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Hubway:
The Bike-Sharing System of Metro-Boston

1.011 Project Evaluation
Spring 2013

Term Project

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FIGURES AND TABLES

Project Background and Motivation

The decision to bring a bike-sharing system to the Boston area was made soon after the Boston Bikes program was founded in 2007. The Boston Bikes program aims to make Boston a world-class bicycling city that creates a healthy and vibrant city for both residents and visitors. Hubway, Boston's bike-sharing system is just one aspect of this program that attempts to strengthen and increase the cycling community. Hubway continues to transform the way people are traveling around Boston and nearby cities.

Official Launch and Growth

Officially launched in Summer 2011, Boston's Hubway is one of the earliest and most popular bike sharing systems in the US. Hubway started out with 600 bicycles and 60 stations in the city of Boston. It has gradually developed into a larger network that connects Boston, Brookline, Somerville, and Cambridge through over 100 stations and 1,000 bikes, providing for thousands of members in the metro Boston area. The locations of all currently active stations can be found in the map below, which also indicates the four main municipalities Hubway operates in.

Figure 1: Current Areas of Operation

In its first ten months of operations, Hubway users logged half a million rides. More than 7,400 people who live or work in Metro Boston became annual members, and more than 70,000 people purchased one- or three-day Hubway passes. It is clear that since the launch of the Hubway system, excitement and growth of this transit system has increased greatly. The table below shows the growth in annual members and Hubway trips made in just its first year of operation. An increase of approximately 280% was seen within just Hubway's first year of operation.

Table 1: Hubway Data for First Two Years of Operation

Year	Number of Annual Members	Number of Trips made
2011	3000	142,289
2012	11130	533,755

The growth Hubway has already experienced in just its first couple years of operation gives some indication as to how it will continue to grow. It is essential to consider its future growth in order to better evaluate the future status of Hubway. We attempt to model the future growth of Hubway using a logarithmic function. This type of function was chosen for a few reasons. A logarithmic fit accounts for a rapid increase that occurs in its initial lifetime. As time increases, the slope of the function decreases, reflecting a growth rate that is slowing down. Using the number of annual members in Hubway's first two years of operation, a logarithmic fit predicted a membership base of almost 30,000 members.

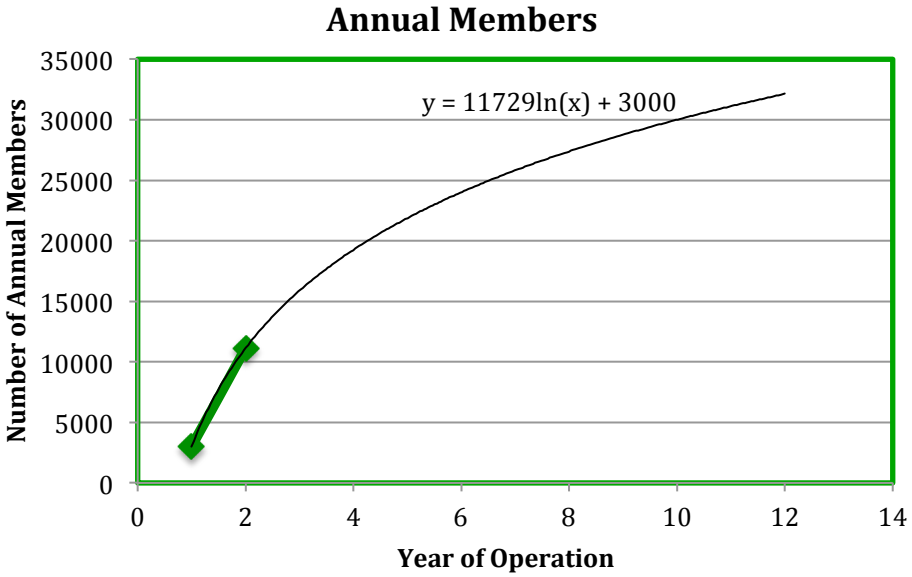


Figure 2: Future Projection for Annual Members

The future projection for the number of Hubway trips made by casual members (riders who purchase a daily pass) was approximately 230,000 in year 10 of operation. Based on our approximations, the growth of Hubway will increase rapidly in its first few years of operation but gradually level out in terms of its membership and trips traveled.

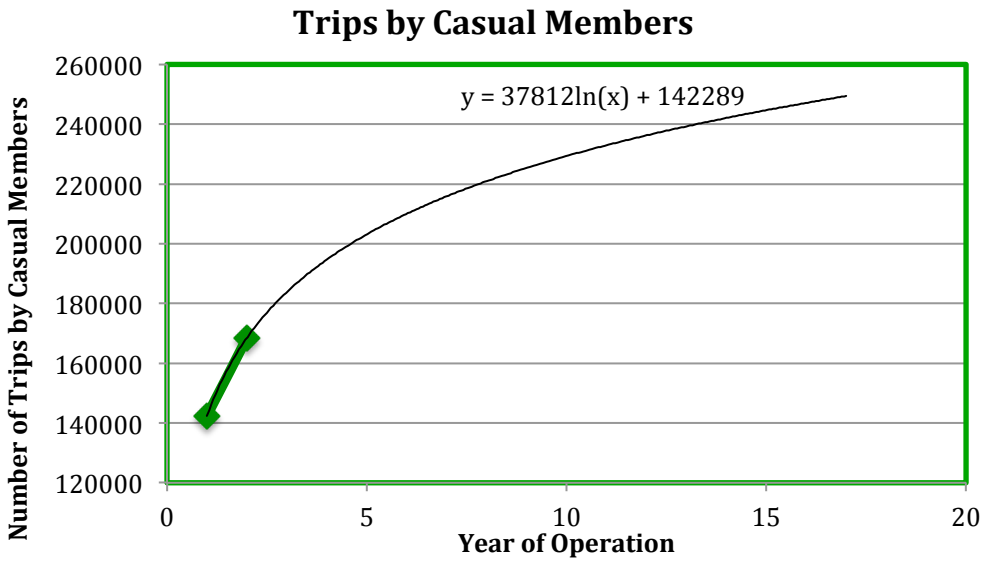


Figure 3: Future Projection for Trips by Casual Members

As we examine the characteristics of the Hubway system today, it is important to keep in mind how future uncertainties and predication will play a role in altering Hubway's sustainability.

Motivation

The Hubway system is a fascinating project to investigate. It is the first large initiative to bring a bicycle-sharing program to the Boston area. As students in the area, we have witnessed the launch and growth of this new transportation method. The Hubway system has become a preferred alternative for many residents in the Boston area, offering a cheaper and faster mode of public transportation in comparison to the MBTA system. We are interested in investigating the social, environmental, and economic impact of this expanding transit system. Hubway is drastically different from other forms of transportation that have been extensively studied, such as air traffic, highway, and rail transit systems. We plan to examine Hubway from the standpoint of the currently existing system as well as the future of its expansion. While Hubway is transforming the mode of transportation among residents and tourists in the metro-Boston area, it is also transforming the culture and stigma associated with riding bicycles. Obtaining an in-depth understanding of the Hubway system will allow for us to evaluate the sustainability of this new transit system in our future.

We are currently in a time where bike-sharing is not only rapidly transforming the transportation decisions in Boston but also in other major cities, such as New York and Chicago. Both of these cities plan to launch city-wide bike-sharing systems that are expected to greatly impact the transportation decisions of residents and visitors. Bikes are beginning to take on a new role in the current generation of travelers. By examining a system that is close to home, we hope to gain an understanding into where bike-sharing systems are headed and the impact that they will have on society.

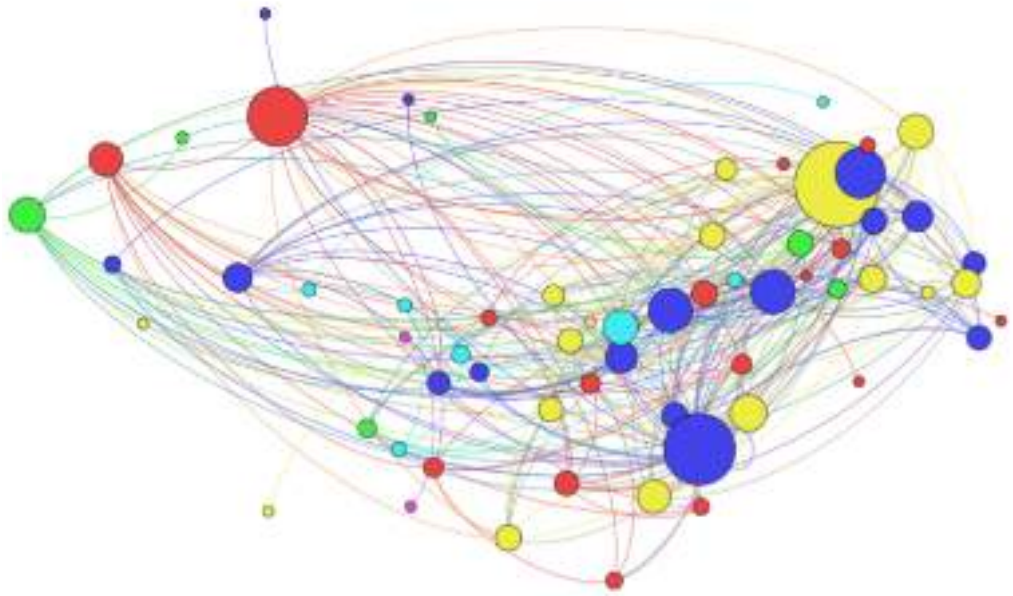


Figure 4: Visualization of Hubway Trips

Stakeholder Analysis

In order to have a better understanding of how the Hubway affects and is affected by other parties, a stakeholder analysis was carried out. Following Freeman's definition of a stakeholder as "any group or individual who can affect or is affected by the achievement of the organization's objectives," we attempt to provide an overview of the various stakeholders of the Hubway system. As the Hubway system expands, the stakeholders are likely to change. More stakeholders will evolve as the company grows. In addition, the categorization of stakeholders is not static; some stakeholders will become more important as the company grows, while others will take a less significant role.

The following chart contains a list of potential stakeholders along with their corresponding typology. The characteristics that each stakeholder possesses are indicated.

Table 2: Stakeholder Analysis

Stakeholder	**Typology** **P-power, L-legitimacy, U-urgency**
City/Town governments - City of Boston, City of Cambridge, City of Somerville, Town of Brookline - Mayor of Boston Operator - Alta Bicycle Share	P,L,U – Definitive P,L,U - Definitive
Transportation Authorities - Boston Metropolitan Planning Commission, Federal Transit Administration, Massachusetts Department of Transportation, Metropolitan Area Planning Council, Massachusetts Bay Transportation Authority	 P – Dormant
Operating Partners - Alta Bicycle Share(Major Operator - Bixi	 P, L, U- definitive L,U – Dependent
Bike shop owners	L - Discretionary
Hubway Employees - Service Technicians, Dispatcher, Redistribution Tech Sponsors - New Balance, Allston Green District, Harvard University, etc.	L - Discretionary L - Discretionary
Commuters - Business commuters - Tourists - Students - Residential commuters	 L,U - Dependent L - Discretionary L,U - Dependent L - Discretionary
Potential Competitors - Zipcar / Car Rental Companies - Taxi Companies	N/A

Mayor of Boston:
[Power, Legitimacy, Urgency]
Boston Mayor Thomas Menino and the Nicole Freedman are one of the most important individual stakeholders in our study. At the most senior decision-making level, Mayor Menino campaigned for better cycling conditions in the City of Boston and oversaw the New Balance Hubway bike share system, signed contracts with sponsors, operators and construction companies, and solicited funding from the State and the federal government. As the five-term Mayor of Boston who dedicated his career for a healthy livable city, Mr. Menino has the legitimacy and urgency to insure successful implementation of Hubway system in his area of supervision.

City Governments - Cities of Boston, Cambridge, Somerville, Town of Brookline:
[Power, Legitimacy, Urgency]
City Government officials have been classified as definitive stakeholders, possessing power, legitimacy, and urgency. As government offices, they are capable of exercising power over Hubway's decisions and activities through laws, financial backing, or coercion. Furthermore, their leadership over the concerned cities gives them a legitimate position as stakeholders and a sense of urgency to maintain the proper function of their constituents.

Sponsors:
[Legitimacy, Urgency]
Sponsors have legitimacy to involve in the Hubway expansion project. In order to maximize the efficacy their investments, major donors such as New Balance, can engage in Hubway operation and planning if they are willing to pay a large sum. But money is usually paid as a sink cost of the sponsors without endowing too much power on them. As the principal supporters of the project, they are legitimate to decide the scale, locations and rates of the Hubway system that align with their marketing needs and business strategies.

Local Businesses:
[Urgency]
The businesses around Hubway stations are not the major part of the stakeholder analysis due to the lack of legitimacy and power. Hubway may provide users a fast and easy access to local restaurants, stores, and companies, which can potentially increase the influx of customers and revenue during its time of operation. They may have some urgency to make sure Hubway stations are built close to their locations. But there's no evidence suggesting a strong correlation between significant local/individual economic growth and the establishment of Hubway stations. On the other hand, Local businesses can sign up for corporate membership to give their employee access to Hubway bikes. Those employees, who are registered Hubway members, can collectively become a stakeholder.

Bike Shop Owners:
[Legitimacy]
Bike shop owners are certainly stakeholders in the Hubway system. Some commuters may steer away from the decision to purchase a bike because of the convenient bike sharing system that Hubway offers. Bike shop owners own legitimate businesses that strive to offer users a convenient mode of transportation. Hubway negatively affects the owners of bike shops since people interested in traveling by bike are no longer required to purchase one. With less people purchasing bikes, the income that bike shop owners obtain from bike repairs and parts also diminishes.

Transportation Authorities:
[Legitimacy, Power]
Transportation authorities that are stakeholders of the Hubway system include the Mass Department of Transportation, Metropolitan Area Planning Council, Massachusetts Bay

Transportation Authority (MBTA) and the Federal Transit Administration. They possess qualities of power, legitimacy. The Metropolitan Area Planning Council, the regional planning agency for the metro-Boston region, joined the efforts of implementing the Hubway system; as a leader in the open bidding process that resulted in the selection of Alta Bicycle Share as the preferred company to operate bike share, MAPC certainly possess power within Hubway as well as legitimacy to bring about transportation changes as one of their responsibilities and transportation authorities. Some of the grants that fund Hubway have come from various government agencies; these contributions include $3 million from the Federal Transit Administration (FTA), $450,000 from the Boston Public Health Commission (BPHC) and $250,000 from the Metropolitan Area Planning Council. There is a sense of legitamacy from these powerful stakeholders to implement and improve new public transit systems, such as Hubway.

Commuters:
[Legitimacy, (Urgency)]
While commuters are the stakeholders that are using the service provided by Hubway, many only possess legitimacy. The transportation needs of the users are legitimate and always present. However, the power that they have over implementing changes in the company is minimal. While Hubway may elicit customer service feedback from users, the ultimate power that is needed to implement improvements and change comes from within the company itself. For some commuters, they possess urgency in addition to legitimacy. Many business commuters who are using Hubway as a means of arriving to work on time and getting home to their families are often choosing their transportation methods with the consideration of travel time. Students who are using Hubway to commute from their homes to campus also have a sense of urgency due to their set class and meeting schedules.

Hubway Employees:
[Legitimacy]
Most Hubway employees do not maintain much power within the company, as they are given specific responsibilities that are predetermined for them to fulfill. Some of these jobs, including service technicians and dispatchers, have important roles that are important to the successful operation of Hubway. The employees of Hubway that may possess some power are the managers. Like in any other institution, hierarchies among employees exist; those with positions that are higher up are able to make decisions and changes that are implemented within the company.

Operating Partners (Alta, Bixi, Consultants)

Operators: Alta Bicycle Share
[Power, Legitimacy, Urgency]
Alta Bicycle Share is Hubway's contractor for operations. Alta been classified as having power, legitimacy and urgency. As operation managers, they have a relevant relationship to Hubways day-to-day operation and their knowledge and expertise in bike sharing market gives them a useful relationship with Hubway and makes them relevant in the decision-

making. Their power comes from the ability to influence the decisions of Hubway through pricing. in this public-private partnership. As a business, Alta also has sense of urgency because a major goal of theirs in working with Hubway is to generate income. They are very urgent in their efforts so as to yield profits and positive impacts as early as possible.

Bikeshare equipment manufacturer - Bixi
[Legitimacy, Urgency]
Bixi is Hubway's contractor for the manufacture and maintenance of bicycle and station equipment. Bixie has been classified as having legitimacy and urgency. Manufacturers have a legitimate relationship with Hubway as they provide and maintain the relevant physical infrastructure for operation. They also are urgent stakeholders because they have a business model whose goal is to generate income.

Potential Competitors:

Zip-Car/Car Rental Companies/Taxi companies
[Non-stakeholders]
Car rental businesses such as Zip-car as well as taxi companies are not stakeholders due to their lack of power, legitimacy and urgency. Although their targeted consumers are those without a car when needed or people searching for alternative transportation methods, the Hubway members are mostly local residents and tourists with short-distance travel needs with possibly even environmentally friendly objectives. Due to the difference in target markets, car rental and taxi companies do not have the incentive to support Hubway financially or prevent its operation and expansion plans; therefore, they are not considered in stakeholders in this analysis.

Figure 5: Stakeholder Venn Diagram

Financing the Project

Cost Benefit Analysis

Hubway is an example of a Public-Private Partnership (PPP) project. It is publicly owned by the City of Boston, yet the city outsources its operation to Alta Bicycle Share, a private company that does consulting for a number of bike sharing systems internationally. Alta is responsible for member fee collection, maintenance and operation, expansion, and organizing the financing of Hubway operations.

Hubway Funding sources

Hubway receives a big portion of its capital from public sources of funding. These include the Bus Livability Grant from the Federal Transit Administration (FTA), Congestion Mitigation and Clean Air (CMAQ) grant and State Capital grants. One additional source of capital is station sponsorship, in which local organizations finance the establishment of a Hubway station on or near their premises for ease of access.
Hubway spends an estimated $10,000 per station per year on operations and maintenance. Operation funds some from user fees, advertising, as well as from certain grants from public foundations such as CMAQ and the Public Health Commission.

Hubway Cash Flows

To build a model of Hubway annual cash flows, we made the following calculations and assumptions:

1. We used a discount rate of 15% and gave the project a 20-year lifecycle from the point of public launching.

Negative Cash Flows:

2. We used a construction cost of $50,000 per station. We also estimated that the number of stations would grow steadily from the current number (112) to 200 by the 6^{th} year of operation.
3. We used an annual maintenance and operation cost of $10,000 per station. We assumed that this amount reduces per station as the number of stations grows. For a number of stations between 100 and 150, we considered $8,000 per station and $7,000 per station when the number of stations exceeds 150.
4. We estimated an initial investment into the system of $2,000,000 for preliminary work such as research and contracting.

Positive Cash Flows:

5. User fees:

   We considered a logarithmic growth pattern for Hubway membership and casual ridership from which we estimated future tolls.

   Annual Members:
   To calculate annual cash flows from membership fees, we used Hubway's annual fee of $85. We did not consider charges on late bike returns for annual members as sources showed that only a negligible percentage of rides logged by members exceed the 30-minute limit.

   Casual Riders:
   We made the following assumptions for the casual ridership:
   Casual riders average two trips (to and fro) per pass.
   Sources informed us that one in three casual rides exceed the 30-minute ride limit. The cost incurred by a rider who returns their bike late ranges from $2 to $100 based on the amount of extra time and the membership status of the rider. We estimated an average charge of $5 for late returns. We also only considered the 24-hour pass for casual riders, as this was the only casual ridership option available in Hubway's first season of operations.
   So, if for a given year, the number of casual rides logged is N, then the cash flow from annual rides would be given by:

$$C(\$) = \left(\frac{1}{2}\right) N * \$6 + \left(\frac{1}{3}\right) N * \$5$$

   Co-operate Members:
   We estimated an annual growth rate of 10 co-operate members per year, reaching a total of 100 co-operate members. We believe that this is a conservative estimate, given the jump in co-operate members Hubway has seen within the last month alone. We estimated an average of 150 Hubway users per co-operate member, and an average of $35 for annual membership per Hubway user under co-operate membership.

6. Others:

   We estimated a total cash inflow of 5.5 Million from grants and station sponsorship in the first five years of the project.

Outcomes of Cash flow Analysis

The above-mentioned assumptions and subsequent analysis of the system yielded a break-even point in 2013 and a net present worth of the project of $7.9 Million. Below is a detailed breakdown of our calculations:

Table 3: Station and Ridership Logistics

Year	# Stations	# Memberships Sold	# Casual Rides Logged	# Corporate Members
1	61	3000	142289	0
2	78	11130	170000	37
3	112	15886	186206	47
4	132	19260	197706	57
5	152	21877	206626	67
6	172	24016	213915	77
7	200	25824	220077	87
8	200	27390	225415	97
9	200	28771	230123	100
10	200	30007	234335	100
11	200	31125	238145	100
12	200	32145	241623	100
13	200	33084	244823	100
14	200	33954	247785	100
15	200	34763	250543	100
16	200	35520	253123	100
17	200	36231	255547	100
18	200	36901	257832	100
19	200	37535	259993	100
20	200	38137	262043	100

Station and Ridership information has a huge impact on Hubway finances. By using the logarithm functions derived from two years of operation records (as described in the Official Launch and Growth Section), we predict in its 20 years of service, a total of 200 stations will be built, with annual membership of more than 38,000 and corporate membership of 100. Total casual trips made per year will grow to about 262,000.

Table 4: Cash Flows

Year	Grants $ Sponsorships	User Fees	Construction	Maintenance & Operations	Preliminary
0	$0	$0	$0	$0	-$2,000,000
1	$2,000,000	$919,015	-$3,050,000	-$610,000	
2	$2,000,000	$1,933,633	-$850,000	-$780,000	
3	$500,000	$2,465,989	-$1,700,000	-$896,000	
4	$500,000	$2,858,966	-$1,000,000	-$1,056,000	
5	$500,000	$3,175,559	-$1,000,000	-$1,216,000	
6	$0	$3,443,840	-$1,000,000	-$1,204,000	
7	$0	$3,678,779	-$1,400,000	-$1,400,000	
8	$0	$3,889,316	$0	-$1,400,000	
9	$0	$4,044,464	$0	-$1,400,000	
10	$0	$4,169,159	$0	-$1,400,000	
11	$0	$4,281,960	$0	-$1,400,000	
12	$0	$4,384,940	$0	-$1,400,000	
13	$0	$4,479,671	$0	-$1,400,000	
14	$0	$4,567,379	$0	-$1,400,000	
15	$0	$4,649,033	$0	-$1,400,000	
16	$0	$4,725,416	$0	-$1,400,000	
17	$0	$4,797,166	$0	-$1,400,000	
18	$0	$4,864,814	$0	-$1,400,000	
19	$0	$4,928,803	$0	-$1,400,000	
20	$0	$4,989,509	$0	-$1,400,000	

Cash flow analysis includes sponsorship grants, annual user fees as part of the cash inflow. Costs on construction, maintenance & operations, preliminary establishment are considered as the negative cash outflow. As demonstrated in the diagram in Figure 6 and Table 4, the preliminary cost is about 2 million, which includes the initial development on the bike sharing systems, operator contracts, etc. The donor grants for the first two years of operation are 2 million annually, but are reduced by half as Hubway evolves into a more self-sustainable system. Construction cost fluctuates for the first eight years due to different expansion plans. We also observe a increasing trend of user fee incomes and a stable maintenance cost over the years.

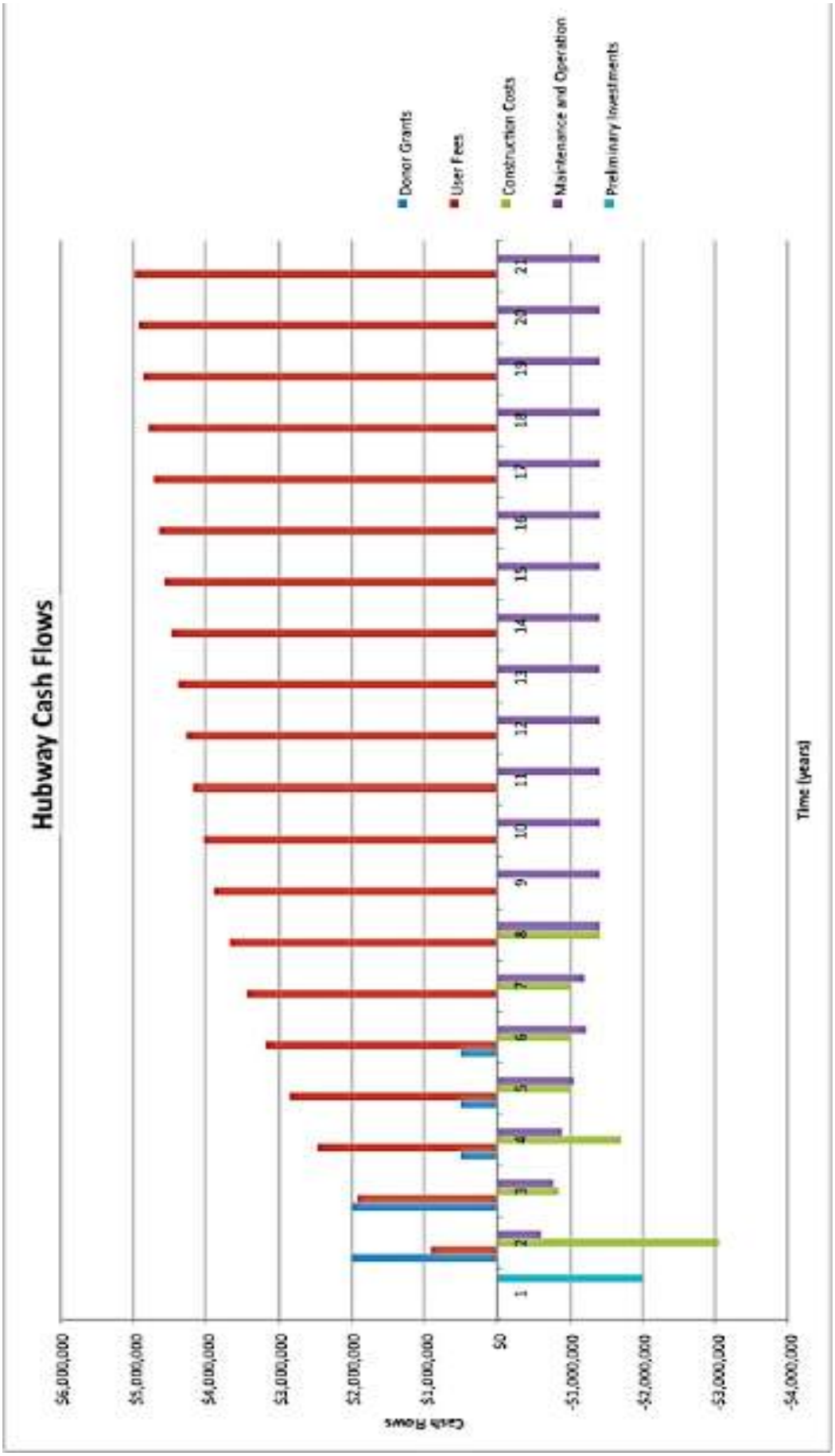


Figure 6: Hubway Cash Flows

Table 5: Net Present Value of Cash Flows

Net Present Values							
Year	Grants $ Sponsorships	User Fees	Construction	Maintenance & Operations	Preliminary	Sum of NPVs	Cumulative Value
0	$0	$0	$0	$0	-$2,000,000	-$2,000,000	-$2,000,000
1	$1,739,130	$799,144	-$2,652,174	-$530,435		-$644,334	-$2,644,334
2	$1,512,287	$1,462,105	-$642,722	-$589,792		$1,741,878	-$902,457
3	$328,758	$1,621,428	-$1,117,778	-$589,135		$243,274	-$659,183
4	$285,877	$1,634,623	-$571,753	-$603,771		$744,975	$85,792
5	$248,588	$1,578,814	-$497,177	-$604,567		$725,659	$811,451
6	$0	$1,488,867	-$432,328	-$520,522		$536,017	$1,347,468
7	$0	$1,382,989	-$526,312	-$526,312		$330,366	$1,677,833
8	$0	$1,271,424	$0	-$457,662		$813,762	$2,491,595
9	$0	$1,149,689	$0	-$397,967		$751,722	$3,243,317
10	$0	$1,030,552	$0	-$346,059		$684,494	$3,927,811
11	$0	$920,378	$0	-$300,921		$619,458	$4,547,268
12	$0	$819,577	$0	-$261,670		$557,907	$5,105,175
13	$0	$728,072	$0	-$227,539		$500,533	$5,605,708
14	$0	$645,502	$0	-$197,860		$447,641	$6,053,349
15	$0	$571,341	$0	-$172,052		$399,288	$6,452,637
16	$0	$504,980	$0	-$149,611		$355,370	$6,808,007
17	$0	$445,781	$0	-$130,096		$315,685	$7,123,692
18	$0	$393,102	$0	-$113,127		$279,975	$7,403,667
19	$0	$346,324	$0	-$98,371		$247,952	$7,651,619
20	$0	$304,860	$0	-$85,540		$219,320	**$7,870,939**

Using the cash flow diagram, we estimated the net present value for each financial year. We observe a dip of NPV at year 1 due to multiple costs that are not yet compensated by revenue. The NPV steadily increases till year 10, when Hubway starts to its saturation point in expansion, with NPV starting to increase at decreasing rate. (Figure 7) The cumulative value at the end of its 20 years of operation is estimated to be 7.8 million.

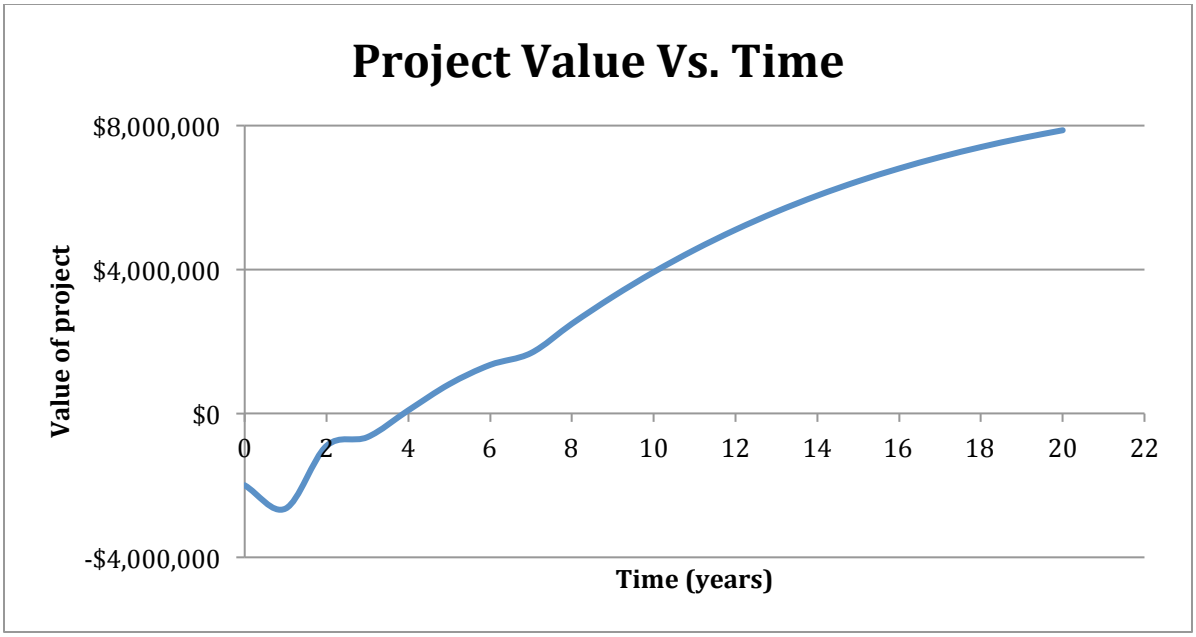


Figure 7: Project Value over Time

Real Options

Just as all infrastructure projects require the consideration of flexibility, the design and implementation of the Hubway system also required the consideration of future uncertainties. The nature of the Hubway system itself is great for flexibility. Unlike some transportation projects that are relatively permanent and unchangeable, such as a railroad project, the Hubway system has the capacity to be expanded, moved, and adjusted based on the needs of users. Despite these inherent characteristics that allow for more flexibility, there are still aspects of Hubway where flexibility can be accounted for in its design and implementation.

Because Hubway is a fairly new bike sharing system that has been implemented in the metro-Boston area, real options are a very important aspect of its future. As the number of users and the potential of expanding to new cities continue to increase, Hubway can attempt to account for these changes as it constructs new stations and increases their number of bikes.

When the Hubway system was initially implemented in 2011, there were several real options that could have been considered. Some potential questions that could have been posed include:

- Does the current plan construction of 61 stations account for the growth of Hubway?
- Will areas for advertisements be included at the stations?
- Should extra racks be constructed to accommodate for future increase in bikes?

It is clear that at the time, Hubway did not construct the number of stations and implement the number of bikes to accommodate for the number of users that it currently has as well as the growing number of users. As a result, the past two and a half years of Hubway has resulted in a station increase from 60 to 112 and a bicycle increase from 600 to 1100. An interesting aspect of Hubway's expansion to keep in mind is whether or not newly constructed stations should account for the growing number of Hubway users, having increased rack space and a greater number of bikes.

For the Hubway system, a "real options" analysis can used to analyze station capacities of new Hubway stations in Cambridge. This expansion could be analyzed by comparing three options:

1) Build new stations with normal capacity now (2013) and double the rack capacity and bikes of these stations in 5 years (2018)
2) Build new stations with double capacity and double bikes in anticipation for future demand increase
3) Build new stations with double the racks capacity without the increased number of bikes - if future demand requires more bikes, bikes will be added to the stations in 2018

In order to make our analysis of these options easier, we decide that 2018 is the first year in which any additional expansions be implemented if needed.

The cost of these three options at present time (t=0, year 2013) will be denoted as C_1, C_2, and C_3 respectively.
When analyzing the costs of these three options at present time, the ranking of these costs from most to least expensive is as follows:
$C_2 > C_3 > C_1$

To make our evaluation of these options simpler, we assume that the capacity expansion of the stations can only be executed 5 years from now (year 2018).
The cost of these three options in 2018 is:
1) C_{11}
2) Zero
3) C_{33}
The expected cost rankings in 2018 would then be: $C_{11} > C_{33}$.

The cash flow diagrams below demonstrate the relative magnitude of costs in year 2013 and 2013 for the three options:

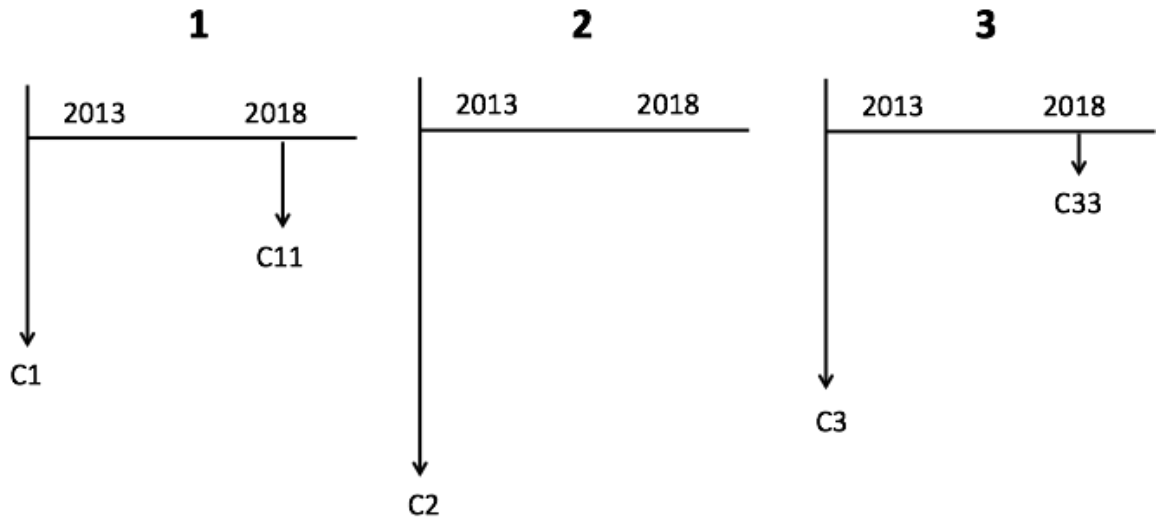


Figure 8: Cash Flows for Station Expansion Real Options

There is a possibility of low or high growth in the Hubway system. The probability of low growth occurs is p and the probability that high growth occurs is 1-p.
There is uncertainty involved in how much growth the Hubway experiences in the rest of its lifetime, which we assume to be 20 years. Under the assumption that the first expansion of station capacities can occur either now or in 5 years, we evaluate our three options by comparing their net present values at the end of the Hubway lifetime.

It is also important to evaluate the different level of service (LOS) provided by the Hubway system to travelers in the various cases. The LOS is a function of the number of bikes that exist. As the number of bikes increase, users are offered a higher level of service from the increased availability of bikes. However, after the number of bikes exceeds the optimal bike number (which depends on the Hubway rider population), there is a decrease in the level of service, which is due to the difficulties in evenly distributing the number of bikes and ensuring proper maintenance of the bikes.

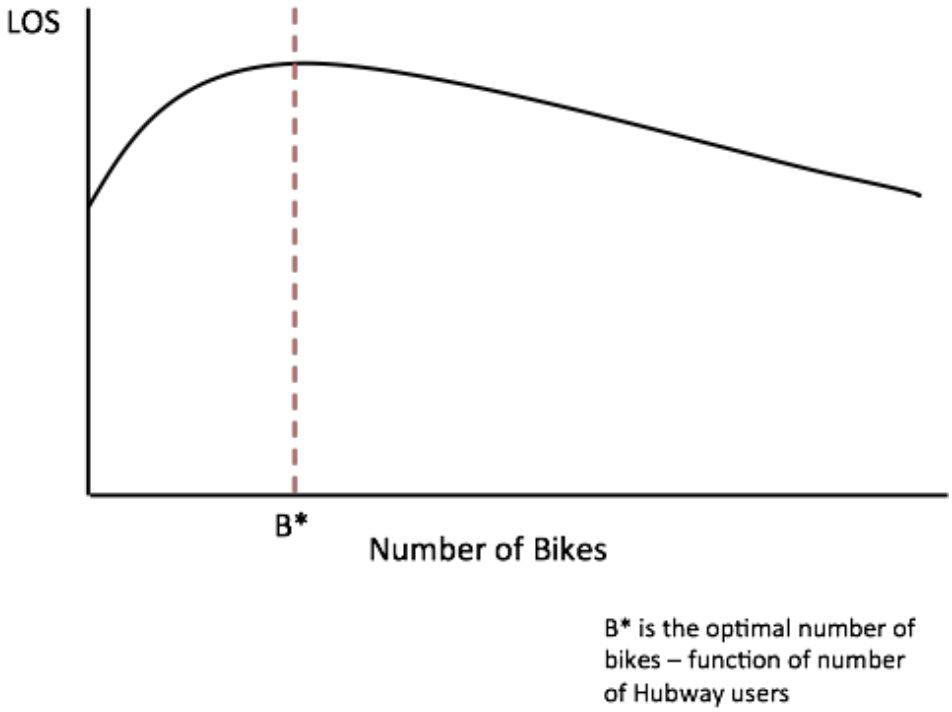


Figure 9: Level of Service vs. Number of Bikes

We start out by evaluating the current situation of the Hubway stations in Cambridge. Currently, Cambridge has 27 stations. The increased number of Hubway subscribers and users has called for an increased demand in Hubway bikes. Stations are constructed with approximately 10 bikes and 18 racks. Hubway plans to expand their number of Cambridge stations by 10 stations. Note that this real options analysis is carried out with only an increase of one station to simplify calculations.

It is important to evaluate the LOS at both 2018 and 2033. We assume that by 2018, the number of bikes has increased but has not surpassed the optimal bike number. We also make the assumption that at 2033, the number of bikes has increased passed the point of optimal service. We monetize the LOS after 5 years (2018) to be LOS5=+$2000 and the level of service deficit after 20 years (2033) to be LOS20=-$8000.

The costs of the three options are as follows:
$E(NPV)_1 = p^*[C1+LOS20] + (1-p)^*[C1+C11/(1+r)^{20}+LOS5]$
$E(NPV)_2 = p^*[C2] + (1-p)[C2]$
$E(NPV)_3 = p^*[C3+LOS20] + (1-p)^*[CC+CCC/(1+r)^{20}+LOS5]$

Approximated costs (for 1 stations):
(1) Normal capacity & bikes - ($50,000) [C1]
    + 18 additional racks & 10 bikes - ($28,000) [C11]
(2) Double capacity & bikes - ($50,000+$12,000+$16,000 = $78,000) [C2]
(3) Double capacity no bikes - ($50,000+$16,000 = $66,000) [C3]
    + 10 Additional bikes - ($12,000) [C33]

We make the assumption that the probability of low growth p is p=0.2 and the probability of high growth (1-p) is 0.8. In addition, the discount rate is assumed to be r=0.05.

Using these values, we can evaluate our three options numerically, to find that:
E(NPV)1 = p*[C1+LOS20] + (1-p)*[C1+C11/(1+r)^5+LOS5] = $67,550.99
E(NPV)2 = p*[C2] + (1-p)[C2] = $78,000
E(NPV)3 = p*[C3+LOS20] + (1-p)*[C3+C33/(1+r)^5+LOS5] = $73,521.85

Based on the evaluation of the net present values of these three options, it would make the most sense to go with option 2 and build new stations with double rack capacity and double the number of bikes now (year 2013). Because there is such a high probability for high growth in the future, it is reasonable that this option is the most economically wise decision.

Project Analysis

Environmental Impact

One of the major motivations for creating such a large-scale bike share system is the positive environmental impact it generates. Automobile emissions comprise 31 percent of total carbon dioxide, 81 percent of carbon monoxide, and 49 percent of nitrogen oxides released in the U.S. (The Green Commuter, a publication of the Clean Air Council). According to the World Watch Institute, a short, four-mile round trip by bicycle can produce about 15 pounds of pollutants out of the air we breathe and the energy associated with 1 gallon of gasoline is equivalent to riding bikes for 500 miles. Assuming that each trip taken by Hubway users is approximated 4 miles, we estimated that 40 tons of CO_2 and 4500 tons of total pollutants are not emitted to the atmosphere. The environmental benefits are predicted to continually increase as more bike stations are constructed and more people start using this ecologically friendly transportation method.

Economic Impact

There are economic spillover effects associated with Hubway's operation. Businesses that are close to Hubway stations may benefit from a higher customer influx from Hubway users. Local Cooperate Members, by providing cheap transportation alternative to their employees, face less parking demand from their employees. One way to look at the economic benefits behind few bike parking vs. car parking statistics: Approximately 10 bikes can be parked in one car parking space in a paved lot, which reduces the parking stress in the surrounding area as people switching to Hubway members.

Most importantly, Hubway provides economic and independent travel for low-income earners and college students. It offers increased mobility to many groups of the population with low rates of car ownership, such as low-income earners, unemployed people, seniors and those under 18 years of age. An annual membership fee is 45 dollars, and 25 dollars (if corporate member), while buying a new sturdy functional bike usually costs over a hundred, and 600 dollars are required for an annual Zipcar membership. Cycling provides economic and independent travel for those who might otherwise have their travel options restricted.

Social Impact

Health benefits are tremendous for Hubway users. Riding to work, school, or taking bikes on short neighborhood trips is a convenient and practical way to incorporate regular exercise into a busy day. There is also evidence for a better psychological wellbeing. Study has shown that cyclists are often happier and more productive employees because low-intensity physical activities help relieve symptoms of depression and anxiety and improve mood and may reduce the risk of developing depression. ("Report on Physical Activity and Health: A Report of the Surgeon General, 1996)

Cycling enables people to interact socially and feel more at home in their local community. More people cycling and walking provides additional opportunity for social interaction on the streets and this enhances a sense of community. More bikes in a neighborhood provides a safer road environment and children can also take advantage of slower and less dangerous traffic to cycle as well.

In the same time, it help alleviates road congestion problems, 13% of the 675,000 rides taken in the first two years of the Hubway system were "car replacement" rides, indicating a potential for people to switch from automobiles to more sustainable, sometimes faster way of transportation.

Although the social impacts made by Hubway users are not evident at this current stage, the potential growth of membership in the next 10 years will definitely have impact on society as a whole as Boston transforms itself into one of the most biking-friendly cities in the nation.

Safety

Like any other public transportation system, Hubway has strived to insure the safety of all users. Since its first launch in 2011, only one accident with major injuries has been reported. But inherent risks within both the station construction and the implementation of safety measures should be carefully addressed.

Due to the limited speed of biking, Hubway stations should be installed in places within speed limit of 25 mph. It also should be built in places with proper bike lines only, as defined by the Boston Bike map. Currently, only 20% of the Hubway users ride with a helmet. So we need a simple, easily accessible helmet system, such as the "HelmetHub" developed by an MIT team, which will be elaborated in later sections. It may be in the best interest to unlock a helmet first as a required step to rent the Hubway bicycle, as opposed to a separate item that must be rented in addition to the bikes.

A Closer Look at Helmets

We had the opportunity to speak with Breanna Berry, one of the co-founders of HelmetHub. Breanna Berry is an alumna of the MIT Class of 2011. HelmetHub started as a course project for 2.009, a design course in the Mechanical Engineering Department.

HelmetHub provides safe, clean helmets for bikeshare users by allowing you to rent a helmet at a bikeshare station and return it when you're finished. This provides a solution to the concern of helmets not being used by users of bikeshare systems. HelmetHub offers safety and convenience, the most important factors for Hubway users.

Q: How does Helmet Hub serve a different role than the helmets that Hubway already sells?
A: The main issue with the helmets that Hubway currently sells is the fact that riders still have to carry around these helmets. One of the main issues associated with riders using helmets is convenience. With HelmetHub, riders don't have to worry about carrying a helmet around with them. Instead, they can easily access one when they need it and then return it after they're done.

Q: When will we see Helmet Hub being implemented?
A: Within the next month, you should see HelmetHub dispensers located at 20 of the Hubway stations in Boston. We're really excited to see how this trial run goes.

Q: What do you see as some obstacles to Hubway's expansion?
A: Some of the main issues with the Hubway system right now is the redistribution of bikes. At HelmetHub, we face that same challenge in trying to optimize the distribution of helmets at different stations as riders rent and return them.

It would also be helpful to include rights, laws, and accident/emergency information at all Hubway stations, which can help promote understanding of the rules and accident procedures. Promoting bike safety education in metro Boston particularly among targeted Hubway users particularly college students and low-income workers can potentially reduce accident rate in the long run.

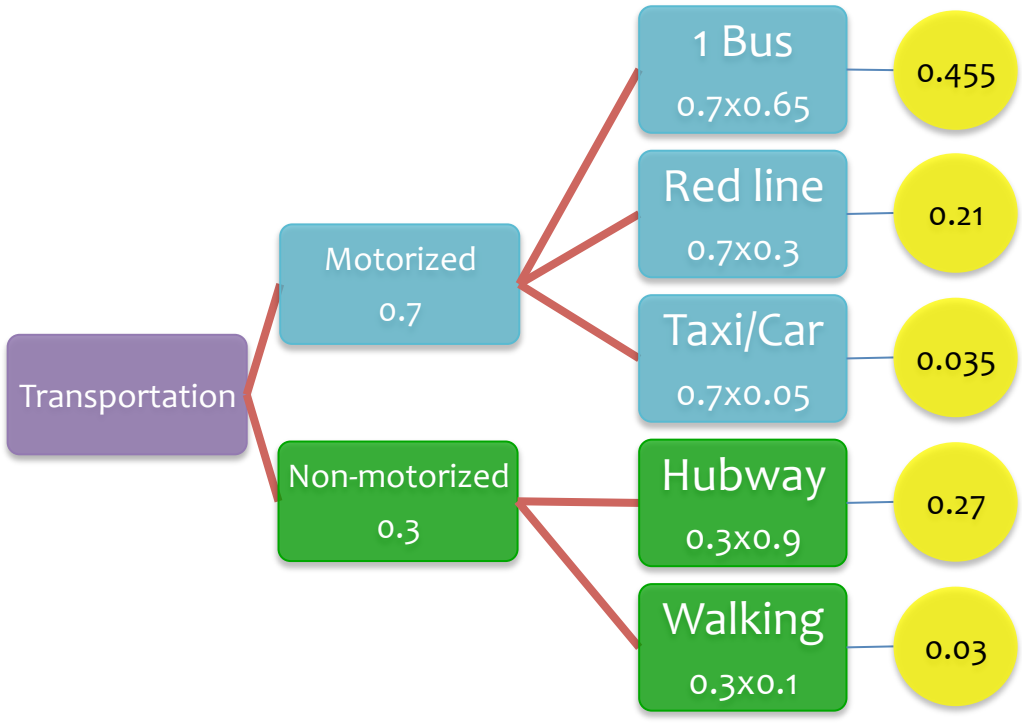
Decision Tree

When comparing the current role of Hubway in regards to other modes of transportation that exist, it is important to evaluate what benefits users obtain from each transportation system. The probability of users choosing Hubway over other transportation methods can be visualized through a decision tree. In order to examine the decisions made by users on a smaller scale, we examine the Hubway travel route that is taken from the station at Mass Ave/Amherst St. to the Harvard Square Station. This example decision tree portrays a real-life application of how Hubway has become incorporated into the decisions of travelers.

Table 6: Modes of Transportation from MIT to Harvard

Mode of Transportation	Travel Times (in minutes)	Travel Costs (in dollars)
Walking	33	0
Red Line (T)	19	$2.50
1 Bus	15	$2.00
Hubway	13	$5
Taxi/Car	5	$9.50

The table above indicates the corresponding transportation times and costs for the most common methods of traveling between these points. Using this information, corresponding probabilities for choosing each mode of transportation were assigned:



It is interesting to see that of the various transportation methods available to people traveling from MIT to Harvard, we approximate that about 30% of travelers will choose to take Hubway. It is important to see what factors come into consideration for travelers. The travel time and costs are just two factors that are taken into consideration by travelers. It is important to keep in mind that other factors impact transportation decisions. Some of these other factors include: size of travel group, the time of day, and whether or not travelers have a monthly Charlie Card pass.

Comparison Analysis

Brief History of Bike Sharing Systems

In order to better analyze how Hubway currently operates and how it will potentially change in the future, we examine the history of bike sharing systems. Bike sharing, as we know it today, has existed in three generations.

1st Generation Bike Sharing

First generation bike sharing was started in Amsterdam 1965. Ordinary bicycles were painted white and distributed within the city for public use. The goal was for riders to pick up a bicycle, use it, and leave it anywhere within the city for the next user. This system, lacking user and bicycle identification, of course failed within days.

2nd Generation Bike Sharing

This generation of bike share systems was enabled by coin drop technology and started in 1993 in Denmark. In this system, a user paid to check out a bicycle by coin deposit. The major issue in 2nd gen system was that the user remained anonymous and could appropriate a bicycle for private use without being identified. This issue is what led to the development of 3rd generation systems shortly after.

3rd Generation Bike Sharing

This new generation was started in 1996 at Portsmouth University in England, where students could check out a bicycle by swiping a magnetic card. It is with the enabling of user identification and bicycle tracking that bike share systems took off, eventually becoming the fastest growing mode of public transportation ever recorded.

Comparison with other US Systems

We have compared Hubway to a number of other bike sharing systems in the United States to get a sense of how Hubway fares on a national level. Comparison also helps to develop insight into possible future prospects for Hubway and identify good ideas that Hubway could implement. Below are examples of three Bike sharing systems with unique features that we considered worthwhile to study.

Capital Bikeshare, DC - 2010

Capital Bikeshare is a regional bike-sharing system shared by Arlington, VA and the District of Columbia. It was officially launched in 2010 as a joint project and has seen high levels of growth since its beginning in 2008 in DC with a modest120 bikes at 10 stations. Today, Capital Bikeshare has 200+ stations, 1800+ bikes and over 24,000 annual members. Its success is attributed to the high population density, thriving tourism, and a young population. Like Hubway, Alta Bicycle Share also operates it and Bixi supplies its infrastructure.

Green Bicycle, St. Xavier University - 2008

The SXU Green Bicycle program was the first 3rd generation Bicycle-sharing system in the US. It is privately owned and operated by the university, with a small ridership comprising of the university's students, faculty, and staff. It opened in the fall of 2008 with 65 bicycles. Renting a bicycle is free for the first fifteen minutes and costs 0.60 every fifteen minutes after. This model of ownership allows the university much control over decisions; however, especially for larger systems, the initial upfront cost of implementation may be high.

Nice Ride, Minnesota - 2010

Nice Ride was launched in early 2010. It is overseen and operated by Nice Ride, a non-profit organization that was set up for the purpose of establishing the bike-share system. Like Hubway, its infrastructure is supplied by Public Bike System (Bixi). Nice Ride relies on local construction companies to do the station assembly at the beginning of each season. It started with 65 stations and 700 bicycles and has expanded to over 100 stations and 1200 bicycles. Nice Ride and Hubway have station and ridership logistics.

The Future of Hubway

Based on the so far transient history of bike sharing, our team has considered what the future of Hubway and Bike Sharing systems in general could look like. Considering how great a success third generation bike sharing has been, it is an interesting venture to speculate on the possible prospects of fourth generation bicycle sharing. We have binned possible future scenarios for bicycle sharing in the three E's of sustainability: Economic development, Environmental Stewardship and Social Equity and we discuss them below.

Economic Development:

Future bike sharing systems could come with better business models that would encourage more financial return on investment. Operators could track bicycles by GPS to enable a better understanding of the functionality of their systems such as popular routes and good locations for stations.

Environmental Stewardship:

One major irony of bike sharing systems is that though they are geared toward reducing environmental impact, they rely on motor transport to redistribute bicycles. With better GPS tracking would also come better environmental stewardship as it would allow operators to position stations and bicycles in such a way as to minimize the amount of redistribution required and this would minimize emission.
Fourth generation bicycle sharing could also usher in alternative ways of powering stations such as solar power, which has already been implemented by Bixi in Montreal.

Social Equity

Fourth generation bicycle sharing could make bicycles available to people that are unable to ride a conventional bicycle for example by adding a pedelecs to bicycles to assist pedaling. Better road planning to accommodate cyclists is also an option for the future of Bicycle Sharing. Boston is already trying to implement this through the Boston complete Roads policy. An even better scheme would be the construction of cyclist-only roads so that cyclists can avoid the busier and city roads.

Conclusions

As of September 2012, Hubway has saved over approximately 45,000 hours of travel delay and plays a significant role in alleviating the traffic conditions of nearby areas. The Hubway system offers a convenient, cheap, eco-friendly, and time-saving alternative of transportation for commuters in the Boston metro area. After doing a complete project evaluation of the current Hubway system, we concluded that Hubway is definitely a worthwhile project. With a project break-even point that occurs this year, we find that the Hubway system offers economic, environmental, and social benefits to not only Hubway users but to the metro-Boston community as a whole. Hubway provides a method to easily run errands, get exercise, and easily access destinations. As the Hubway system continues to expand to new areas and obtain increased membership, it will have an increased impact on the transportation decision and lifestyle of Boston residents and visitors.

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