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Analysis of barriers to greater use of the Melbourne BSS

ENGN2226

Tutor : Ashley Ellis, Tutorial : Wednesday 15:00 - 17:00
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Abstract

The following paper analyses Barriers to greater use of the Melbourne Bicycle Share system and offers recommendations to decrease their effect. The analysis was conducted from both a user's and owner's perspective and the recommendations take both their goals for the system into account. Human factors was the key analysis technique used as the barriers for the system came from a survey conducted on MBS users and non-users in Melbourne and Brisbane. Several recommendations were made based on information from this survey, the main one being an increase in the density of the stations. Energy Factors were not analyzed in this paper as they wouldn't offer any useful recommendations with regards to the barriers given the current system design.

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1. Introduction

A BSS (BSS) is another form of public transport mainly focused in busy city centres and short in range. Stations are located around the city which contain docks that are use to securely store unused bikes, when a users wishes to use one of these bikes they can either use the terminal located at each station and purchase a number/ticket (sometimes the bike lock just disengages without the need for a ticket or number depending on the system) to unlock the bike or, if they have a membership usually a card can be used. When they have finished using the bike they can return it back to any station that has an available empty dock.

BSSs were first introduced in 1965 by Amsterdam city councilman Luud Schimmelpennink as a way to reduce congestion in the city centre (ITDP, 2013). Since then bike share have been increasing in popularity with more and more being introduced, in 2013 Wuhan China's 6th largest city boasted to have an estimated 90,000 bikes within its system. The benefits of Bike Shares are numerous and especially noticeable when located in big city centres with high population density.

- Reduce congestion and improvement in air quality
- Improve health of users
- Increase accessibility for locals
- Acts as complementary service for other public transport
- Improves the image of cycling and attracts new cyclists.

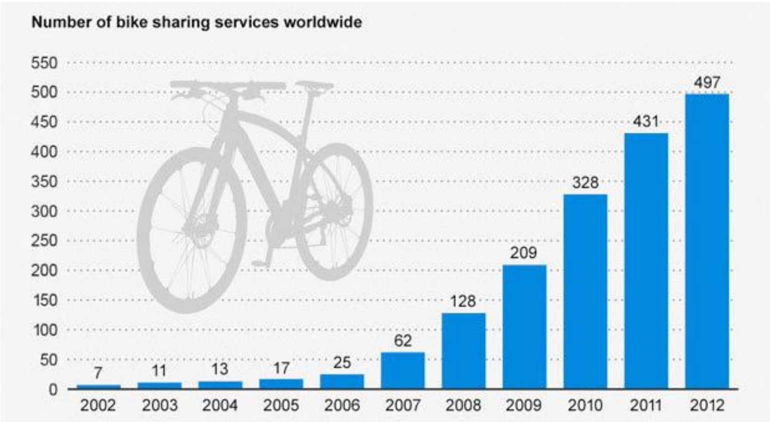

Figure 1 Graph of number of bike sharing system worldwide (McCarthy. N, 2013)

Currently Australia has two BSSs (Melbourne and Brisbane) both implemented in 2010 with another being planned in Fremantle.

The Melbourne Bike Share (MBS) has 51 stations located mainly in the CBD with several also placed down the coastline all together holding 600 bikes. However the MBS have frequently underperformed since it was introduced and with its low ridership large subsidies have needed to be provided by the Government to keep it afloat.

2. Recommendations

Several recommendation are made in the paper with a focus on increasing the ridership numbers.

1. Increase the density of Bike Share Stations so that a user is always within a 305 metre walk to one while with the system boundaries
2. Place the stations in a consistent pattern, regardless of populations density, age demographics etc and instead manipulate the capacity of the stations.
3. Integrate the MBS with local Hotels/Motels with a large enough capacity to sustain the system
4. Direct cyclist's only paths between stations, optimally not on the side of roads.
5. Bike pumps built-in to stations.
6. Introduce a incentivised pricing scheme with stations that are on average are full or empty.

3. Qualitative

3.1 Survey Design

The main survey data used in the paper come from Traffix (2012), the survey was carried out over 2 weeks using a probabilistic sampling technique with separate duplicate surveys online (Fishman et al, 2013). The 921 participants were invited through email with 40.7% of these people responding (Fishman et al, 2013). As a large proportion of respondents were MBS users, weighting (calculated using ABS census 2011 data) was added to correct this bias. Due to the low non-user numbers, data from the same survey performed in Brisbane for non-users was added after being adjusted for socio-demographic characteristics (Fishman et al, 2013) From the results in the survey, the main data used for this paper was on the topic of *Reasons preventing greater use of Melbourne Bike Share.*

However the participants in this survey either lived, worked or studies in Melbourne and therefore do not reflect the entirety of the customer base as tourists haven't been considered. It is estimated that 7.1 and 1.9 million domestic and international overnight visitors stayed in Melbourne in 2013 (Tourism Victoria, 2013). Surveys of other systems like the Capital BSS (CaBi) in Washington D.C demonstrate that a large portion of the causal user base is made up from international and domestic tourists in this case approximately 66% (Virginia Tech, 2012). Therefore this analysis will also be considered from a tourist's point of view.

4. Quantitative

The basic descriptive statistics for the survey group are below in figure 2

Variable		Melbourne Bike Share
Most frequent age range		30–34 (16.9%)
Male		$N = 285$ (76.6%)
Female		$N = 87$ (23.4%)
Mean distance between home and work		10.7 km (SD 9.5)
Percentage living within 500 m of a docking station		44%
Percentage working within 500 m of a docking station		83.9%
Annual income range	Less than $41,599	7.6%
	$41,600–$77,999	20.0%
	$78,000–$103,999	19.2%
	$104,000 or more	43.0%
	No response	10.3%
Car ownership		76.6%
Free car park at work		19.9%
Mean number of family/friends who are bike share members		0.59 (SD 0.87)
Most frequently reported bicycle riding activity in past month		16+ trips (35.8%)

Figure 2 Basic Descriptive statistic for survey group (Fishman et al, 2013)

5. Human Factors

Human factors play a vital role in the analysis of this topic, as the *Barriers* which are referred to come mostly from the opinions and experiences of the users/non-users in Melbourne/Brisbane. From the surveys performed by the Traffix Group (2012) on the MBS (below in figure 3), multiple barriers were cited for current and potential users.

Given this survey was performed in 2012, several changes have already been made to the system the primary one being the introduction of complimentary bicycle helmets as well as vending machine which sell helmets near stations. The main focus for this factor analysis will therefore be on the *Docking stations not near origin/destination*, or in plainer terms the placement of the Bicycle Share stations. Many researchers like Shaheen et al., Bachand-Marleau et al. (2012) and Transport for London (2011) have studied factors affecting bicycle share use and has found convenience as the largest motivating factor and therefore will be one of the main considerations of the station's placement when performing the analysis.

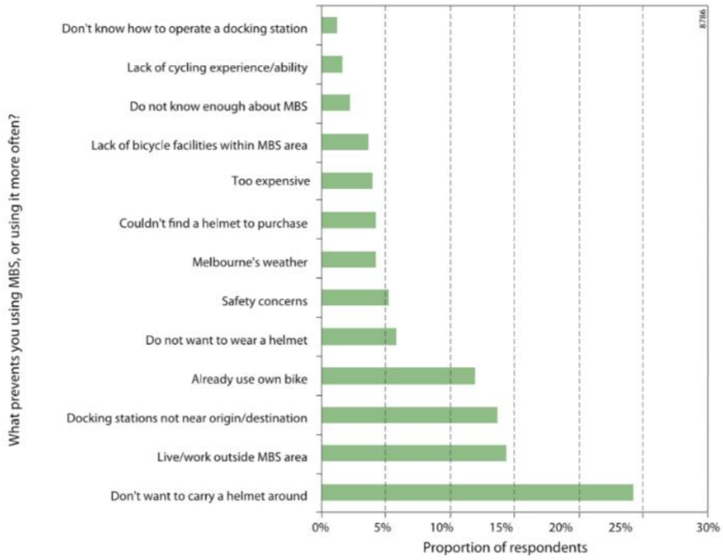

Figure 3 Graph of survey of perceived barriers to MBS use (Traffix, 2012)

5.1 Station Locations

The locations of the current MBS stations are on figure 11 located in the appendix.

The main human factor associated with this aspect of the system is the distance users are willing to walk to and from the stations. From research performed by NACTO (2015) approximately 5 minutes walking distance (or 305 meters) is the average distance people are willing to walk. Another important consideration in placement is consistency, a consistent pattern of stations will make it more convenient for the users to remember where they are located without the need for other technology like phone applications or maps. Combining these two constraints the system should have stations placed so that a user is within 305 metres of a station while inside the system boundaries and placed in a constant pattern, one simple example pattern is below in figure 4.

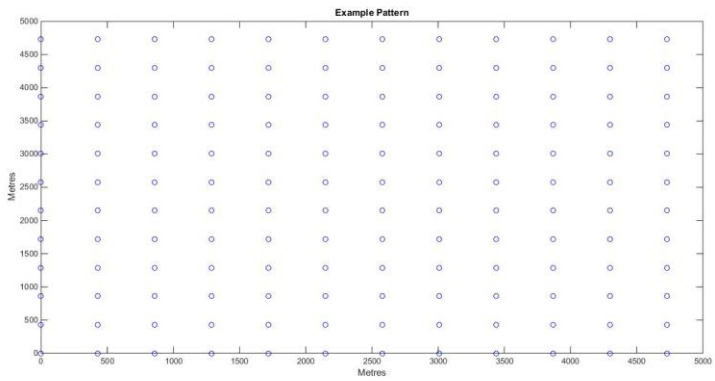

Figure 4 Example distribution of stations

The figure above is an example layout that the stations (marked as o) could be placed in, the distance between each neighbour station is 430 metres meaning that wherever a user may be within this area they will always be approximately less than a 305 metre walk away from the nearest station (in appendix equation 1).

It was considered that placing the constant pattern of stations even is low population density and incorrect age demographic areas (outside 18 - 34 (Fishman, 2013)) might be was wasteful as the possible users base would not be large enough to warrant building infrastructure there. However, if instead of the stations position being varied with population density and age demographic the capacity is, this will not only mean that at the current time the stations are reaching the largest possible share of the user base but also if these areas have a surge in population or change in age demographic the basic infrastructure will already be there and this pattern will make it easier to expand with more stations. Research by NACTO (2015) and ITDP (2013) has also found similar results from analysis of several systems in New York, Paris, London, Boston and especially low income areas where station density is generally low.

Two recommendations can be derived from this analysis while considering the current MBS station layout:

1. There are currently 16 stations where the nearest station is more that 430 metres away (name of stations are located in appendix in table 6), therefore when extra stations are being placed within the current boundary focus should be concentrated on these areas.
2. When further expansion of the system is started, a constant pattern of placement should be implemented like above in figure 4.

The current and expected growth rates and age demographics of the surrounding area should be considered when placing stations to determine the bike capacity.

5.2 Tourist Users

Tourists users make up are large percentage of the casual user base and the placement of stations should also keep them in mind. Instead of these tourist users taking bikes from the main system a secondary system could be implemented to better suit their needs. This secondary system should be located at hotels/motels with large enough capacity to provide for that specific station. This integration of MBS and hotels/motels could also be taken further by adding the use of the system into the cost of the room.

6. Time Factors

Time factors plays an important part in the use of the MBS and bicycle share systems in general, as convenience is the largest motivator to its use by customers and generally the quicker the user can do something the more convenient it is. To find the areas where improvements can be made in terms of barriers for customers a PERT chart can be used.

6.1 Queue Theory

The general flow of the system is broken up into 5 areas, to and from the station, operating the station when receiving and when returning the bike and when using the bike itself.

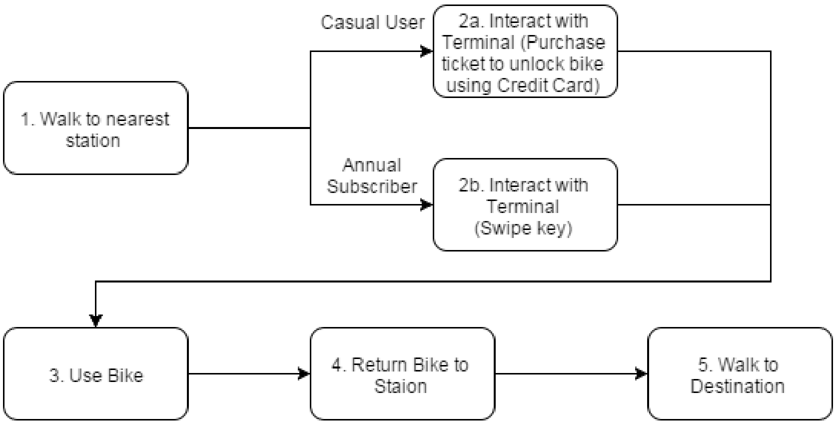

Figure 5 Pert chart of user interaction the BSS (drawn with www.draw.io)

There are two perspectives that can be taken when analysing this PERT chart, first is from the customer. The time needed at steps 2 and 4 is negligible, the main concern in the chart for users is 1, 3 and 5, given that the locations of stations are not within their control. By increasing the density of stations walking time can be decreased thereby improving the convenience of the system.

When analysed from the owners perspective 1, 3 and 5 are a concern but for different reasons. A smaller time on average at 3 will result in larger ride numbers as bicycles are more available. Therefore for the user's bike rides to be a quick as possible, detours need to be minimised, this can be done two ways:

1. Higher station density (i.e. closer to final destination of customers).
2. Direct bicycle paths between stations for cyclists only.

The addition of bicycle paths for cyclists will lower the distance and time needed as interruptions to users (i.e. other pedestrians, road crossings) are reduced and direct paths can be taken. Another advantage of these dedicated bike paths is the reduction in crashes and injuries for users (Cohen,

2013) however this only refers to bike paths with physical barriers to outside interference as ones without can bring other dangers (i.e. bike only lanes on the edge of roads). Many other cities (listed in the figure below (ITDP, 2013)) have also introduced extra bike paths (for cyclists only) alongside their bicycle share systems to improve ease of use. Although these are examples of systems currently much larger than the MBS, by preplanning bicycle paths for when later stations are added future expansions will become easier to manage.

City	Bike Infrastructure With Bike-Share System
Guangzhou, China	46 kilometers of segregated bike lanes
Paris, France	68 kilometers of segregated bike lanes, in addition to 371 existing kilometers
London, United Kingdom	37.8 kilometers of 4 cycle superhighways
Barcelona, Spain	150 kilometers of segregated bike lanes
Boston, United States	80 kilometers of segregated bike lanes (Kaiser 2012)
Rio de Janeiro, Brazil	300 kilometers of physically segregated (ciclovias), painted lanes (ciclofaixas) and signalized shared routes (either with traffic or pedestrians)

Table 1 Table of bike path infrastructure built (ITDP, 2013)

In either case the two perspectives result in the similar conclusion, keep bicycle share stations relatively close to each other (higher station density) to promote shorter rides. From the user perspective this will make the distance needed to travel to and from the stations shorter and thereby more convenient and from the owner's it will allow the bikes to be used more often resulting in an increased user capacity with the same amount bikes. However the benefit due to the increase in riding numbers will have to be balanced with the cost of adding this extra infrastructure which may be unused a large majority of the time.

7. Material Factors

The most useful material analysis technique that could be used for this topic is to model the failure of the parts of the bike. As the cost of replacing/repairing the bike is quite large, by finding which parts have the shortest time to failure, they can replaced with either parts which are more costly but last longer or that are cheaper and easier to change depending on which option offers the most favourable outcome to the system.

Below is the labelled photo of a Bixi bike which the MBS bikes are based off of.

1. Headlight*
2. Carrying basket (8 kg capacity)
3. Elastic cord
4. Brake lever*
5. Twist grip shifter*
6. Bell*
7. Quick release seat clamp
8. Seat post
9. Seat
10. Rear mudguard
11. Rear skirt
12. Rear lamp*
13. Chain guard
14. Sidestand*
15. Pedal
16. Bicycle frame
17. Tire
18. Front mudguard

*These components are explained in detail on next page's « Bicycle features» section

Figure 6 Labelled photo of a Bixi Bike with legend (Bixi, 2013)

Since there is no further data on the exact makeup of components, only general issues relating to the material aspects of the system will be analysed.

7.1 Replacement/Repair

Generally the parts which need the most regular maintenance/replacing are the brakes pads, drive train and tyres (tubes) (ITDP, 2013). The brake pads needs to be replaced, the drive train need to be lubricated and tighten and tyres inflated and checked for leaks. To minimise the cost of maintenance some of this basic maintenance could be passed on to the users, however of these three basic checks really only basic tyre maintenance (inflating) can be performed by the user.

To facilitate this a built-in pump could be added to the stations so that if a users sees that the bike they are using has a flat they easily fix it.

There are also other options such as changing the design of the bikes so that maintenance is needed less frequently. In Shanghai Bike-share system, bikes have been developed with this in mind, they have lightweight solid foam-rubber tires that never need to be inflated, belt-driven drive trains which don't need lubrication and tightening and drum brakes with don't need to be replaced as regularly as brake pads. However changing the designs would be costly and needs to be balanced with the decreased cost in maintenance.

8. Energy Factors

In regards to the topic *Barriers to Greater Use of the MBS,* there are two reasons (both indirect) for which energy factors should be analysed. Firstly, one of the major reasons customers use the system is because it is better for the environment (approximately 40% of respondents listed this as a reason, graph in appendix, figure 13) therefore energy use could be considered. Secondly as energy usage has a cost (in this system it is a variable cost), if electricity costs increase, for the owners to earn a profit or at least break even prices (to use the system) also need to be increased. By lowering the energy requirements or energy loss in the system these costs can be reduced which can then be passed along to the user. This is also important to the users as price was also found to be one of the barriers to use of the MBS (Traffix, 2012).

However this has already be taken into account in the original design as the stations themselves are run entirely off power provided by solar panels (Blain, 2013) and the only part of the bike itself which uses electricity, the headlights, are run of the front dynamo which acts as a generator (Tse, 2011).

Therefore although energy factors would normally be an important aspect of such a system, the energy used in this case has a zero variable cost therefore the analysis of this factor with regards to the topic wouldn't offer any useful recommendations.

9. Control and Dynamics

9.1 Incentivised pricing feedback structure

Currently there are not any major feedback structures involved in the MBS system as a whole. One feedback system that could be introduced is an incentivised pricing scheme to help combat current and future balancing problems.

Balancing is a dynamic problem BSSs especially ones with mountainous terrain or high rush hour numbers are affected by. Balancing refers to how bikes in the system are distributed so that all station are filled to a certain percentage. The problem in this is that throughout the day demand for certain stations can fluctuate and other factors like weather, terrain or events (Bartok et al, 2014) can disturb this balance, so that some stations are empty/full and therefore not available for use to the user (depending if they are taking or returning a bike). Currently to combat this problem MBS hires staff to drive around Melbourne re-distributing bikes, which isn't in line with the user's perception of an environmentally friendly transport and can also be costly as exampled by Paris's BSS where it is estimated that repositioning costs on average $3 per bike (DeMaio, 2009).

One feedback structure which could elevate some of this problem is an incentive based pricing system, in which stations which have lower bike return rates (i.e. generally close to or empty) offer incentives if returned to and stations which are generally full offer incentives for bikes which are taken. In Paris a similar scheme was introduced to combat the same problem, in which stations that were located on hills (which were usually empty) were offered an extra 15 minute bonus free time that could be saved for future use. In the first three months after the introduction 314,443 instances of this were given (DeMaio, 2009). Given the current two stage pricing model for the MBS (lump sum payment and usage pricing) the usage prices are the ones that will be modified to suit demand. This can done either of two ways:

1. Decrease pricing for usage directly
2. Increase the duration of the cost free period (which currently is 30 minutes)
3. Either of these method but added as future credit instead

As there is currently no data on the habits of the users, that is popular and unpopular stations, their strategic behaviour and how they value their time, only the basic structure of the recommendation can be made with more data needed for the specifics.

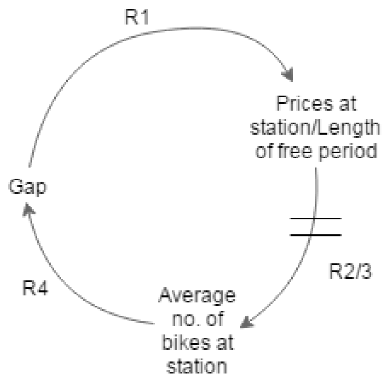

Figure 7 Causal Loop diagram of incentivising feedback pricing scheme (drawn using www.draw.io)

The basic structure of the feedback system will be a balancing loop. From figure 7 there are 3 variables and 4 relationships (depending on gap sign) in the system:

Gap (desired state): The absolute difference between the optimum number of filled docks at a stations and the average actual amount taken from data collected over a long enough period.

Prices at stations/length of free period: The price of using a bike at that station/ length of free period when using that bike.

Average no. of bikes at station (current state): This is the averaged data of the amount of bikes located at that station over time, taken over a suitability long period (until long term behaviour stabilizes).

R1 : A basic positive relationship, as the Gap increase the decrease in the prices for bikes taken from full stations and bike returned to empty stations increases.

R2/3 : There can either be a positive or negative relationship here depending if the gap (not absolute value) is positive or negative. If the gap is positive the station is fuller than it should be and after the price/free period length change the average number of bikes at that stations will decrease (negative relationship). If the gap is negative then the station is emptier than it should be and after the change in prices/length of free period the average number of bikes will increase (positive relationship) as users will have more incentive to bring bikes to these particular stations. In either case the overall effect of this is a decrease in the difference of the current state and the desired state so the loop still balances either way.

R4 : A basic negative relationship between the desired state and the current state.

From this appropriate pricing and/or free periods for individual stations can be found through trial and error. This feedback system will have two positive effects on the users, one, it will help spread bikes around the stations so there will be more chance of finding a bike/free dock and two, for customers who use these stations which are full or empty prices (or future costs) will decrease, which was also one of the barriers listed in the Traffix survey (2012).

10. Cost Factors

It is highly unusual for any bike share scheme to break even, but the Melbourne Bike Share had consistently underperformed since its introduction in 2010 (Carey, 2014), this along with the fact that the price was named as one of the barriers to using the system taken from the survey (Traffix, 2012), makes costs factors essential for this analysis.

10.1 Total Project Costing

The costs of the MBS system were unable to be found for this analysis therefore the Bixi system in Montreal will be used as a representative.

Operating costs for the Bixi system which the MBS is based on are fairly low when compared to other system mainly because of the modular design. Below is a list of the capital and operating costs of the system as well as 'Other' which are the differences between the Bixi and MBS systems.

Costs		Amount
Capital	Bikes	*
	Stations/Docks	
	Internet Presence	
	Software	
	Control centre, Depot	
Operating	Staff	**
	Maintenance	
	Insurance	
	Redistribution	
	Marketing	
Other	Per Helmets	$8

Table 2 Table of BSS costs

*The costs for the total capital in the system averages to AUD$4850 per bike (averaged from multiple sources) (ITDP, 2013) (NYC Dept. of Planning, 2009).

** The operating costs averages to AUD$2217 per bike per annum (NYC Dept. of Planning, 2009)

A rough estimate of the costs is below, the costs were assumed over two periods (length of one year) in which period 1 is the setup of the system and in period 2 it begins to operate.

Costs	Period 1 (AUD$)	Period 2 (AUD$)
New Capital	2,912,000 (100%)	242,500 (10%)
Operating	0	1,108,000
Other	0	60,000
Total	2,912,000	1,410,500 per annum

Table 3 Table of total project costs

In period 1 100% of the capital needs to be bought while in the second period (and onwards) only around 10% of bikes need to be replaced annually (averaged from multiple systems) Midgley. P, 2011) (Foursquare ITP et al, 2013).

10.2 Revenue Streams

The main source of income for the system is the user fees which are split into two stages, first is a lump sum payment (subscription fee), depending on how long the user wants to be able to use the bike. Then a usage fee depending on how long the user has the bike outside the system dock. Detailed prices are below in figure 8.

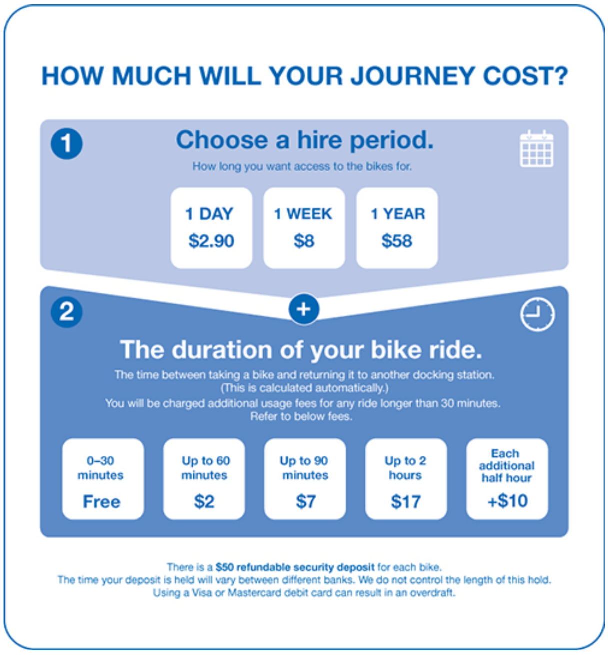

Figure 8 Current pricing scheme of the MBS (Vic roads, 2010)

Currently there is no available data on riding numbers/lengths and the distribution of casual and annual members therefore an estimate of this revenue stream isn't possible.

A possible second source of revenue, that is currently underutilized is advertising. Many system offer opportunities to other businesses for advertising, either on the station terminal, built-in structures specifically for advertising (approx. the same size as bus shelter billboards) or on the share bikes. The revenue created by the advertising in Paris, and Barcelona has reach AUD[1]$19.95 - 32.7 million and AUD$110.8 million respectively in 2007 (Nadal, 2007). Although these systems are much larger in scale, profit will still be achievable even in the small scale MBS given the entry costs will be fairly negligible as there is already existing infrastructure, however this is only at the stations. The advertising on the bike is generally printed on the rear mud flap (or sometimes the wheel) however the current design of the MBS bikes does not have sufficient space.

[1] All prices in AUD converted on 14/10/2015

Figure 10 Example figure of share bike with advertising space (nextbike, 2012)

Figure 9 Back half of bixi bike (bixi, 2013)

An estimation of revenue (only at stations) using a bus shelter billboard as reference can range from AUD$208 - 9008 (per 4 weeks), for a more accurate estimation at each station quotes are need, generally prices will depend on through traffic in the placement area and income levels (BlueLine Media, 2015). A rough range of the possible revenue brought in through advertising is AUD$137,820 - AUD$5.97 million annually.

10.3 Cost-Benefit Analysis

There are multiple benefits from the MBS system that not only affect the users and owners but also the city in general. Below is a list of the possible benefits these parties can gain from the system.

	Benefits
Operator	Profit
User	Health
	Cheaper
	Quicker short distance trips
	Less worry over locked bikes
City (External)	Decrease congestion
	Lower pollution levels
	Less infrastructure needed

Table 5 Table of Benefits of a BSS

	Costs
Operator	Lower share to other public transport
User	Slower over long distances
	More expensive for long times
	Confided into the system boundaries
City	Cost to tax payers
	Safety

Table 4 Table of Costs (includes non-monetary) of a BSS

At the moment the benefit for the profit is nonexistent as the system does not breakeven and has to be partially funded by the government. The main benefit to the user will be the improved health from using the sort of transportation as well as the convenience when using this system for short rides (15 - 30 minutes). The benefits to the city will also be significant as the increased bike use will decrease cars use along with other transport options which will lower both the congestion as well as the pollution levels in the city (increase in air quality). Lastly the modular design of the system costs significantly less than most other public transport infrastructure and the design also allow for quick implementation times.

Above (in table 5) is costs of the system relative to other forms of public transport (i.e. Buses, Trams, Cars, Personal bikes)

For the operator the main cost of this system relative to other public transport is its low ridership numbers making it difficult to create profit. The largest cost of the system for the user is when they are using the system for long trips as this can be both tiring as well as costly given the pricing structure. They are also confided to the system boundaries because unlike a personal bike the share bike needs to be returned to a station. Finally there are two cost to the city the first being the cost of subsidising the system as that comes from tax payers and the second is the safety of non-users especially in the case where novice cyclists use the system.

11. Conclusion

BBSs can bring large benefits when added into city centres however the current MBS is and has been underperforming, mainly in terms of revenue and ridership numbers. After analysing the MBS several recommendations have been formed around decreasing the effect of the barriers to use so to combat this underperformance. The key techniques used in this analysis were a human comfort analysis, queue theory and feedback structures. The recommendations gained from these improved several areas of the system such as ease of use, balancing the bike distribution and lowering prices.

12. Appendix

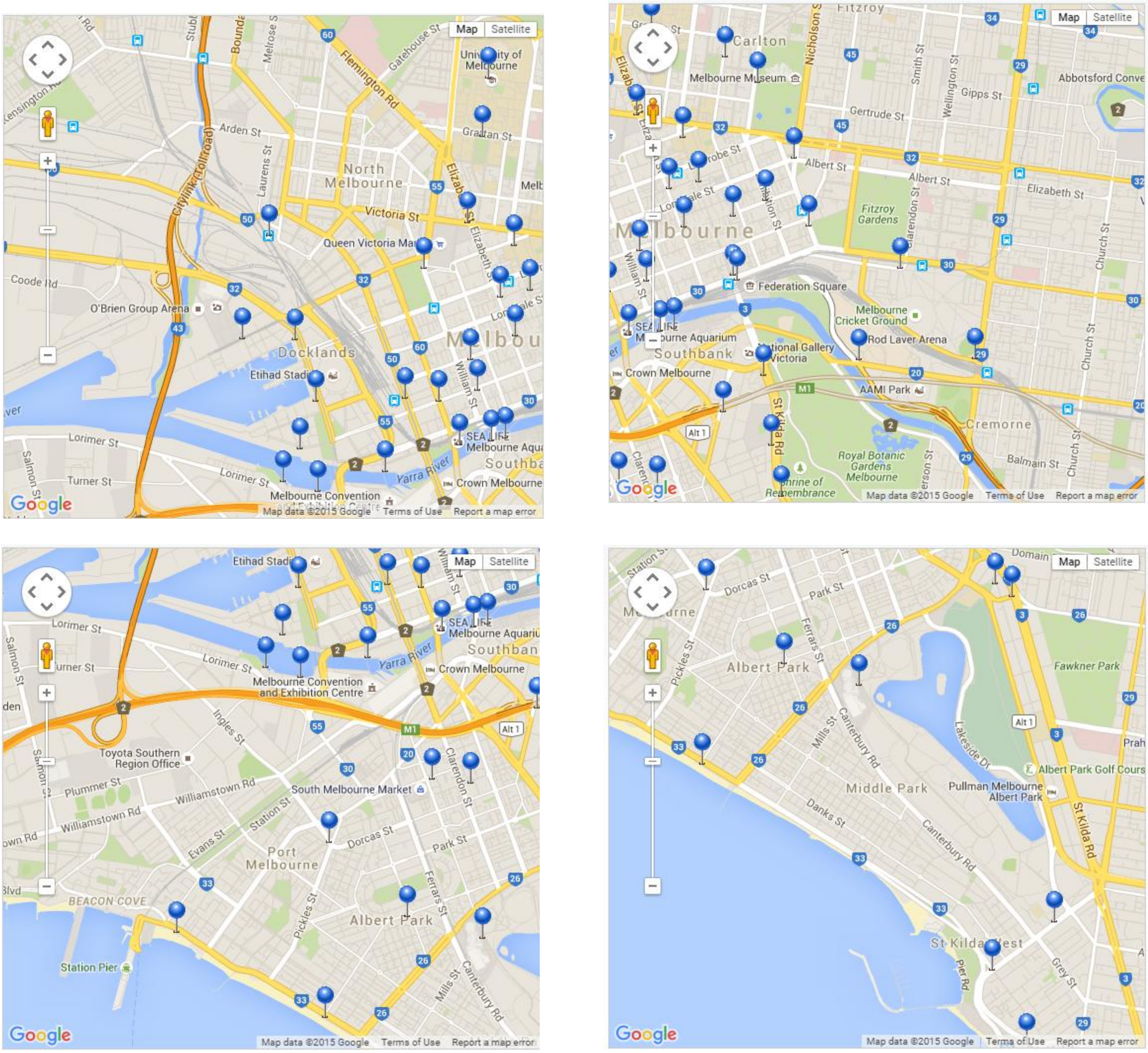

Figure 11 Map of MBS stations (Google Maps, 2015)

```
M =
csvread('latlng_MBS.csv');% Coordinates of stations (Formatted: column 1
Latitude, column 2 Longitude)
K = fopen('MBS_names.txt');% Names of Stations (Formatted column 1 names of
stations)
O = textscan(K,'%s','Delimiter','\n');
fclose(K);
Q = O{1}
R = 6371000; % metres
shortdist = ones(length(M),1)*2000;

for x = 1:length(M)
    Latit1 = M(x,1)*pi/180;
```

```
    for y =1:length(M)
        Latit2 = M(y,1)*pi/180;
        latdiff = (M(y,1)-M(x,1))*pi/180;
        lngdiff = (M(y,2)-M(x,2))*pi/180;

        a = sin(latdiff/2) * sin(latdiff/2)...
            + cos(Latit1) * cos(Latit2)...
            * sin(lngdiff/2) * sin(lngdiff/2);% formula to calculate distance
        c = 2 * atan2(sqrt(a), sqrt(1-a));
        d = R * c;
        if d < shortdist(x,1) && x~=y % check to see if calculated
            shortdist(x,1) = d;       %distance is shorter than current min
            shortdist(x,2) = y;
        end
    end
end
disp(M)
```

Figure 12 Code to calculate distance between stations (MATLAB 2014b)

Station	Min. distance to nearest station (>305 orange, >430 red)	Nearest Station
'Docklands Drive - Docklands'	400.71	'Docklands - New Quay / Harbour Esplanade'
'Federation Square'	51.43	'Swanston St (East) / Flinders St (St Pauls)'
'Plum Garland'	992.02	'Bridport st/Montague st Albert Park'
'Swanston St / Little Lonsdale St'	231.18	'Elizabeth St / Little Lonsdale St (360 Elizabeth)'
'205 Bourke St near Russell St'	274.4	'Bourke Street / Exhibition St (opp. Department of Transport)'
'Melbourne Uni - Tin Alley'	443.37	'University Square - Grattan St'
'RMIT - Swanston St / Franklin St'	353.54	'Swanston St / Little Lonsdale St'
'Swanston St (East) / Flinders St (St Pauls)'	51.43	'Federation Square'
'MSAC (Melbourne Sports & Aquatic Centre)'	600.44	'Bridport st/Montague st Albert Park'
'Elizabeth St / Bourke St (GPO)'	315.55	'Elizabeth St / Little Lonsdale St (360 Elizabeth)'
'Coventry Street / St Kilda Rd'	397.36	'Park St / St Kilda Rd'
'Docklands @ NAB - Harbour Esplanade / Bourke St'	383.99	'Docklands - Collins St (ANZ)'
'Yarra''s Point'	272.09	'Docklands - Yarra''s Edge (near Lorimer St)'
'Lygon St / Argyle Square'	315.6	'Museum - Rathdowne St'
'Parliament Station - Nicholson St / Albert St'	397.05	'Bourke Street / Exhibition St (opp. Department of Transport)'
'Bridport st/Montague st Albert Park'	600.44	'MSAC (Melbourne Sports & Aquatic Centre)'
'Pickles st / Ingles st'	821.06	'Bridport st/Montague st Albert Park'
'Docklands - Yarra''s Edge (near Lorimer St)'	272.09	'Yarra''s Point'
'North Melbourne Station - North	805	'Docklands Drive - Docklands'

Melbourne'		
'Sandridge Bridge Southbank'	104.59	'Queensbridge Southbank'
'Beach St Port Melbourne'	1307.1	'Plum Garland'
'Docklands - New Quay / Harbour Esplanade'	400.71	'Docklands Drive - Docklands'
'Queensbridge Southbank'	104.59	'Sandridge Bridge Southbank'
'Southern Cross Station'	261.74	'Collins St / King St'
'Collins St / Market St (Suncorp Forecourt)'	233.7	'Bourke Street / New Chancery Ln (RACV)'
'St Kilda - Cleve Gardens'	602.02	'St Kilda - Fitzroy Street'
'Bourke Street / Exhibition St (opp. Department of Transport)'	274.4	'205 Bourke St near Russell St'
'Docklands - Siddeley St / Seafarers Bridge'	538.07	'Docklands - Yarra''s Edge (near Lorimer St)'
'Bourke Street / New Chancery Ln (RACV)'	233.7	'Collins St / Market St (Suncorp Forecourt)'
'Elizabeth St / Little Lonsdale St (360 Elizabeth)'	231.18	'Swanston St / Little Lonsdale St'
'Collins St / King St'	261.74	'Southern Cross Station'
'University Square - Grattan St'	443.37	'Melbourne Uni - Tin Alley'
'Aquarium - Kings Way / Yarra River'	247.11	'Queensbridge Southbank'
'Richmond Station - Brunton Avenue'	882.56	'Rod Laver Arena - Batman Ave / Swan St'
'Rod Laver Arena - Batman Ave / Swan St'	745.63	'VCAM - St Kilda Rd / Southbank Blvd'
'Park St / St Kilda Rd'	376.59	'Queens Rd / Bowen Cres'
'Kingsway / St Kilda Rd'	165.63	'Queens Rd / Bowen Cres'
'Spring St / Collins St'	383.46	'Bourke Street / Exhibition St (opp. Department of Transport)'
'Queens Rd / Bowen Cres'	165.63	'Kingsway / St Kilda Rd'
'St Kilda - Luna Park'	624.32	'St Kilda - Cleve Gardens'
'York St / Cecil St'	292.35	'Coventry St / Clarendon St'
'VCAM - St Kilda Rd / Southbank Blvd'	416.53	'ACCA (Australian Centre of Contemporary Art)'
'Museum - Rathdowne St'	315.6	'Lygon St / Argyle Square'
'Jolimont Station - Wellington Parade South'	762.22	'Rod Laver Arena - Batman Ave / Swan St'
'ACCA (Australian Centre of Contemporary Art)'	416.53	'VCAM - St Kilda Rd / Southbank Blvd'
'Docklands - Collins St (ANZ)'	278.93	'Yarra''s Point'
'William St / Peel St (Flagstaff Gardens)'	481.5	'Victoria Market - Elizabeth St / Victoria St (NW)'
'Victoria Market - Elizabeth St / Victoria St (NW)'	400.4	'RMIT - Swanston St / Franklin St'
'Coventry St / Clarendon St'	292.35	'York St / Cecil St'
'St Kilda - Fitzroy Street'	602.02	'St Kilda - Cleve Gardens'

Table 6 Table of shortest distances between stations

In the pattern the furthest distance from a stations will be halfway between to diagonally adjacent stations.

$$\frac{1}{2} * distance\ between\ diagonal\ station \leq 305$$

$$dds = \sqrt{2 * distance\ between\ neighbour\ stations^2} = dns * \sqrt{2}$$

$$dns \leq 2 * \frac{305}{\sqrt{2}}$$

$$dns \leq 431.3$$

Equation 1 Calculation of station pattern spread

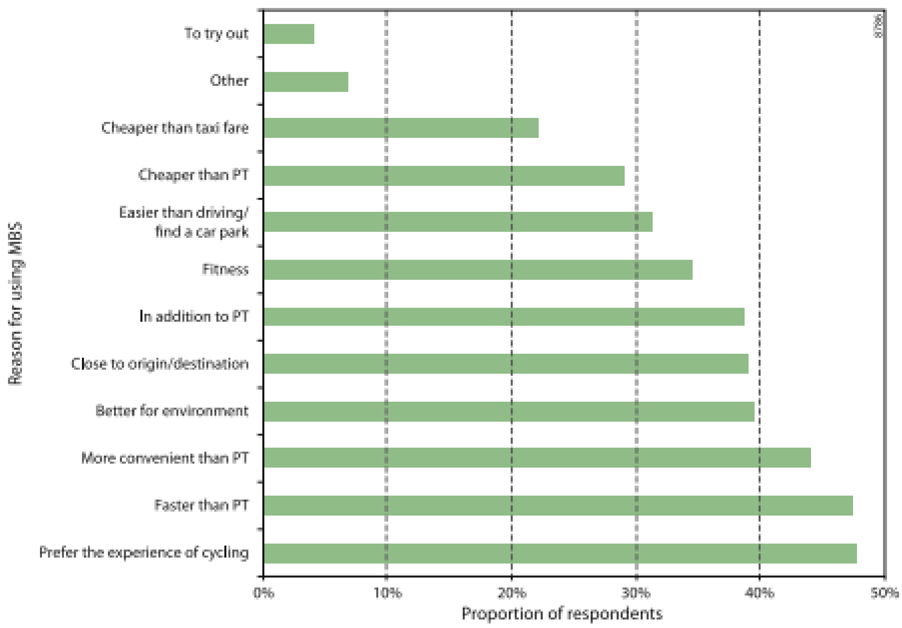

Figure 13 Graph of Reasons for using the MBS (Traffix, 2012)

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