Bike share Programs to Promote Ridership

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May 8, 2016 Final

Personal transportation represents a significant portion of energy usage in modern society. Especially in compact urban environments, there are viable, more efficient means of transport to the current standard of automobiles. The most promising of these is bicycle riding, which is well suited to many of the short range trips made by huge portions of the population every day. However, for bicycles to make a significant contribution to energy saving efforts, ridership must be increased over current levels. This paper discusses to utility and cost of "bike share" programs in this effort, and will show that they are potentially useful tools for any large scale program for increasing ridership to have.

I. Transportation Costs

Oil and gasoline usage is an important modern issue in the United States. Although the US has increased its own production of fuels recently, it is still dependent on imports from abroad. In addition, emissions of CO_2 and other products harmful to the environment from using non-renewable energy sources like gasoline is an imminent threat. Considerations of environmental damage must be important in the future energy marketplace in the US. This paper will look at the monetary and environmental costs, as well as the energy costs of movement using automobiles to compare with that of bicycles. We talk about energy and emissions in transportation by motor vehicle somewhat interchangeably, as for our purposes they are proportional.

I.I Transportation as a Portion of Total Usage

According to Figure 1.1[1], transportation accounted for 26% of all energy usage in the United States in 2014. This is out of a total 6,870 million metric tons of CO_2 equivalent, meaning it includes the effects of other greenhouse gasses emitted, translated into the equivalent CO_2 amount. Of course, not all of this energy usage of transportation is in trips suitable for replacement by bicycles. First of all, we are not as interested in trips done by mass transit including buses, trains, or even airplane, because these forms of transit tend to be either more efficient that personal transport or used over length scales incompatible with bicycling. We are also not interested in many commercial trips, such as trucking, because bicycle transit has limited cargo capacity. About 60% of energy usage in the

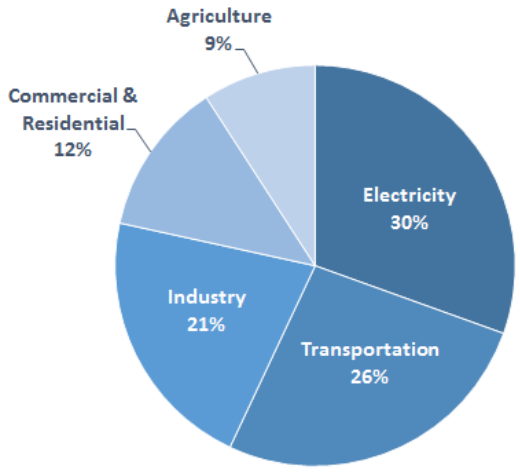

Figure 1.1: Energy Usage Breakdown

[1] "Sources of Greenhouse Gas Emmisions." *US EPA*. 2016. https://www3.epa.gov/climatechange/ghgemissions/sources/transportation.html.

US is personal Energy Usage in the vehicles[2]. Still, we are not interested in all of this energy usage, because many personal trips are too long for bicycling. The trips where bicycling is a good alternative, those with lengths of less than five miles, account for 51% of all personal trips in the US[3]. If we estimate that these trips average about 2 miles in length, and all other trips average about 20, (19% are 5-10 miles, and 25% are >10 miles) then we can estimate the energy usage in bicycle friendly trips. If we look at a sample of 100 trips, then we estimate 51 are short trips for 102 miles total, while 49 are long trips totaling 980 miles. So, for every 1082 miles driven, 102, or around ten percent, are bicycle friendly. Assuming that all miles are equal, that is they use the same amount of energy, then about ten percent of the energy used in personal trips could be saved at a maximum by bicycling rather than driving (as we will see later, bicycling takes a fairly minimal amount of energy relative to cars). Of course, this assumption is not very accurate. The short trips that bicycles aim to service are likely to use more energy per mile in a motor vehicle, since they are generally start and stop city driving[4]. Another possibly faulty assumption we have made is that all trips of this length are suitable for bicycles. In fact, some portion come with undue cargo or are made with less able companions, like children in tow. To correct for this, we will make a conservative estimation that 6% of all energy used in personal trips could be saved by bicycle use. Now backing out to find the actual energy that could be saved, we see this is:

$$6\% \times 60\% = 3.6\%$$

of all energy used in transportation, and:

$$3.6\% \times 26\% = .94\%$$

of all energy usage in the United States. About one percent of the energy usage is certainly significant, though it is good to keep in mind that 100% transition to bicycles in even this subset of trips is probably overambitious. Theoretically, bicycling could make a contribution to lowering energy usage, though it would have to be accompanied by many other efforts.

I.II Consequences of Energy Usage in Transportation

The whole point behind considering alternatives to conventional transport is to ameliorate the costs attached to them. The first cost we consider is the environmental cost, measurable in terms of emissions which cause climate change, as well as lower air quality in some places. Cars and similar vehicles tend to emit somewhere on the order of 250 kilograms of greenhouse gasses per mile[5]. As we said earlier, the US emits around a total of 6,500 million metric tons of CO_2 equivalent each year, a number which has been fairly steady for over 20 years[6]. These emissions, along with those of other countries, have increased the concentration of CO_2 from around 280

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[2] "How We Use Energy - Transportation." *The National Academies*. 2016. http://needtoknow.nas.edu/energy/energy-use/transportation/.

[3] "Short and Sweet: Analysis of Shorter Trips Using National Personal Travel Survey Data" *Todd Litman.* 2012

[4] "Many Factors Affect Fuel Economy." *US Department of Energy*. 2016. https://www.fueleconomy.gov/feg/factors.shtml.

[5] "Life Cycle Assessment of Transportation Options for Commuters". *Shreya Dave.* 2010.

[6] "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013" *US EPA.* 2013

ppm before significant human emissions to now over 400 ppm. The effects of this change have been numerous, including rising ocean levels, higher temperatures, more extreme climates in many places, and stronger storms, and are predicted to worsen[7]. These changes have generally harmed ecosystems, as might be expected, and in places have caused droughts or otherwise degraded human quality of life.

We can also consider the economic cost of the energy used in transportation, as most of it comes from petroleum fuel sales. Every month, the US uses around thirteen million barrels of petroleum[8]. A slightly more relevant figure for our purposes is the cost to drive one mile in a car, which is around 65 cents, depending on the type of car[5]. This figure is more relevant when considering the economic advantages and incentives to bicycling more for the average person. According to our estimation, 6% of all miles driven could be replaced by bicycling, representing a significant savings for a consumer.

II. Bicycles as a Form of Transport

The topic of this paper necessitates a closer look at bicycles for transportation, in order to see the benefits of using them as an alternative to motor vehicles. As we saw in the last section, there is a small but significant portion of transportation ripe to be done on bicycles. Bicycles do make up some portion of the transportation landscape in the US, but much less than in some other countries, and much less than they could in the US. We need to look at both the environmental and economic costs of bicycle ridership to compare them to driving. We will also look at bicycle ridership to see how bike share programs can increase bicycle use.

II.I Mechanics and Cost

The mechanics of a standard bicycle are simple and well known. The rider sits on the bicycle, steering by turning handlebars, and more importantly for this investigation, powering the bicycle by pushing on pedals with their feet. The wheels and gear system make bicycling more efficient and convenient than walking due to higher average speeds and conserving energy well. Because bicycles are much lighter than motor vehicles and powered by the relatively efficient machinery of the human body, rather than a combustion engine, they are also significantly more efficient than cars and trucks. Looking at the emissions over the lifetime of the vehicle, a passenger car emits approximately 271g CO_2 for a passenger traveling a kilometer, while bicycles emit about 10% that much, at 21g CO_2[9]. The cost gap is not quite so large when considering the monetary cost, which is what

Figure 2.1: Standard Bicycle

[7] "Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program". *Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds.* 2014
[8] "Monthly Energy Review." *US Energy Information Administration*. 2016. https://www.eia.gov/totalenergy/data/monthly/index.cfm#petroleum.
[9] "Cycle more often 2 cool down the planet: Quantifying CO2 savings of cycling." *European Cyclists' Federation.* 2011.

one would expect an average consumer to consider. A bike costs about 10 cents per mile to ride, while as mentioned earlier, cars cost around 65 cents[5]. However, the economic incentive of a consumer to ride a bicycle in the context of bike share programs is higher, since they do not directly pay the cost of manufacturing or maintaining the bike. In addition, there are significant health benefits to bicycle ridership that improve quality of life and also save money for riders[10]

II.II Challenges to Increasing Ridership

Despite these advantages, bicycle ridership in the US is quite low. In 2014, only about 20% of people ride a bike every month, and less than 1% ride on most days, as we would expect of someone using bicycles to commute and otherwise travel the short trips we hope to use bicycles for[11]. Why do so few people use bicycles?

While bicycle ridership has its environmental and economic advantages, the mechanics of bicycling also result in important limitations that keep bicycle ridership at the low levels it is. The most obvious downsides to using bicycles as a mode of transportation is their relative slowness, low cargo capacity, and the effort required to use. Along with this, many cities lack the infrastructure necessary to make bicycling reasonable easy and safe. These challenges are being addressed by changes in bicycle design[12] and efforts to increase bikeability in many cities[13]. However, this paper is more concerned with another difficulty in increasing ridership.

Perhaps the most difficult obstacle to widening bicycle ridership is changing the culture in the United States to encourage more people to ride bicycles. Closely linked to this problem is the number of people with bicycles available to them. This is the difficulty that bike share programs aim to resolve, by providing bicycles for public use.

II.III Effectiveness of Introducing Rideshare Programs

Bicycle sharing or rideshare programs aim to provide the ability to use bicycles as transport to more people. Generally, this involves having stations near high use destinations as otherwise spread through a city or area which hold a number of bicycles. These bicycles can be checked out, possibly for a fee, and ridden to another station where they are deposited. Ideally, this provides a convenient means for users to collect, ride, and deposit a bicycle as they make their commute or other short, bicycle friendly trip.

One useful case study to look at to see the effectiveness of such programs is the Bay Area Bike Share, a private venture with 700 bikes and 70 stations in San Francisco and nearby cities. Between September 2013 and December 2015, they reached 750,000 rides daily[14]. In similar

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[10] M, Ohta, Mizoue T, Mishima N, and Ikeda M. "Effect of the Physical Activities in Leisure Time and Commuting to Work on Mental Health." *PubMed*2007, 46–52. http://www.ncbi.nlm.nih.gov/pubmed/17314466.

[11] Yoon, Anum . "Bike Commuting: Why the U.S. Is Far Behind Other Nations."*Triplepundit*, November2015. http://www.triplepundit.com/2015/11/bike-commuting-u-s-far-behind-nations/#.

[12] "SuperPedestrian - The Copenhagen Wheel." *SuperPedestrian*. 2016. https://www.superpedestrian.com/.

[13] "Seattle Bike Master Plan." *Seattle Department of Transportation*. 2016. http://www.seattle.gov/transportation/bikemaster.htm.

[14] "System Metrics." *Bay Area Bike Share*. 2016. http://www.bayareabikeshare.com/system-metrics.

programs in other cities, like the CitiBike program in Ney York reached nearly 80,000 miles traveled in a day over a similar timeframe[15]. These real cases seem to suggest that availability of bike sharing programs does indeed convince people to bicycle more, as one might expect. However, even CitiBike, the largest program in the country, has just under 100,000 users in a city of over eight million[14]. With this figure we can estimate that only about one percent of trips in the prime bicycling length are being bicycled. Clearly, any bike share program must be a small part of a larger effort to make a city more bicycle friendly, so we would like to see that such a program can be run at cost somewhat in proportion to this.

III. Cost Analysis of a Sample Program

In the final piece of this paper we want to consider the cost to a city that wants to implement a bike share program as part of a larger attempt to increase ridership, in order to comment on the value of having such a program in the package. While most large ride sharing programs have been commercial in nature, we want to look at the cost in places where the profitability from such a venture may not be high enough to have attracted this business yet. As such, the cost to consumers to check out a bike should be lower than the cost of owning and riding one oneself, but there will be a cost, similar to a bus fare. For this estimate we will say that fares can support the continued maintenance of the system, but will not recover up-front costs or pay for expansion. The overall goal should be to have an ambitious percentage of the population participate. For this calculation we will use 5% of the population, about four times that of CitiBike. We will focus on the upfront cost of purchasing the fleet of bicycles and stations.

III.I Up-Front Costs

The first most obvious cost of setting up a public bike share system is of course buying the bicycles. The bicycles we need probably cost around 1000$ each[16]. Looking at the examples of the programs we have seen so far, we can try to estimate how many bikes we need. CitiBike has something on the order of one bicycle for 20 users, so we will take that estimate. Let's say our sample city has 500,000 residents, so we hope that 25,000 will use the bikes, and therefore we need 1,250 bikes. This adds up to a total cost of 1.25 million to buy the bikes. There is likely a savings involved in buying in such bulk, but it will be split up into shipments as the system slowly ramps up and there were underestimations in the calculation that offset this.

Figure 3.1: Bicycle Locker

The other obvious up front cost is building the necessary stations. The data on this is not as readily available as the price of a bicycle, but some imagination and comparisons can help. One can imagine that a simplistic bike share station would be similar to a bicycle locker like the one in Figure 3.1, but with some additions to accommodate payment.

[15] "System Data." *CitiBike*. 2016. http://www.citibikenyc.com/system-data.
[16] Roth, J D. "The Costs and Savings of Bicycle Commuting." *Forbes*. 2011. http://www.forbes.com/sites/moneybuilder/2011/06/15/the-costs-and-savings-of-bicycle-commuting/#4c70f441c1da.

The locker in Figure 3.1 costs around $2000[17], and we can guess that with the additions our station will cost something like $2500. It is reasonable to say that each station will hold 20 bikes, but we need to have as much as 200% capacity to account for imbalances in bicycle location through the day. This puts us at a similar ratio of stations to bikes as the Bay Area Bike Share, so it seems reasonable. Therefore, we need 125 stations. This comes out to a cost of:

$$125 stations \times \frac{\$2500}{station} = \$312{,}500\ total$$

Together with the cost of the bikes, we get a cost of about 1.5 million in up-front cost to build a bike share system.

III.II Value Vs Price

Now all we need to do is decide if this cost if worth the benefits. As we said earlier, the evidence seems to show that any bike share program needs to be a small part of a larger agenda focused on increasing bikeability. The bike share program we described and attempted to estimate the price of is an ambitious one, hoping to capture 5% of a sizeable city's population, so the overall budget should be one of a similarly ambitious and wide-reaching program. We can look at some such government programs to draw conclusions.

The city of Seattle is in the process of such a transportation overhaul. It is not quite as ambitious as out proposed bike share program, but takes place in a slightly larger city than our sample, so the prices are at least comparable. Based on the effectiveness of bike share programs attracting riders, we thought that any program should cost no more than a few percent out of the total. Seattle's Bike Master Plan is projected to cost about $80 million over the next five years[18], a time frame in which we might expect our sample program to ramp up over. This puts our program at costing somewhere on the order of 1-3% of the total budget, exactly where we would like it to be.

IIII. Conclusion

A significant portion of trips taken in vehicles powered by fossil fuels and other unsustainable means are in the perfect length range to be shifted towards bicycle transport. This could be an important piece in reducing energy usage overall, if bicycle ridership can be increased sufficiently. There are many factors reducing ridership, including the lack of a bicycle culture in the US and not enough access to bicycles. This makes bike share programs a potentially effective part of general ridership programs. As we have seen in a rough estimation of the cost of one such program, the cost is at about the level required to make the investment worthwhile. This suggests that city governments that are trying to raise bicycle use should consider including a publicly funded bike share program in their package.

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[17] Bushell, Max A, Bryan W Poole, Cherles V Zeeger, and Daniel A Rodriguez. "Costs for Pedestrian and Bicyclist Infrastructure Improvements." *PedBikeInfo*. 2013. http://www.pedbikeinfo.org/cms/downloads/Countermeasure%20Costs_Report_Nov2013.pdf.

[18] "BMPImplementationPlanMarch2015." *City of Seattle*. 2015. http://www.seattle.gov/transportation/docs/bmp/BMPImplementationPlanMarch2015.pdf.

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