552	Fast Speed
Toledo	83,108	High Speed
Guadalajara	84,453	
Talavera de la Reina	88,674	Non-Electrified
Las Rozas de Madrid	89,151	Fast Speed
Lorca	92,869	Non-Electrified
Cáceres	95,026	Non-Electrified
Santiago de Compostela	95,207	Non-Electrified
Girona (Gerona)	96,722	Fast Speed
San Fernando	96,894	Fast Speed
Lugo	98,007	Non-Electrified
Reus	106,709	Fast Speed
Ourense (Orense)	108,002	Non-Electrified
Jaén	116,781	Fast Speed

Algeciras	117,810	Non-Electrified
Parla	121,995	Fast Speed
Mataró	123,868	Fast Speed
Cádiz	124,892	Fast Speed
León	132,744	Fast Speed
Tarragona	134,085	High Speed
Lleida (Lérida)	138,416	High Speed
Huelva	148,918	Fast Speed
Badajoz	151,565	Non-Electrified
Logroño	152,641	Fast Speed
Salamanca	153,472	Non-Electrified
Getafe	170,115	Fast Speed
Albacete	171,390	Fast Speed
Burgos	179,251	Non-Electrified
Santander	179,921	Fast Speed
Castellón de la Plana(Castelló de la Plana)	180,114	Fast Speed
Donostia-San Sebastián	186,185	Fast Speed
Leganés	186,552	Fast Speed
Almería	190,349	Non-Electrified
Pamplona (Iruña)	197,932	Fast Speed
Alcalá de Henares	203,686	Fast Speed
Móstoles	205,015	Fast Speed
Sabadell	207,721	Fast Speed

Jerez de la Frontera	210,861	Fast Speed
Terrassa (Tarrasa)	213,697	Fast Speed
Cartagena	214,918	Non-Electrified
Oviedo	225,391	Fast Speed
Elche (Elx)	230,354	Non-Electrified
Vitoria-Gasteiz	239,562	Fast Speed
Granada	240,099	Non-Electrified
A Coruña (La Coruña)	246,028	Non-Electrified
Gijón	277,559	Fast Speed
Vigo	297,241	Fast Speed
Valladolid	313,437	High Speed
Córdoba	328,659	High Speed
Alicante (Alacant)	334,329	Fast Speed
Bilbao	352,700	Fast Speed
Palma de Mallorca	405,318	Non-Electrified
Murcia	442,203	Non-Electrified
Málaga	568,030	High Speed
Zaragoza	674,725	High Speed
Sevilla	703,021	Fast Speed
Valencia (València)	798,033	High Speed
Barcelona	1,615,448	High Speed
Madrid	3,265,038	High Speed

Table 14 Summary of Coverage for Spain

Total Population of Cities/Towns with Stations	20,345,890
Total Population	46,081,574
% Population Located within Cities/Towns with Stations	44.15%
Total Rail (km)	15,288

(Brinkhoff, 2012)

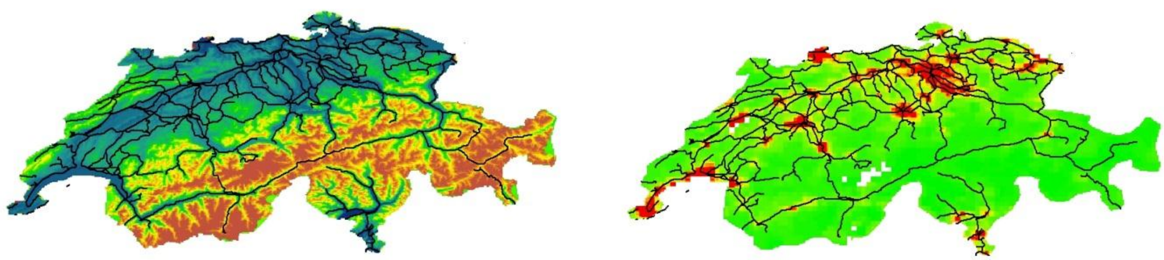

Figure 23 Elevation Profile (left) and Population Density (right) for Switzerland with Rail Map

Table 15 Population of Cities/Towns in Switzerland with Stations

Station-Cities	Pop 12-31-2010	Rail speed(s)
Wasserauen	30	High
Ziegelbrücke	70	High
Montbovon	265	High
Tiefencastel	269	High
Göschenen	410	High
Wassen	434	High
Filisur	461	High

Buttes	601	High
Les Verrières	667	High
Sembrancher	862	High
St. Gingolph	888	High
L'Isle	975	High
Linthal	1,088	High
Les Brenets	1,089	High/Non-Ev
Bercher	1,109	High
Zemez	1,140	High
Tamins	1,184	High
Glovelier	1,204	High
Waldenburg	1,221	High
Kandersteg	1,231	High
Les Ponts-de-Martel	1,265	High
Champéry	1,276	High
Andermatt	1,304	High
Rodersdorf	1,315	High
Palézieux	1,326	High
Boltigen	1,376	High
Ormont-Dessus	1,457	High
Bière	1,480	High
Airolo	1,558	High
Le Noirmont	1,661	High

Trogen	1,687	High
Fahrwangen	1,862	High
Flüelen	1,950	High
Pontresina	1,994	High
Disentis	2,111	High
St. Sulpice	2,123	High
Arosa	2,251	High
Broc	2,296	High
Ilanz	2,315	High
Scuol	2,376	High
Lenk im Simmertal	2,399	High
Muhlenberg	2,654	High
Niederweningen	2,729	High
Thusis	2,791	High
Zweisimmen	2,922	High
Samedan	2,968	High
Brienz	2,981	High
Gais	3,065	High
Orsières	3,077	High
Gstaad	3,200	High
Stein am Rhein	3,209	High
Ins	3,229	High
Vallorbe	3,312	High

Nesslau	3,348	High
Cossonay	3,368	High
Leuk	3,381	High
Tavannes	3,478	High
Poschiavo	3,506	High
Fleurier	3,518	High
Schöftland	3,715	High
Leysin	3,839	High
Klosters	3,892	High
Engelberg	3,903	High
Heiden	3,990	High
St. Moritz	4,202	High
Eglisau	4,213	High
Le Chenit	4,325	High
St. Croix	4,509	High
Meiringen	4,583	High
Romont	4,588	High
Kerzers	4,598	High
Huttwil	4,704	High
Konolfingen	4,763	High
St. Imiier	4,771	High
Sumiswald	5,027	High
Echallens	5,189	High

Oensingen	5,245	High
Flamat	5,322	High
Sargans	5,330	High
Interlaken	5,429	High
Estavayer	5,554	High
Alpnach	5,568	High
St. Margrethen	5,568	High
Appenzell	5,712	High
Zermatt	5,720	High
Châtel-Saint-Denis	5,727	High
Balsthial	5811	High
Uznach	5,840	High
Glarus	5,877	High
Murton	6,125	High
Sissach	6,275	High
Bex	6,500	High
Porrentruy	6,679	High
Schwarzenburg	6,716	High
Frutigen	6,718	High
Herzogenbuchsee	6,766	High
Visp	7,014	High
Moutier	7,466	High
Bagnes	7,726	High

Chiasso	7,737	High
Stans	7,961	High
Egg	7,997	High
Aigle	8,100	High
Wattwil	8,130	High
Lenzburg	8,341	High
Ingenbohl	8,411	High
Payerne	8,728	High
Altdorf	8,861	High
Sursee	8,941	High
Langnau	9,017	High
Rotkreuz	9,085	High
Romanshorn	9,606	High
Suhr	9,743	High
Sarnen	9,971	High
Le Locle	10,049	High
Weinfelden	10,383	High
Brugg	10,386	High
Arth (-Goldau)	10,699	High
Zofingen	10,803	High
Val-de-Travers	10,812	High
Altstätten	10,819	High
Davos	11,166	High

Buchs	11,242	High
Villars-sur-Glâne	11,397	High
Delémont	11,639	High
Lyss	11,821	High
Brig-Glis	12,467	High
Spiez	12,475	High
Muri bei Bern	12,625	High
Küsnacht	13,501	High
Liestal	13,600	High
Einsiedeln	14,385	High
Schwyz	14,423	High
Wohlen	14,443	High
Morges	14,744	High
Langenthal	14,938	High
Locarno	15,153	High
Herisau	15,236	High
Burgdorf	15,374	High
Steffisburg	15,431	High
Sierre	15,527	High
Illnau-Effretikon	15,602	High
Grenchen	15,928	High
Solothurn	16,066	High
Martigny	16,143	High

Monthey	16,408	High
Olten	16,987	High
Thalwil	17,213	High
Bellinzona	17,373	High
Bülach	17,511	High
Gossau	17,763	High
Baden	17,929	High
Wil	18,000	High
Vevey	18,394	High
Reinach	18,656	High
Nyon	18,728	High
Bulle	18,947	High
Aarau	19,497	High
Kreuzlingen	19,544	High
Wädenswil	20,433	High
Wetzikon	22,118	High
Frauenfeld	23,298	High
Dietikon	23,624	High
Landquart	24,093	High
Montreux	24,579	High
Rapperswil-Jona	26,212	High
Zug	26,327	High
Yverdon-les-Bains	27,511	High

Sion	30,363	High
Uster	32,265	High
Neuchâtel	33,054	High
Chur	33,756	High
Fribourg	34,897	High
Schaffhausen	34,943	High/Non-Ev
La Chaux-de-Fonds	37,504	High
Thun	42,623	High
Biel (Bienne)	51,203	High
Lugano	54,667	High
St. Gallen	72,959	High
Luzern	77,491	High
Winterthur	101,308	High
Bern	124,381	High
Lausanne	127,821	High
Basel	163,216	High
Genève [Geneva]	187,470	High/Basic
Zürich [Zurich]	372,857	High

Table 16 Summary of Coverage for Switzerland

Total Population of Cities/Towns with Stations	2,948,644
Total Population	7,825,243
% Population Located within Cities/Towns with Stations	37.68%

Total Rail (km)	5,063

(Brinkhoff, 2012)

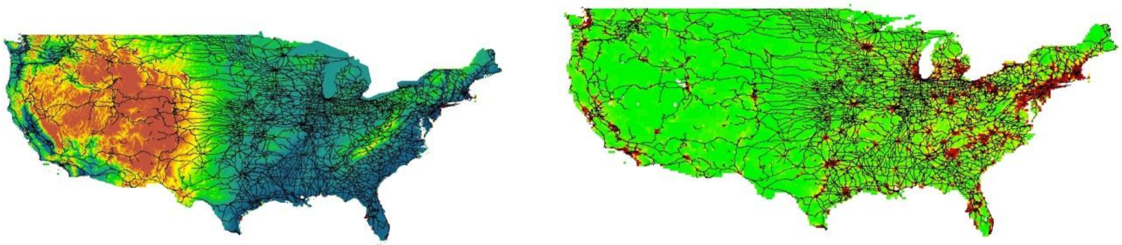

Figure 24 Elevation Profile (left) and Population Density (right) for the US with Rail Map

Table 17 Population of Cities/Towns in the US with Amtrak Stations

Station City	Population of City (Mid 2009)	Type of Rail
Thurmond	7	Basic
Prince	116	Basic
Wishram	339	Basic
Bingen	678	Basic
Yemassee	867	Basic
Alderson	1,064	Basic
Pittsfield	1,334	Basic
Colfax	1,878	Basic
Montgomery	1,912	Basic
New Iberia	2,086	Basic
Martinsburg	2,137	Basic
White Sulphur Springs	2,263	Basic
Hinton	2,533	Basic
Dover	2,682	Basic
Denmark	2,934	Basic
Kingstree	3,176	Basic
Rutland	3,250	Basic
Surf (Lompoc)	3,338	Basic
Denair	3,880	High Speed
Clifton Forge	3,927	Basic
Hazlehurst	4,327	Basic
Walnut Ridge	4,720	Basic
McGrego	4,910	Basic
Mineola	5,219	Basic

Hamlet	5,764	Basic
Pauls Valley	6,067	Basic
Schriever	6,114	Basic
Purcell	6,224	Basic
Guadalupe	6,594	Basic
Camden	7,103	Basic
St. Albans	7,243	Basic
Bay St. Louis	7,538	Basic
Rensselaer	7,851	Basic
Malvern	8,854	Basic
Toccoa	9,065	Basic
Louisville	9,453	High Speed
Summit	10,169	Basic
Brookhaven	10,207	Basic
Palatka	10,677	Basic
Fort Madison	10,884	Basic
Arkadelphia	11,175	Basic
Niles	11,272	Basic
Picayune	12,008	Basic
Elizabethtown	12,103	Basic
Kelso	12,150	Basic
Kewanee	12,241	Basic
Rantoul	12,247	Basic
Effingham	12,557	Basic
New Carrollton	12,656	Basic
Williamsburg	12,729	Basic
Southern Pines	12,862	Basic
Claremont	12,963	Basic
Clemson	13,002	Basic
Solana Beach	13,059	High Speed
Grover Beach	13,200	Basic
Auburn	13,352	Basic
Centralia	13,465	Basic
McComb	13,644	Basic
Carpinteria	13,764	Basic
Aberdeen	14,099	Basic
Lincoln	14,523	Basic
Yazoo City	14,798	Basic
Crawfordsville	15,090	Basic
La Grange	15,186	Basic
Greensburg	15,255	Basic

Depew	15,261	Basic
Red Wing	15,681	Basic
Centralia	15,700	Basic
Greenwood	15,808	Basic
Dyer	15,927	Basic
Truckee	16,260	Basic
Corcoran	16,446	High Speed
Mattoon	17,120	Basic
Tukwila	17,392	Basic
Amsterdam	17,465	Basic
Saco	18,204	Basic
Laurel	18,831	Basic
Warrensburg	19,203	Basic
Plattsburgh	19,380	High Speed
Macomb	19,748	Basic
Hammond	20,037	Basic
Carbondale	20,196	Basic
Texarkana	20,221	Basic
Cumberland	20,449	Basic
Sedalia	21,151	Basic
Johnstown	21,497	Basic
Alliance	22,586	Basic
Fredricksburg	23,193	Basic
Anniston	23,589	Basic
Pascagona	23,677	Basic
Marshall	24,089	Basic
Barstow	24,528	Basic
Wasco	24,724	High Speed
Ardmore	24,850	Basic
New London	26,184	Basic
Winona	26,502	Basic
Kirkwood	26,808	Basic
Kankakee	26,840	Basic
Suisun	27,003	Basic
Slidell	27,475	Basic
Salisbury	27,808	Basic
Winter Park	28,449	Basic
Saratoga Springs	29,126	Basic
Alton	29,264	Basic
Poughkeepsie	29,564	Basic
Cleburne	29,931	Basic

Port Huron		30,568	Basic
Galesburg		31,006	Basic
Oregon City		31,826	Basic
Mount Vernon		32,139	Basic
Florence		32,180	Basic
Chatsworth		32,188	Basic
Petersburg		32,986	Basic
Jackson		33,315	Basic
Rome		33,443	Basic
Holland		34,053	Basic
San Juan Capistrano		35,142	Basic
Gainesville		35,750	Basic
Manassas		36,514	Basic
Del Rio		36,676	Basic
Moorpark		36,695	Basic
Woburn		38,987	Basic
Meridian		39,695	Basic
Quincy		40,062	Basic
Spartanburg		40,387	Basic
Edmonds		40,773	Basic
Jefferson City		41,297	Basic
Lacey		42,046	Basic
Paso Robles		42,751	Basic
Kannapolis		43,404	Basic
San Luis Obispo		44,075	Basic
Danville		44,400	Basic
East Lansing		45,563	Basic
Biloxi		45,768	Basic
Glenview		46,207	Basic
Altoona		46,287	Basic
Harrisburg		47,418	Basic
Palm Springs		48,181	Basic
Albany		48,582	Basic
Wilson		48,721	Basic
Huntington		49,129	Basic
Hanford		50,053	High Speed
La Crosse		50,980	Basic
Sanford		50,998	Basic
Niagara Falls		51,295	Basic
Burlington		51,577	Basic
New Brunswich		51,579	Basic

Normal	52,799	Basic
Elkhart	53,060	Basic
San Marcos	53,205	Basic
Hattiesburg	53,533	Basic
Rocklin	53,572	Basic
Elyria	54,969	Basic
Goleta	55,302	Basic
Lancaster	55,439	Basic
Madera	56,692	Basic
Utica	58,040	Basic
Meriden	59,186	Basic
Taylor	59,308	Basic
Rocky Mount	59,576	Basic
Temple	60,118	Basic
Lodi	61,450	High Speed
Schenectady	61,469	Basic
Haverhill	61,588	Basic
San Clemente	61,610	Basic
Greenville	61,782	Basic
Rockville	62,105	Basic
Kissimmee	62,632	Basic
Davis	62,947	Basic
Portland	63,008	Basic
Delray Beach	64,691	High Speed
Lafayette	65,704	Basic
Pontiac	66,247	Basic
St. Cloud	67,136	Basic
Deerfield Beach	69,144	High Speed
Gulfport	70,732	Basic
Lake Charles	71,475	Basic
Kalamazoo	72,825	Basic
Gastonia	72,934	Basic
Lynchburg	73,933	Basic
New Rochelle	74,323	Basic
Merced	76,273	High Speed
Hammond	76,545	Basic
Longview	78,038	Basic
Bellingham	80,055	Basic
Champaign	80,286	Basic
Trenton	83,242	Basic
Dearborn	84,575	Basic

Santa Barbara	86,353	Basic
Lees Summit	86,556	Basic
Sparks	89,346	Basic
Wilmington	89,621	Basic
Tuscaloosa	93,215	Basic
Lakeland	93,738	Basic
North Charleston	97,601	Basic
Everett	99,384	Basic
West Palm Beach	99,504	High Speed
Antioch	101,182	Basic
Berkeley	102,822	Basic
Burbank	103,121	High Speed
High Point	103,396	Basic
Erie	103,571	Basic
South Bend	104,215	Basic
Gainsville	104,875	Basic
Norman	109,063	Basic
Beaumont	110,099	Basic
Ventura	110,873	Basic
Victorville	110,873	Basic
Flint	111,475	Basic
Santa Clara	111,997	Basic
Ann Arbor	112,852	Basic
Lafayette	114,915	Basic
Roseville	115,687	Basic
Springfield	118,033	Basic
Stamford	121,026	Basic
Fayetteville	123,287	Basic
New Haven	123,330	Basic
Hartford	124,060	Basic
Columbia (SC)	129,333	Basic
Fullerton	132,620	High Speed
Cary	136,600	Basic
Bridgeport	137,298	Basic
Syracuse	138,560	Basic
Hollywood	142,622	High Speed
Salinas	144,276	Basic
Hayward	144,289	Basic
Joliet	147,633	Basic
Pomona	152,367	High Speed
Eugene	153,231	Basic

Salem	155,719	Basic
Fort Lauderdale	163,160	High Speed
Vancouver	165,809	High Speed
Van Nuys	166,616	Basic
Santa Clarita	169,174	High Speed
Ontario	171,602	High Speed
Providence	171,909	Basic
Tallahassee	172,574	Basic
Oceanside	172,901	Basic
Jackson	175,021	Basic
Worcester	182,421	Basic
Oxnard	187,535	Basic
Little Rock	191,930	Basic
Mobile	193,171	Basic
Grand Rapids	193,710	Basic
Glendale	196,847	High Speed
San Bernardino	198,410	High Speed
Tacoma	199,637	Basic
Yonkers	201,162	Basic
Modesto	202,747	High Speed
Richmond	204,451	Basic
Fremont	205,514	Basic
Rochester	207,294	Basic
Irvine	209,716	High Speed
Reno	219,636	Basic
Durham	229,174	Basic
Birmingham	230,131	High Speed
Orlando	235,860	High Speed
Greensboro	255,061	Basic
Buffalo	270,240	High Speed
Newark	278,154	Basic
Stockton	287,578	High Speed
Riverside	297,859	High Speed
Pittsburgh	311,647	Basic
Toledo	316,238	High Speed
Bakersfield	324,463	High Speed
Cincinnati	333,013	High Speed
Santa Ana	340,340	High Speed
Tampa	343,890	High Speed
New Orleans	354,850	Basic
St. Louis	356,587	High Speed

Wichita	382,368	High Speed
Minneapolis	385,542	High Speed
Tulsa	389,625	High Speed
Raleigh	405,791	High Speed
Oakland	409,184	Basic
Colorado Springs	416,427	High Speed
Cleveland	431,363	High Speed
Miami	433,136	High Speed
Sacramento	466,687	High Speed
Fresno	479,921	High Speed
Kansas City	482,299	High Speed
Atlanta	540,921	High Speed
Albuquerque	545,852	High Speed
Oklahoma City	560,332	High Speed
Portland	566,141	High Speed
Las Vegas	567,641	High Speed
Denver	600,158	High Speed
Washington	601,723	High Speed
Milwaukee	604,133	High Speed
Seattle	617,334	High Speed
Baltimore	637,418	High Speed
Boston	645,169	High Speed
Charlotte	709,441	High Speed
Fort Worth	727,575	Basic
Columbus	769,360	High Speed
Austin	786,382	High Speed
Indianapolis	807,584	High Speed
Jacksonville	813,518	High Speed
San Francisco	815,358	High Speed
Detroit	910,920	High Speed
San Jose	964,695	High Speed
Dallas	1,299,543	High Speed
San Diego	1,306,301	High Speed
San Antonio	1,373,668	High Speed
Philadelphia	1,547,297	High Speed
Houston	2,257,926	High Speed
Chicago	2,851,268	High Speed
Los Angeles	3,831,868	High Speed
New York City	8,391,881	High Speed

Disclaimers

Amtrak stations only
Bold cities are proposed high speed stations

Table 18 Summary of Coverage for the US

Population With Station in City	58,773,423
Total Population	307,006,550
% Population in city of station	19.14%
Total Rail (km)*	21,200

*only current length of Amtrak, does not take into account of proposed tracks (National Railroad Passenger Corporation, 2012)

(Brinkhoff, 2012)

H.1.2. Cost

Table 19 Cost of Building Rails/km from International Rails

Country	Rail Type	Cost/km (in millions)	Currency	Year	Source	Comments
Belgium	High Speed	15	US $	2005	(Arduin & Ni, 2005)	
California	High Speed	14	US $	1994	(Levinson, Mathieu, Gillen, & Kanafani, 1997)	Proposal/estimates (details found on the 'California Estimates' Tab)
China	Main Line	9.1	US $	2011	(Net Resources International, 2011)	Tyichang-Wanzhou line (377 km), Surface with 278km in tunnel or bridges
China	High Speed	10	US $	2010	(Net Resources International, 2011)	Haikou-Sanya Line (308 km)
Denmark	Metro Line	247.5	US $	2011-2018	(Net Resources International, 2011)	Copenhagen (16 km), all underground

Country	Rail Type	Cost/km (in millions)	Currency	Year	Source	Comments
England	Upgrades	69	pounds	2011	(Net Resources International, 2011)	Crossrail, London; New twin bore tunnels
France	High Speed	10	US $	2005	(Arduin & Ni, 2005)	
France	High Speed	3.4	US $	1994	(Levinson, Mathieu, Gillen, & Kanafani, 1997)	TGV average (details found on 'French TGV' tab)
France	Upgrades	35	Euros	2010	(Net Resources International, 2011)	RFF, new double-track line
Germany	High Speed	15	US $	2005	(Arduin & Ni, 2005)	
Germany	High Speed	57	Euros	2010	Infrastructure Cost Review: Technical Report	
Germany	High Speed	44.4	US $	2008	(Net Resources International, 2011)	
Germany	High Speed	89	US $	2010	(Net Resources International, 2011)	Nuremburg-Munich
Germany	High Speed	60	US $	2010	(Net Resources International, 2011)	Stuttgart 21
Germany	High Speed	171	US $	2010	(Smith, 2009)	Nürnberg-Ingolstadt-München
Italy	High Speed	25	US $	2005	(Arduin & Ni, 2005)	
Korea	High Speed	35	US $	2005	(Arduin & Ni, 2005)	
Korea	Airport Line	98.1	US $	2010	(Net Resources International, 2011)	Seoul-Gimpo Line (20.4 km)

Country	Rail Type	Cost/km (in millions)	Currency	Year	Source	Comments
Netherlands	High Speed	53	US $	2005	(Arduin & Ni, 2005)	
Spain	High Speed	10	US $	2005	(Arduin & Ni, 2005)	
Spain	High Speed	9.57	Euros	2010	(Net Resources International, 2011)	Madrid-Albacete line (304 kms)
Spain	Upgrades	2.125	Euros	2011	(Net Resources International, 2011)	Route Doubling and electrification
Spain	High Speed	60.5	Euro	2010	(Live, 2010)	Pajares de Vienteres; 3006 M€ por 49.7 km
Spain	High Speed	35.7	Euro	2008	(Live, 2010)	Ourense-Pontevedra/Vigo-Cerdedo AV
Spain	High Speed	21.72	Euro	2006	(Live, 2010)	Madrid-Segovia-Valladolid
Spain	High Speed	22.57	Euro		(Live, 2010)	Basque; under construction
Spain	High Speed	19.24	Euro		(Live, 2010)	Cordoba-Malaga
Spain	High Speed	15.88	Euro		(Live, 2010)	Madrid-Zaragoza-Barcelona French Border
Spain	High Speed	15.07	Euro	2010	(Live, 2010)	Madrid-Levante; 6600M€ for 438km
Spain	High Speed	4.88	Euro	2001	(Live, 2010)	Madrid Sevilla
Switzerland	High Speed	33.1	CHF	2010	(Net Resources International, 2011)	

Country	Rail Type	Cost/km (in millions)	Currency	Year	Source	Comments
Switzerland	Upgrades	109	Euros	2011-2016	(Net Resources International, 2011)	Bremmer; New twin born tunnels
Switzerland	High Speed	32.288	CHF	2010	(SBB CFF FFS)	Mattstetten–Rothrist New Line
Switzerland	High Speed	94.5	CHF	2010	(SBB CFF FFS)	Zimmerberg Base Tunnel
Switzerland	High Speed	73	CHF	2010	(SBB CFF FFS)	Adler Tunnel
Switzerland	High Speed	35.5	CHF	2010	(SBB CFF FFS)	Vauderens Tunnel
Switzerland	High Speed	47	CHF	2010	(SBB CFF FFS)	NRLA
Switzerland	High Speed	165	CHF	2010	(Net Resources International, 2011)	AlpTransit Gotthard
Switzerland	High Speed	145	CHF	2010	(Net Resources International, 2011)	Ceneri Tunnel
Switzerland	High Speed	6.5	CHF	2010	(Net Resources International, 2011)	Rhine, Switzerland to Rhone, France
Taiwan	High Speed	37	US $	2005	(Arduin & Ni, 2005)	
UK	High Speed	74	US $	2005	(Arduin & Ni, 2005)	

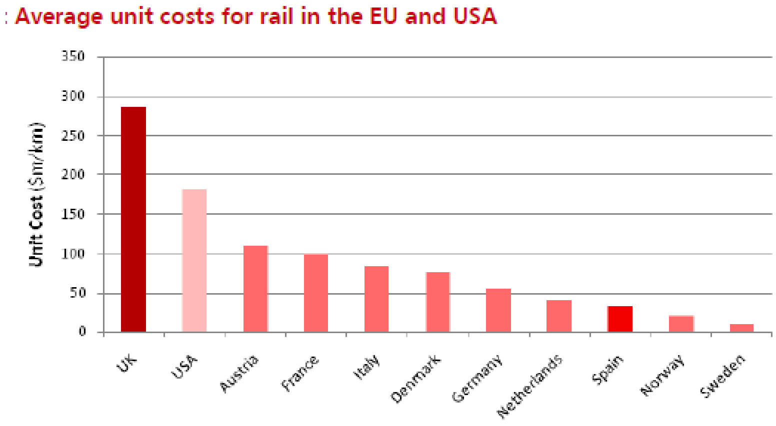

Figure 25 Average Unit Cost for international rails

H.1.3. Frequency and Travel Times

Paris–Lyon (427 km): 1:55
Paris–Marseilles (749 km): 3:00
Paris–Bordeaux (569 km): 2:59
Paris–Tours (223 km): 0:58
Paris–Nantes (387 km): 1:59
Paris–Lille (226 km): 0:59
Paris–Brussels (314 km): 1:25
Paris–London (498 km): 2:40
Paris–Geneva (540 km): 3:30
Paris–Amsterdam (494 km): 4:10
Paris–Cologne (541 km): 4:00
London–Brussels (360 km): 2:20
Brussels–Cologne (227 km): 2:20

Figure 26 Travel Times for France TGV

(Arduin & Ni, 2005)

Table 20 Travel Times and Frequencies for German Rails

High-Speed

InterCity Express

Hours of Operation: 24 hours

Frequency: 1-2 hours

Berlin-Frankfurt	4.1 hours
Berlin-Hamburg	1.6 hours
Berlin-Munich	5.8 hours
Frankfurt-Munich	3.2 hours
Nuremburg-Vienna	4.9 hours

InterCity

Hours of Operation: 24 hours

Frequency: 1-2 hours

Berlin-Munich	5.8 hours
Frankfurt-Munich	3.2 hours
Berlin-Frankfurt	4.1 hours
Frankfurt-Cologne	1.2 hours
Frankfurt-Stuttgart	1.3 hours

EuroCity

Hours of Operation: 24 hours

Frequency: 1-2 hours

Fast-Speed

InterCityNight

Hours of Operation : Overnight (6PM to noon)

Frequency: Once (per destination)

EuroNight

Hours of Operation : Overnight (6PM to noon)

Frequency: Once (per destination)

CityNightLine

Hours of Operation : Overnight (6PM to noon)

Frequency: Once (per destination)

Nachtzug

Hours of Operation : Overnight (6PM to noon)

Frequency: Once (per destination)

RegionalExpress

Hours of Operation: 24 hours

Frequency: 30-120 min

StadtBahn Hours of Operation: 24 hours Frequency: 10-20 min **S-Bahn** Hours of Operation: 24 hours Frequency: 20-30 min **U-Bahn** Hours of Operation: 24 hours Frequency: 5-15 min

(Purcell, 2010)

(Rail Europe, Inc., 2012)

Table 21 Travel Time and Frequency of Rail in Great Britain

Operate from 6:00 til 0:00		
Fast Speed	**Travel Time**	**Sources**
London Blackfriars to Glasgow	5.5 hrs* (run every 30 mins)	(Association of Train Operating Companies)
London Euston to Glasgow	5 hrs* (run every hour)	(Association of Train Operating Companies)
London Euston to Liverpool	2 hrs* (run twice every half hour)	(Association of Train Operating Companies)
	* Some trains do not run direct; these trains take	

		30-60 minutes longer to reach their destinations	
First Great Western			
			(First ScotRail)
To and from London Paddington			
	Half hourly to Cardiff Central with hourly continuation to Swansea		
To and from Swansea			
	Half hourly to Bath Spa and Bristol Temple Meads		
	Hourly to Exeter and Plymouth, with 5 trains running		
	past Plymouth to Penzance in Cornwall		
To and from Penzance in Cornwall			
	Bihourly to Cheltenham and Gluocester		
			(First ScotRail)
	Almost every fast speed train stops at Reading		
High Speed 1			
London Central to Ashford (109 km away; end of the			(Association of Train Operating

line)			Companies)
	37 minute train ride		(HS1)
	Trains leave once per hour		
			(Rail Saver)

Table 22 Travel Times and Frequencies for Italian Rail

Operate from roughly 5:30 til 0:00				
Trains		**Travel Times**	**Additional Comments**	**Sources**
High Speed				
Frecciarossa			"High Speed Line" - Reach speeds of up to 360 km/h	(Gruppo Ferrovie, 2008)
Milan-Rome-Milan	68 daily connections	3 hrs-no stop (roughly every hour)		(International Rail Australasia)
		3.5 hrs-stop at Bologna and Florence (roughly every hour)		
		2.75 hrs-stop in Milan Rogoredo (4 throughout the day)		
Milan-Naples-Milan	37 daily connections	4.5 hrs-stop at Milan Rogoredo (4 throughout the day)		
		4.5 hrs-stop at Rome (7 throughout the day)		
		5 hrs-stop at Bologna,		

		Florence, and Rome (Once every hour)		
Turin-Rome-Turin	14 daily connections	4.5 hrs-stop in Milan, Bologna, and Florence (roughly every hour)		
		4.33 hrs-stop at Milan (4 throughout the day)		
Bologna-Florence-Bologna	46 daily connections			
Rome-Naples-Rome	40 daily connections	1.17 hrs		
Eurostar Italia			"High Speed Line" that connects the European countries	(Gruppo Ferrovie, 2008)
Connect Rome to Ancona, Genoa,		~3 hrs (run roughly every 2 hrs) from Ancona to Roma		(International Rail Australasia)
Lamezia Terme, Reggio Calabria,				
Perugia, Ravenna, Rimini, and Taranto		~6-6.5 hrs (run roughly every hour) from Taranto to Roma		
Fast Speed				
Frecciargento			"Fast Speed Line" Reach speeds of up to 250 km/h	(Gruppo Ferrovie, 2008)
Rome-Venice-Rome	26 daily connections	3.5 hrs (2 every day)		
		3.75 hrs (every half hour)		
Rome-Verona-Rome	6 daily connections	3 hrs		

Rome-Bari-Rome	8 daily connections	4 hrs (once a day)		
		6 hrs (the non-fast trains)		
Rome-ReggioCalabria-Rome	2 daily connections	4 hrs		
Basic Speed				
Frecciabiance		Stop at all stations along the lines	Reach speeds of up to 200 km/h	(Gruppo Ferrovie, 2008)
Connect Milan to: Venice, Udine e Trieste,			Run regularly throughout the day (hourly)	(International Rail Australasia)
Genoa e Rome, down to Bari, Lecce				

Table 23 Travel Times and Frequency of Japanese Rail

High Speed Trains (Bullet Trains)	
Tokaido Shinkansen	
	Trains reach speeds of up to 270 km/h
	Connects Japan's 3 largest metropolitan areas
	Departures every few minutes
Nozomi	
	2.5 hours from Tokyo to Shin-Osaka
	Departs 4 times per hour (more often during peak hours)
	Most continue along **Sanyo Shinkansen** to Hiroshima or Hakata
	Most cars are reserved seating; however, there 2-3 non-reserved cars per train

Hikari

3 hrs from Tokyo to Shin-Osaka

Departs 2 times per hour

Slightly more non-reserved seating, but still most reserved seating cars

Kodama

4 hrs from Tokyo to Shin-Osaka

Departs 2 times per hour

Some trains during rush hour are fully non-reserved

Sanyo Shinkansen

Trains reach speeds of up to 300 km/h

Nozomi

2.5 hrs from Shin-Osaka to Hakata

Departs 3 times per hour (2 to/from Hakata, 1 to/from Hiroshima)

More service provided during peak hours

8-car Hikari Railstar

Slightly slower than the *Nozomi*

16-car Hikari

Runs each hour

Stops at every station between Shin-Osaka and Okayama

Kodama

5 hrs from Shin-Osaka to Hakata

Stops at every station

Mizuho

Faster than *Nizomi*

Provides through service to **Kyushu Shinkansen** to/from **Kangoshima**

4 round trips per day in am and pm

Sakura

Similar to *Mizuho* but stops at more stations

Tohoku Shinkansen

Hayabusa

Fastest train category on line

Serves Tokyo, Omiya, Sendai, Morioka, and Shin-Aomori Stations only

2 round trips per day

# of services to be increased in the future

Runs up to 300 km/h

Planned to be increased to 320 km/h in 2013

No non-reserved seating

Hayate

Second fastest train on line

Runs same route as *Hayabusa*, but with more stops

No non-reserved seating

Yamabiko

Third fastest category

Runs to Morioka, though some stop at Sendai

Some trains are 2 story, called *MAX Yamabiko*

Nasuno

Slowest train category

Serves all stations between Tokyo and Koriyama

Komachi

Only train category of the **Akita Shinkansen**

Couled with a *Hayate* train between Tokyo and Morioka

Run on their own between Morioka and Akita

No reserved seating

Tsubasa

Only train category of the **Yanmagata Shinkansen**

Almost all trains are coupled with a *MAX Yamabiko* between Tokyo and *Fukushima*

Run on their own between Fukushima and Shinjo

Some trains stop at Yanmagata Station

Joetsu Shinkansen

Toki

Faster of the 2 train categories

Runs between Tokyo and Niigata stations

Some use 2 story trains, called *MAX Toki*

Tanigawa

Slower of the 2 train categories

Serves all stations between Tokyo and Echigo-Yuzawa stations

During the winter, some trains continue to Gala Yuzawa Station

Base of the Gala Yuzawa ski resort

Nagano Shinkansen

Scheduled to be extended to Kanzawa by 2015

Asama

Operates between Tokyo and Nagano stations

Different stopping patterns

Kyushu Shinkansen

Planned Nagaski branch line

Mizuho

Fastest train category

Stops at Hakata, Kumamoto, and Kagoshima-Chuo only

Through service to **Sanyo Shinkansen** to and from Shin-Osaka

4 round trips per day in am and pm

Sakura Second fastest train category Serves more stations than *Mizuho* 1 or 2 departures per hour Some trains providing through service to/from Shin-Osaka *Tsubane* Slowest train category Stops at all stations Most trains run between Hakata and Kumamoto only

(Japan-Guide.com, 2012)

Table 24 Travel Times and Frequency of Spanish Rails

High Speed ***AVE*** ***Madrid to Barcelona*** Average duration 169 min based off of 25 trains 2hr49min Hours of Operation 5:50 22:50

Frequency of Deperature

36.4 min

average deperature of each train

AVE

Madrid to Sevilla

Average duration

151min

2hr31min

Frequency of Departure based on 19 trains

45.25min

Average

AVE

Madrid to Valladolid

Average Duration

56min

Frequency of Deperature 2 trains

7hr50min

AVE

Madrid to Huesca

Duration 133 Frequency of Deperature 1 train 19:05 ***AVE*** ***Madrid to Malaga*** Average Duration 155.23min Frequency of Deperature 10 Trains 84min ***AVE*** ***Barcelona to Sevilla*** Average Duration 150.5min Average Frequency of Deprature 17 53.23mi ***AVE*** ***Barcelona to Malaga*** Average Duration

350 Average Frequency of Deperatures 2 trains 350min

(Passengers - Timetables)

Table 25 Travel Times and Frequency of Swiss Rails

High-Speed		
Zürich Verkehrsverbund		
Hours of Operation: 24 hours		
Frequency: 30-60 min		
	Zurich-Bern	1.1 hours
	Zurich-Lausanne	2.2 hours
	Zurich-Geneva	2.8 hours
	Zurich-Winterthur	0.4 hours
	Zurich-Luzern	0.9 hours
Tarifverbund Nordwestschweiz		
Hours of Operation: 24 hours		
Frequency: 30-60 min		
	Basel-Zurich	1.2 hours

	Basel-Geneva	2.8 hours
	Basel-Bern	1.1 hours
	Basel-Winterthur	1.5 hours
	Basel-Luzern	1.2 hours
Fast-Speed		
Libero		
Hours of Operation: 22:00-02:00		
Frequency: 15 min		

(ZVV, 2012)

(SBB CFF FFS)

"Public Transport in Switzerland". (PDF) [I'll fix this later]

Table 26 Frequency of Amtrak Trains

Name	Route	Frequency	2009 Passengers	Route miles
Acela Express	Boston – Washington, DC (high-speed rail)	15 trips per weekday, 4 trips per Saturday, 8 trips per Sunday	3,019,627	456
Adirondack	Montreal – New York via Albany	daily	104,681	381
Amtrak Cascades	Vancouver, BC – Eugene, Oregon via Portland and Se attle	5 trips daily (2 Seattle-Eugene, 1 Seattle-Portland, 1 Vancouver-Portland, 1 Vancouver-Seattle)	740,154	467

Name	Route	Frequency	2009 Passengers	Route miles
Auto Train	Lorton, Virginia – Sanford, Florida	daily	232,955	855
Blue Water	Chicago – Port Huron, Michigan	daily	132,851	319
California Zephyr	Chicago – Emeryville, California(Oakland/San Francisco)	daily	345,558	2,438
Capitol Corridor	Auburn, California – Sacramento– San Jose via Oakland	16 trips per weekday (8 Oakland-Sacramento, 7 San Jose-Sacramento, 1 Oakland-Auburn), 11 trips per Saturday/Sunday (6 San Jose-Sacramento, 4 Oakland-Sacramento, 1 San Jose-Auburn)	1,599,625	172
Capitol Limited	Chicago – Washington, DC viaCleveland and Pittsburgh	daily	215,371	764
Cardinal	Chicago – New York viaIndianapolis, Cincinnati, andWashington, DC	3 trips per week	108,614	1,147
Carl Sandburg	Chicago – Quincy, Illinois	daily	202,558	258
Carolinian	New York – Charlotte, North Carolina	daily	277,740	704
City of New Orleans	Chicago – New Orleans	daily	196,659	926
Coast Starlight	Seattle – Los Angeles viaSacramento and Oakland	daily	432,565	1,377
Crescent	New York – New Orleans viaAtlanta	daily	286,576	1,377
Downeaster	Portland, Maine – Boston	5 trips daily	460,474	116

Name	Route	Frequency	2009 Passengers	Route miles
Empire Builder	Chicago – Portland, Oregon/Seattle viaMinneapolis–St. Paul, Minnesota	daily	515,444	2,206 miles (Chicago–Seattle) 2,257 miles (Chicago–Portland)
Empire Service	New York – Niagara Falls, New York via Albany	9 trips per weekday, (7 Albany-New York, 2 Toronto-New York), 4 trips per Saturday (2 Albany-New York, 2 Toronto-New York), 5 trips per Sunday (3 Albany-New York, 2 Toronto-New York)	925,746	460
Ethan Allen Express	New York – Rutland, Vermontvia Albany	daily	46,748	241
Heartland Flyer	Oklahoma City, Oklahoma – Fort Worth, Texas	daily	73,564	206
Hiawatha Service	Chicago – Milwaukee, Wisconsin	7 trips daily	738,231	86
Hoosier State	Chicago – Indianapolis	4 trips per week	31,384	196
Illini	Chicago – Carbondale, Illinois	daily	259,630	310
Illinois Zephyr	Chicago – Quincy, Illinois	daily	202,558	258
Keystone Service	New York – Harrisburg, Pennsylvania via Philadelphia	13 trips per weekday (9 Harrisburg-New York, 4 Harrisburg-Philadelphia), 7 trips per Saturday/Sunday (6 Harrisburg-New York, 1 Harrisburg-Philadelphia)	1,215,785	195
Lake Shore Limited	New York – Chicago via Albanywith connection from Boston	daily	334,456	959 (Chicago – New

Name	Route	Frequency	2009 Passengers	Route miles
				York) 1018 (Chicago – Boston)
Lincoln Service	Chicago – St. Louis, Missouri	4 trips daily	506,235	284
Maple Leaf	New York – Toronto, Ontario viaAlbany	daily	354,492 (2008)	544
Missouri River Runner	St. Louis – Kansas City	daily	150,870	283
Northeast Regional	Boston, Massachusetts/Springfield, Massachusetts – New York –Philadelphia – Baltimore –Washington, DC – Newport News, Virginia	20 per weekday (13 Boston-Washington, 3 Boston-Richmond, 2 Boston-Newport News, 1 Boston-Lynchburg, 1 Springfield-Washington), 17 per Saturday/Sunday (9 Boston-Washington, 3 Boston-Richmond, 2 Boston-Newport News, 2 Springfield-Washington, 1 Boston-Lynchburg)	6,920,610	664
Pacific Surfliner	San Luis Obispo, California –San Diego, California via Los Angeles	12 per weekday, (7 Los Angeles-San Diego, 3 Goleta-San Diego, 1 San Luis Obispo-San Diego, 1 San Luis Obispo-Los Angeles), 13 per weekday, (8 Los Angeles-San Diego, 3 Goleta-San Diego, 1 San Luis Obispo-Los Angeles, 1 San Luis Obispo-San Diego)	2,592,996	350
Palmetto	New York – Savannah, Georgia	daily	171,316	829
Pennsylvanian	New York – Pittsburgh, Pennsylvania via Philadelphia	daily	199,484	444

Name	Route	Frequency	2009 Passengers	Route miles
Pere Marquette	Chicago – Grand Rapids, Michigan	daily	103,246	176
Piedmont	Raleigh, North Carolina – Charlotte, North Carolina	2 trips daily	68,427	173
Saluki	Chicago – Carbondale, Illinois	daily	259,630	310
San Joaquins	Oakland/Sacramento – Bakersfield, California	6 trips daily (4 Oakland-Bakersfield, 2 Sacramento-Bakersfield)	929,172	318 (Bakersfield–Oakland) 280 (Bakersfield–Sacramento)
Shuttle	Springfield, Massachusetts –New Haven, Connecticut	4 per weekday, 5 per Saturday/Sunday	325,518	63
Silver Meteor	New York – Miami, Florida	Daily	330,734	1,389
Silver Star	New York – Miami, Florida	Daily	371,235	1,522
Southwest Chief	Chicago – Los Angeles viaKansas City, Missouri andAlbuquerque, New Mexico	Daily	318,025	2,256
Sunset Limited	Orlando, Florida – Los Angelesvia New Orleans and Houston	3 trips per week. *New Orleans-Orlando segment suspended since Hurricane Katrina.*	78,775	1,995

Name	Route	Frequency	2009 Passengers	Route miles
Texas Eagle	Chicago – San Antonio, Texasvia St. Louis and Fort Worth, Texas	Daily	260,467	1,306 (Chicago – San Antonio) 2,728 (Chicago – Los Angeles)
Vermonter	St. Albans, Vermont – Washington, DC	Daily	74,016	611
Wolverine	Chicago – Pontiac via Detroit	3 trips daily	444,127	304

(National Railroad Passenger Corporation, 2012)

H.2. Australia

H.2.1. Population and Current Station Location

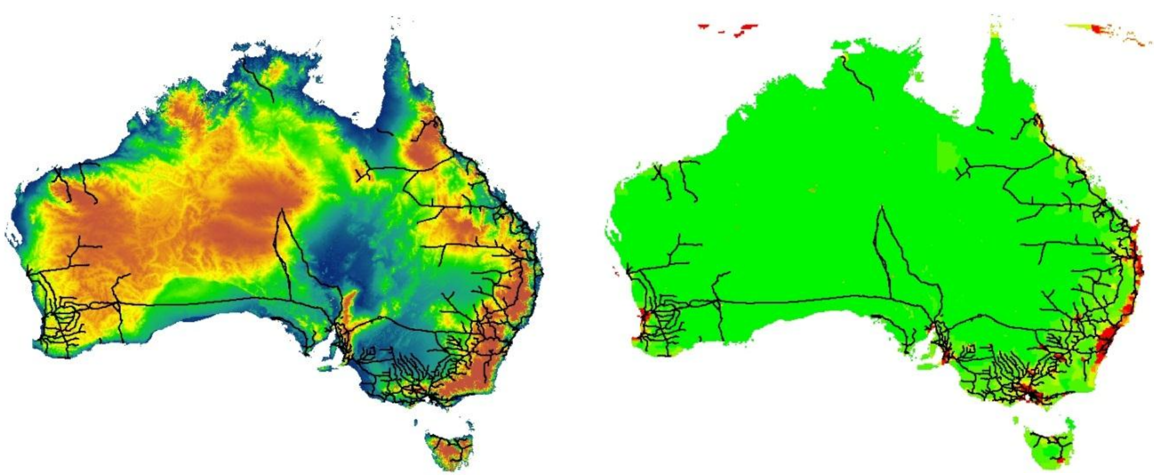

Figure 27 Elevation Profile (left) and Population Density (right) for Australia with Rail Map

H.2.2. Proposal Options

Figure 28 High Speed Rail Options from Adelaide to Melbourne

Figure 29 High Speed Rail Option from Perth to Adelaide

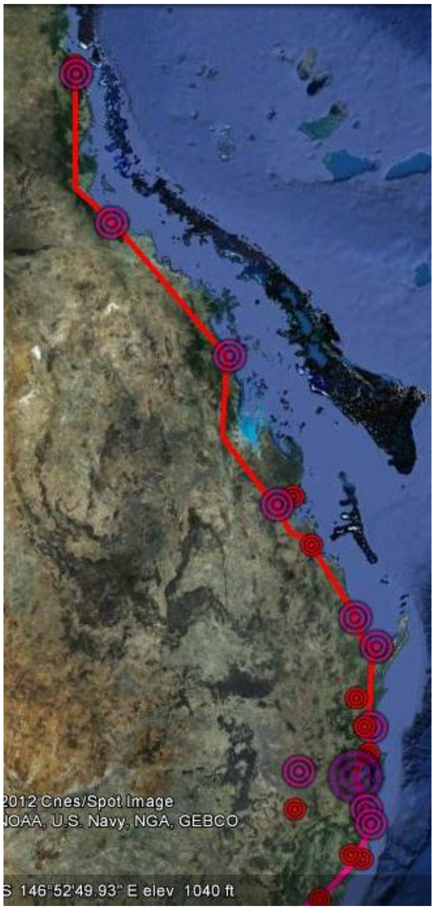

Figure 30 High Speed Rail Option from Brisbane to Cairns

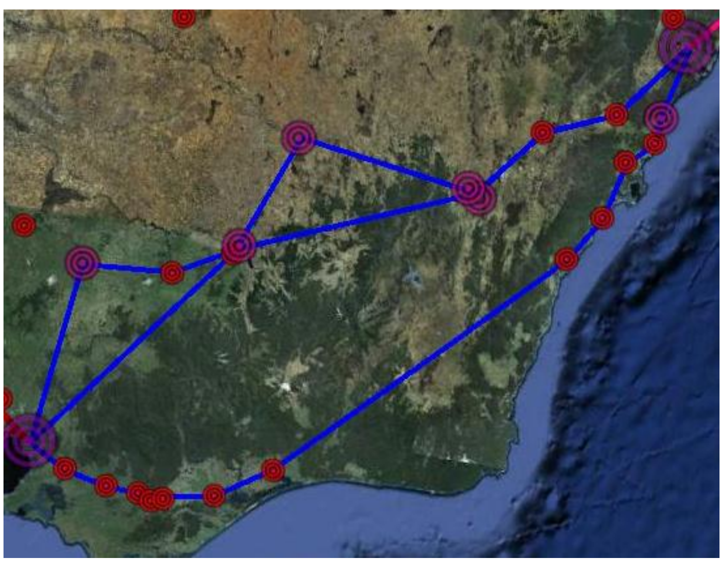

Figure 31 High Speed Rail Options from Melbourne to Sydney

Figure 32 High Speed Rail Options from Sydney to Brisbane