Promoting Sustainable Transportation Through The Integration Of Cycling With Public Transit – Lessons From Copenhagen And Munich For Singapore

By

Lee Siong Aun, Eugene

B.Soc.Sci. (Hons) in Geography
National University of Singapore
Singapore (2004)

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Author

Certified by ________________________________

Ford Career Development Assistant Professor of Transportation and Urban Planning
Department of Urban Studies and Planning
Thesis Supervisor

Accepted by ________________________________

Professor Joseph Ferreira
Committee Chair
Department of Urban Studies and Planning
Promoting Sustainable Transportation Through The Integration Of Cycling With Public Transit – Lessons From Copenhagen And Munich For Singapore

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ABSTRACT

Sustainable modes of transportation like cycling and public transit are always desired, but trying to achieve a mode shift from the automobile to cycling and public transit can be quite a challenge because cycling and public transit on their own cannot easily replace the convenience and comfort that automobile mobility affords for many trips. By marrying the merits of cycling and public transit together (bike + ride), we may increase the attractiveness of both and thereby offer a good alternative mode of transport to the automobile. This thesis begins by looking at travel behavioural theories to provide a better understanding of people’s travel preferences and this knowledge helps with the search for appropriate sustainable transport solutions capable of influencing travel preference away from the automobile and towards cycling and public transit. The thesis moves on to use the theories established as a framework to examine how Copenhagen and Munich have encouraged bike + ride. Some of the lessons learnt from the two cities are applied to Singapore.

Thesis Supervisor: P. Christopher Zegras
Title: Ford Career Development Assistant Professor of Transportation and Urban Planning
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CHAPTER 1 – INTRODUCTION

1.1 Aims and objectives of thesis

The need for a mode shift towards sustainable transportation is high on the agenda of every city and transport planner, but many cities today still struggle to try to make this a reality because it requires an integrated planning process taking into account many factors revolving around urban development and transport planning.

One of the major struggles is the attempt to get people to switch from the automobile to sustainable modes of transportation such as cycling and public transit. On their own, cycling and public transit do not present themselves as strong alternatives to automobile use. I argue that only by bringing cycling and public transit together (bike + ride or B+R) can they become a potential alternative to the automobile.

This thesis aims to look at how the integration of cycling and public transit in Singapore can be an effective and sustainable mode of transportation by learning from the bike and ride (B+R) experiences of Copenhagen and Munich.

1.2 Thesis overview

After establishing the potential role that B+R can play as an alternative mode of transport to the automobile, Chapter 2 begins by exploring some basic terms such as sustainability and sustainable transportation to get a better understanding of how B+R can potentially
contribute as a sustainable way of moving people. Some travel behavioural theories are also explored to understand the basic factors influencing people’s travel patterns. This knowledge will be useful in formulating appropriate strategies aimed at influencing people’s travel patterns to shift towards sustainable modes of transport.

Chapter 3 makes use of the theories established in Chapter 2 to understand the challenges behind developing B+R into a popular alternative mode of transport. The factors behind the success and shortcomings of the automobile and B+R are examined and summarized into a table to further analyze the areas where B+R has the potential to develop as a good alternative to the automobile.

Having established some basic ideas about how B+R can work, Chapter 4 looks at the existing literature on B+R. Since B+R involves two separate components brought together, the literature review also covers some of the research done individually in both the areas of bike (B) and public transit (R). This chapter concludes that existing research has established important trends about B+R, but do not go into in-depth discussions about how B+R can be implemented in a specific city.

Chapter 5 addresses the need to do an in-depth analysis about how cities attempt to make B+R a reality. Hence, a case study approach exploring what existing cities are doing for B+R is appropriate to provide the details about how Singapore can learn from it. It is a big challenge to find another city similar to Singapore for comparison. Hence, this chapter makes a case for Copenhagen and Munich as case study cities by pointing out
that despite relatively high automobile ownership and existence of extensive automobile infrastructure, these two cities are still able to get people to use B+R as an alternative means of transportation. The lessons obtained from these two cities offer some insights for Singapore on how to encourage higher levels of bicycle and public transit use amidst rising affluence which allows people to own automobiles.

Chapters 6 and 7 provide an in-depth examination of the policies and infrastructure that Copenhagen and Munich have put in place to facilitate B+R. Throughout the discussion, the transport development and travel behavioural theories discussed in Chapter 3 are used to explain how the measures taken by Copenhagen and Munich are encouraging people to adopt sustainable modes of transport. Chapter 8 takes the lessons learnt from Copenhagen and Munich and attempts to apply them to Singapore. The theories are once more used to help justify why applying some of the Copenhagen and Munich strategies will work for Singapore.

Chapter 9 concludes with a recap of how the theories and case studies established in the earlier chapters have helped to distill some important lessons from Copenhagen and Munich which Singapore can learn from. The chapter concludes with the shortcomings of the current research topic in the Singapore context and proposes some possible future area of research.
CHAPTER 2 – UNDERSTANDING SUSTAINABILITY AND TRAVEL BEHAVIOURAL THEORIES

2.1 Overview

There are many definitions of what sustainability is and in this first section, the discussion will begin with a broad definitions of sustainability and subsequently narrow down to sustainable transportation and finally focus on the role of cycling as a sustainable mode of transportation. Since one of the main foci of this thesis is the role of cycling as a mode of sustainable transportation, transport behavioural theories will be brought in to understand people’s transport behavioural patterns so as to figure out the appropriate policies and infrastructure to introduce to change people’s travel behavioural patterns towards more sustainable modes.

2.2 Sustainable transport development

A very basic way of looking at sustainable development is to see it as a form of development that aims to ‘meet the needs of the present without compromising the ability of future generations to meet their own needs’ (Levy, 2011: 293). Extending this concept to the field of transport will imply that transportation systems should be developed in a responsible manner that continues to provide mobility to people without compromising the needs of the future generation in any way. One of the ways to see this is reflected by Black’s (2010: 10) attempt to define a sustainable transport system as one that ‘provides transport and mobility with renewable fuels while minimizing emissions detrimental to the local and global environment, and preventing needless fatalities, injuries, and
congestion’. This definition is very relevant to current debates on how the automobile is not a sustainable mode of transport because it mostly runs on petroleum whose reserves are finite, it pollutes the environment, it results in high fatalities and congestion. In view of this situation, there has been a global search for modes of transportation that can provide mobility without the negative impacts.

Over the years, an area receiving a lot of attention is the automobile’s contribution to higher carbon dioxide (CO₂) emission levels. Many countries have responded with measures and policies aiming at reducing CO₂ emission levels by turning to more sustainable and non-motorized modes of transportation such as walking and cycling. Although the bicycle does not produce any greenhouse gas emission, it does not bring people very far. The earlier definition on sustainable transportation highlights that sustainability is not just about being environmentally responsible, but transport still needs to achieve its basic role of providing mobility. Hence, this thesis will look at how the bike, despite its low capacity to cover distance, can still contribute to transport sustainability through means like combined usage with other sustainable modes of transportation. Before going straight into that discussion, it will be useful to establish some transport related theories to provide a theoretical background to appreciate the role cycling can play as a sustainable mode of transportation.

2.3 Components of mobility and access management

Three of the most important components of any transportation program aimed at improving the mobility and access conditions include supply management, demand
management and land use management. Meyer (1998) has nicely summarized these components in Figure 1 below including some examples for each of the components. Transport planning for large metropolitan areas can be challenging because no one solution can fully address the transport needs of an area, but a coordinated program including a combination of the three components is needed instead (Meyer & Miller, 2001).

Supply management

Of the three components, supply management is the most common approach cities have taken in response to a deteriorating traffic condition. Strategies such as widening of highways and building more transit facilities aim to increase the capacity of transport facilities to accommodate the growth of traffic. Such a management strategy is beneficial since it reduces problems such as traffic congestion. However, the added road capacity makes driving more attractive and hence attracts more traffic to use the roads leading to further congestion problems again. So the increase in road capacity is merely a temporary solution because once the capacity is reached, the road will have to be further widened and this is not sustainable in a long run because not only is the traffic congestion problem not resolved, the CO₂ emission levels continue to rise.

Demand management

Some cities have invested heavily in transit facilities but still fail to see any substantial drop in automobile usage because driving the automobile is still relatively attractive. For instance, some cities place their transport infrastructure investments on both building
more transit facilities and highway widening at the same time. To attract people to switch over to transit, one of the means is to manage the transport demand by carrying out a set of actions resulting in the reduction in traffic demand. One way of doing this is to make driving unattractive by introducing disincentive programs such as road pricing where automobile users bear the cost of the externalities they impose from automobile usage by paying to use the automobile.

Land use management
On the other hand, some cities may have the best policies to deal with transport supply and demand management, but the policies are not effective because they are not coordinated with the existing and planned land use policies. A metropolitan area characterized by urban sprawl may not be able to maintain an extensive public transit network serving low-density areas with low ridership levels. For effective traffic management purposes, land use planning has to guide the spatial distribution of cities so that the population base is clustered around transit lines to provide sufficient ridership. However, the results of land use management strategies are not immediate and may only become apparent in the long term because existing built up areas cannot just be leveled overnight to change their spatial layout to be transit oriented. In such situations, bicycles can be introduced to feed people from the low-density developments into the transit line. In this way, there is no need to bring the transit line to every single household and run a financially unsustainable transit service.
This is clearly an example of how an integrated program involving the management of transport supply, transport demand and land use management is crucial to ensure effective mobility and access. The combination of the bicycle with public transit forms the central topic of discussion for this thesis, but not before looking at some travel behavioural theories to provide a theoretical background to understand how combining the bicycle and public transit works.

![Diagram of Mobility and Access Management](image)

*Figure 1 - Components of mobility and access management*  
(Source: Meyer, 1998)
2.4 Transport behaviour - utility theory, activity based approach and multi-modal transportation planning concept

The earlier discussion clearly shows that no one solution can solve mobility and access problems associated with transportation planning. Instead, multi-dimensioned approaches need to be identified and altered to meet the needs of the local environment. Before coming up with such integrated programs, one needs to first understand why and how people travel. For instance, assuming that the introduction of transit facilities leads to higher transit usage and lower automobile usage is being too simplistic because people consider a list of other factors such as time, cost and convenience in their decision making process. Hence, this section introduces the utility theory, activity based approach and multi-modal transportation planning concept to provide a more in-depth analysis of travel behaviour.

Utility theory

The utility based theory assumes that individuals make choices to travel based on how much net utility they can get out of the journey. Net utility for any journey is calculated based on the trade off between the benefits obtained from carrying out the journey (utility) and the costs (disutility) incurred to bridge the distance between the origin and destination of the journey (Matt et al., 2005). Disutility can be subdivided into three main categories – time, cost and convenience.

Time

Assuming that all trips to accomplish a particular task generate a fixed utility value, any disutility value in the form of time would lower the net utility (overall
utility) of the journey. Matt et al. (2005) highlights that people are more concerned with the amount of time spent bridging the journey than the distance of the journey itself. People want to maximize utility (e.g., accomplish as many tasks as possible) within a given time frame. For instance, people are willing to accept a longer journey distance if other secondary activities (Walle and Steenberghen, 2006), not transport related, can also be accomplished within the journey. In other words, a trip accomplishing more than one task generates more net utility than one accomplishing only one task in the same amount of time.

Cost
The impact of cost on net utility of a journey is most clearly illustrated by how automobile congestion pricing makes driving an automobile less attractive by increasing disutility. The introduction of congestion pricing in London led to an increase in cycling mode share (Pucher et al., 2010) possibly because the net utility of cycling becomes higher than driving once congestion pricing poses a disutility to drivers.

Convenience
Disutility can also exist in the form of inconvenience and discomfort. Krygsman et al., (2004) point out that among other factors, falling public transit usage can be attributed to disutility associated with the absence of seamless connections. Walle and Steenberghen (2006) show that waiting time and transfer time are both
negatively perceived and are assigned penalty values. These will bring down the net utility of journeys involving waiting and transfers.

The discussion above illustrates how the utility theory explains that people wish to maximize net utility by accomplishing as many tasks within the shortest possible time and reducing any form of disutility in the form of high costs and great inconvenience. The discussion will now turn to the activity based approach to understand how transport planning can help people to achieve maximum net travel utility.

**Activity based approach**

People make many journeys a day to accomplish different activities. Matt et al. (2005) explain that the activity based travel behavioural theory assumes that people do not make decisions on their journey based on one segment of a trip, but look at the whole trip (comprising various segments) as a whole. In other words, people do not just assess how much net utility they obtain from one segment of a journey, but look at the net utility gained for the journey from the start of the day to the end of the day. Walle and Steenberghen (2006) highlight that travel consists of various segments that affect mode choice – a) preparation time; b) walking time; c) waiting time; d) transfer time; e) in-vehicle time. Since the activity based approach views a journey in its entirety, it implies that sustainable transport policies should aim to provide users with a good experience for the entire journey including the transition from one segment of a journey to another.
Multi-modal transportation planning concept

Sometimes, one mode of transportation alone is not able to provide users with a good experience for the entire journey. Instead, different modes of transport need to be combined into a multi-modal journey that allows people to get the best out of each mode of transport. Multi-modal transportation planning is the process through which different modes of transport (e.g. cycling, public transit) are considered and how these modes can be connected so that ‘each can fill its optimal role in the overall transport system’ (Litman, 2009: 1). The next chapter will illustrate how B+R can be planned as a form of multi-modal transportation combining the merits of the bike and public transit.
CHAPTER 3 – BIKE AND RIDE (B+R) AS A CONCEPT

3.1 Mode shift

Many people are aware of the benefits of a mode shift from the automobile to the bicycle, but this mode shift cannot take place overnight especially in societies where people’s lives are already very well established around the automobile and its extensive infrastructure. So this chapter aims to use the travel behavioural theories established in the earlier chapter to look at what makes automobile use so attractive and look at how the same set of theories can be used to derive strategies to make the combined mode of the bike and public transit (B+R) an effective and attractive alternative to the automobile.

3.2 The success of the automobile

The automobile owes its success to its ability to provide door-to-door accessibility with no waiting and transfers required during the journey (Webber, 1994; Cervero, 1998). Based on the utility travel behavioural theory, automobile users obtain utility out of using the automobile because the automobile, to a large extent, causes a lower level of disutility than other modes like public transit and cycling. For instance, the disutility of time and inconvenience for the automobile is minimized by its ability to provide door-to-door accessibility without the need for transfers or waiting time. The concept of applying penalty values to waiting and transfer times highlighted by Walle and Steenberghen (2006) will definitely give automobile journeys a higher net utility value when compared to other modes such as public transit and cycling.
Based on the utility theory, the only area in which public transit or cycling can give the automobile a good run for its money is the automobile’s potential disutility in the form of high costs. In addition to this, policies should also aim to decrease the disutility of time and inconvenience arising from the use of public transit or cycling if the intention is to bring about mode shift to more sustainable modes of transportation like public transit and cycling. Figure 2 provides a summary of the contribution each mode of transport makes towards net transport utility.

<table>
<thead>
<tr>
<th></th>
<th>Automobile</th>
<th>Bicycle</th>
<th>Public Transit</th>
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<tbody>
<tr>
<td><strong>Time</strong></td>
<td>Reduces need for waiting and transfer</td>
<td>Time consuming because it is human powered</td>
<td>In-vehicle segment of journey can be relatively fast especially for rail public transit</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>Expensive to own and maintain. Parking costs involved</td>
<td>Cheap – only need to pay for fare and minimal maintenance cost and parking cost</td>
<td>Cheap – only need to pay for fare and no maintenance cost and no parking cost involved</td>
</tr>
<tr>
<td><strong>Convenience</strong></td>
<td>Capable of providing door-to-door accessibility</td>
<td>Capable of accessing right to door step</td>
<td>Not financially viable to build stops at every house</td>
</tr>
</tbody>
</table>

✓ contributes to net travel utility with minimal disutility
❌ reduces net travel utility and contributes to disutility

Figure 2 - Advantages and disadvantages of various modes from utility theory perspective
3.3 Cycling as competitor to automobile

The flexibility of the bicycle allows it to reach right to the doorstep of both origin and destination. However, its popularity as a mode of transportation declines with greater distance between origin and destination. For cycling and other modes of human powered transport modes, ‘resistance to travel increases disproportionately with distance’ because of the physical effort involved (van Wee et al., 2006; Heinen et al., 2010: 61).

3.4 Public transit as competitor to automobile

Public transit, especially rail systems, is capable of covering greater distances, but not flexible enough to reach every single household. This is especially so in the case of attempting to introduce public transit in areas of dispersed suburban development because it is not financially sensible since these areas do not generate enough ridership. Public transit is also less attractive than the automobile because it does not offer the flexibility of on-demand availability.

3.5 Combining cycling and public transit to compete with automobile

The discussion above shows that both contain some traits of sustainable mobility. However, both modes of transportation, on their own, impose disutilities like long travel times and inconvenience on users. Hence, the automobile still remains more attractive in comparison as shown in Figure 2 providing a summary of the relative advantages and disadvantages of the three modes of transport analyzed from a utility theory perspective. This table provides a closer look at areas of improvement for the bicycle and public transit to encourage higher usage. The table shows the potential for the bicycle and public
transit to be combined since there is scope for both to complement each other. They are both lower in cost when compared to the automobile and strategies can be designed to take advantage of the speed of public transit and convenience of the bicycle. Combining the bike and public transit through multi-modal transportation planning would be a good example of how the merits of the bike and public transit are optimized to provide an alternative to automobile use.

3.6 B+R as a form of multi-modal transportation

A multi-modal journey is typically made up of a series of trip segments carried out on different transport modes. Multi-modal transportation planning aims to combine these trip segments so that people can maximize travel utility from one multi-modal journey.

One of the reasons why B+R can help maximize travel utility is because it holds the potential to allow people to accomplish more than one activity within one journey. For instance, someone who wants to do grocery shopping after work at a particular grocery store located between office and home is not able to do it by public transit because there are no public transit stops near this grocery store. With the introduction of B+R, people are offered the flexibility to use public transit and transfer to the bike to get to the grocery store. So here, a multi-modal B+R transport system allows people to trip chain and achieve more than one activity in a journey and hence maximize travel utility. From the activity based approach which views a journey in the entirety of all its segments, such a B+R journey can be viewed as an alternative to the use of the automobile since B+R is able to cover different activities within one journey.
Trip chaining is an increasingly popular phenomenon because increasingly, people wish to maximize travel utility from one journey. Levinson and Kumar (1995) did a study on trip chaining patterns between 1968 and 1988, and found trends indicating an increasing combination of work and non-work trips. One of the reasons for this trend was the increasing number of women going out to work, resulting in families where both parents work during the day. Hence, any travel needed to accomplish household related activities need to be carried out in between office hours.

3.7 Components of B+R in a multi-modal trip

Just as Walle and Steenberghen (2006) have pointed out that there are various components of a journey (eg. waiting time, transfer time, etc) affecting mode choice, B+R also has its various components as shown in Figure 3. Laying in out in this fashion helps to break down B+R into its various components to understand the infrastructure required for the whole system to work. Figure 3 illustrates the flow of a typical B+R commute from home to destination. The red arrows refer to areas where appropriate infrastructure has to be introduced to ensure seamless transition from one location to another.
Some of the earlier discussions have alluded to the fact that the individual components of a multi-modal trip must be well connected together for the whole system to work. This section will look at some related research to illustrate the importance of proper connections between the different components of a multi-modal journey.

In a related study on trip chains, Walle and Steenberghen (2006) used the data obtained from a travel survey to understand the determinants of public transit use in trip chains. One of the determinants studied was the role of missing links in trip chains and its effects on the use of public transit. The study concluded that even one missing link in a trip chain can prevent the whole trip from being carried out by public transit. Car dependency is higher in trip chains with missing links. Their analysis also showed that many of these missing links are at the end of the trip chain. One of the potential solutions they proposed is to get public transit operators to promote the use of bikes to cover the missing link at the end of the trip chain. Likewise for the B+R multi-modal system, any missing links in the system will break the continuity of the system and pose disutilities on users.
Krygsman et al. (2004) made use of travel diaries to analyze the role of access and egress time on multi-modal public transit systems. In their study, they establish that the access and egress stages (together with waiting and transfer) form the weakest links in multi-modal systems. The analysis also shows that the longer the overall total journey time (line haul time), the longer people are willing to spend on access and egress trips. To illustrate that transfers play an important role in trip chains, they have highlighted that people are willing to accept longer access trips if they can get a more direct connection requiring fewer transfers during the whole journey.

3.8 Implications of research for B+R

The studies above point out the importance of providing appropriate infrastructure to ensure the smooth flow of people throughout a multi-modal transportation system. When it comes to the promotion of cycling and public transit, many cities may have planned infrastructure to facilitate cycling or public transit on their own and overlooked the need to provide infrastructure facilitating the combination of both modes, resulting in missing links that discourage people from choosing B+R. Any missing links in this network would result in friction of travel, thus making this mode of transportation unattractive. Just as a car requires a complete network of roads and facilities such as parking lots and gas stations to operate, so too does a bike require a complete network including parking facilities and bike paths to be effective.
The concept of B+R providing door-to-door mobility should be understood in terms of systems rather than individual discrete objects (Cox, 2008). Pucher et al. (2010) recognizes that the sum of the individual initiatives put together is more effective than any individual initiative on its own. Studies have also shown that if the ‘continuity of bicycle infrastructure’ (Heinen et al., 2010) is not present, it will deter people from cycling. This is applicable to B+R since the continuity of bike infrastructure linking people to transit stops is essential to make cycling as a feeder mode of transport to public transit attractive.
CHAPTER 4 – EXISTING RESEARCH ON B+R AND ISSUES RELATED TO B+R

4.1 Overview

In the earlier chapters, the discussion mainly focuses on general transport theories and the need to plan for multi-modal transportation systems to better meet the transport needs of a dynamic society. The previous section ended off recognizing B+R as a multi-modal transportation system and this section will look into the research materials compiled on B+R. Since B+R is actually a combination of more than one mode of transport, this section will include materials pertaining to B+R as a concept and the various components of B+R such as bike sharing and different modes of transit.

4.2 Types of B+R

The ‘B’ component of B+R can exist under two ownership categories – individually owned bikes and shared bikes. Both forms of the ownership will be discussed in this thesis. The ‘R’ refers to public transit and generally covers two broad types – rail and bus. Figure 4 summarizes the different forms of B+R, but the focus of this thesis will be on rail transit.

\[
\text{Bike (B)} \quad + \quad \text{Ride (R)}
\]

- Personal bikes
- Shared bikes
- Bus
- Rail

Figure 4- Different forms of B+R
4.3 Existing research

Behavioural patterns of different modes of transport

An analysis done on Denmark’s National Travel Survey results between 1998 and 2003 revealed that walking is a popular mode of transport for distances under 500m. Beyond that, the popularity of walking reduces and cycling as a mode of transport becomes increasingly popular between 500m and 3km. Distances more than 3km are less popular with bicycles and public transit starts to become more popular as a mode of transport. On the other hand, the automobile just gets increasingly popular over distance as a mode of transport (refer to Figure 5). Based on this analysis, neither walking, cycling or public transit on their own can replace the automobile for the whole duration of a long journey. For instance, the bike is only a choice mode at around 3km while public transit is popular after 3km. Under such circumstances, only a combination of the bike and public transit can rival the automobile.
Some conference proceedings have also provided relatively valuable insights into some existing studies on B+R. For instance, Böhmer and Pitrone (2008) examined the mode share of various modes of transport in relation to trip lengths to determine whether cycling and public transit might compete with one another or whether there exist synergies between the two. This study used data for 15 cities from the German mobility survey and represented a weighted average of the mode share in Figure 6 below. Figure 6 reveals that 43% of all journeys are under 3km. While a large amount of such journeys are covered on foot (60%), the next two most popular modes are the car (18%) and the
bike (16%). The relatively close mode shares of the car and the bike show that these two modes are potential competitors for trip distances less than 3km. Public transit has a low mode share of 6% for short trips and only becomes more popular for trips beyond 3km. This finding has a similar implication as the earlier Denmark study revealing that bikes and public transit could potentially complement each other through a combination involving bikes used for short trips where public transit is less popular and involving public transit for longer trips where bikes are less popular.

Figure 6 - Mode share in relation to trip length
(Source: Böhmer and Pitrone, 2008)

The discussion in this section shows that many medium- to long-distance trips are covered by the automobile and could be potentially covered by public transit as long as appropriate policies are put in place for the use of the bike on the access and egress trips.
Asymmetrical nature of bike availability

Rietveld (2000) looked at the access and egress modes of transport at Dutch railway stations and found that the further people lived from the train station, the less likely they are inclined to ride to the station. The statistics showed that the use of bikes to get to train stations remains relatively high for distances of up to about 3.5km, beyond which they start to fall. These numbers are quite similar to the threshold distance for cycling to a train station in both Denmark and Germany as discussed earlier. The statistics show that about 37% of homes at the origin train stations are within 0.5km to 2.5km, and such a distance is manageable on the bike. The statistics also show that 40% of trip destinations are within about 0km to 1.5km, with the majority of it being less than 1km, and such distances are easily covered on foot. This probably explains the asymmetrical nature of bike use at the train station where mode choice for the access trip to train station is 35% while mode choice for the egress trip from train station is 10%. Although shorter egress trip distances is one of the reasons accounting for lower levels of bike use, Rietveld also points out that the lack of availability of bikes for the egress trip is a major reason for the lower levels of cycling use and highlights that cities should attempt to make bikes available at destination train stations in the form of bike rentals, bike parking and allowing commuters to bring bikes on board trains from their homes.

Martens (2004) highlights that the use of bikes in access trips is about four to nine times more than in egress trips. In Copenhagen, access trips on bikes are about six to eight times higher than that of egress trips (Wood, 1993). This is probably because bikes are usually more readily available in people’s homes, making the first mile’s ride (access
trip) a much more convenient one. However, many commuters are not permitted to bring their bikes on board transit. As a result, commuters would either have to place a second bike at the destination station to complete the egress trip, or they would have to depend on other modes of transportation such as the automobile. These studies point to a certain trend – bikes are available for access trips; transit usually cannot spare any capacity for bikes on board; and bikes are needed for the egress trip, but are not available. These trends reflect the need to find solutions that can address the need for parking bikes at the origin station and the need to make bikes available for use at the destination station.

These two articles reveal the asymmetrical nature of the B+R system. Hence, having shared bikes at end stations may also be a good solution to this problem. The next section will provide some background information summarizing some of the important points brought up by academic research on bike sharing, with a focus on the bike’s role to facilitate B+R.

Bike sharing

Public bike sharing systems provide a pool of bikes at the individual’s disposal when needed without the cost and responsibilities of bike ownership. Many cities have made such bikes available in city areas to encourage people to cycle on shorter distances within the city and also to improve the first mile and last mile connection to and from transit stations. DeMaio (2009) and Shaheen et al. (2010) provide comprehensive summaries of the successes and failures of bike sharing systems around the world. Since the focus of
this thesis is B+R, the discussion of bike sharing systems will be framed around how bike sharing contributes to B+R.

Better use of resources and space

Bike sharing systems permit a better utilization of bike resources and space. Most people covering the last mile would typically use their bikes for short periods in the mornings and evenings. The bike spends the rest of the day taking up precious space in a city centre bike parking lot. Bike sharing allows the bike to be used by other groups of people (eg. tourists) outside the rush hour. A UK study observed that the people removing their bikes from the parking lots arrived later than those wanting to park their bikes. Hence, there always seemed to be a shortage of parking lots during the time when the demand for parking lots for these two groups of people overlapped. They did think of providing more parking lots, but there is a chance that new parking space made available would not be taken by people who commute daily, but by people who leave a second bike at a destination station to be used on two out of the seven days of the week (Sherwin, 2009). If that is the case, the bike parking lots will be full again. Hence, they eventually decided to try out a bike sharing system because it not only caters to people who use the bike daily, it also caters to the needs of the occasional cyclist who may decide to go by B+R whenever bikes are available.
Bridging the Last Mile

The earlier discussion has clearly revealed that the use of bikes in egress trips is much lower due to lack of availability of bikes at the destination stations, usually in the city centre. Hence, bike sharing systems make such bikes available for rail customers who wish to complete the last mile on a bike but do not own a bike. For those who do not have a place to park their bikes at their destination, bike sharing would be useful since these systems provide a docking station to park bikes. Martens (2007) looks at how the introduction of public bike sharing systems has helped to increase the levels of cycling for egress trips. The introduction of the OV-fiets system (Dutch public bike sharing system) led to a substantial increase in the use of the bike for egress trips previously completed by other modes of transportation (see Figure 7). So this probably implies that the bike is an effective mode of transportation for access and egress trips.
Figure 7 - Egress mode of OV-fiet users prior to use of OV-fiet

(Source: Martens, 2007)

Future of bike sharing

Shaheen et al. (2010) reviewed existing bike sharing systems around the world and compiled a list of important lessons learnt and shortcomings of existing bike sharing systems. They also attempted to project how the next generation of bike sharing systems should ideally look like by combining the strengths of the existing ones and proposing solutions to overcome the shortcomings of the current bike sharing systems. They predict that the next generation of bike sharing systems would be ‘demand-responsive’ and ‘multi-modal’ (Shaheen, 2010: 15).

The earlier discussion about the asymmetrical availability of bikes clearly shows that the demand for bikes varies at different locations and different times of the
day. Hence, an effective system to distribute the bikes is crucial to ensure bikes are available when needed. This is especially important when bikes are intended as an extension of the public transit system since people want to have the bikes available upon getting off the train, so that they can continue on their journey. For instance, to redistribute the demand for bikes through the city, the Paris bike sharing system, Velib, introduced a 'V+' concept where users are given extra 15 minute credit if they access a bike at an uphill station which requires more physical effort to get to (DeMaio, 2009).

Another way of encouraging the next generation of bikes to be more demand responsive is to either have flexible docking stations used by BIXI system in Montreal, Canada or have no docking stations at all, but depend on mobile phones to deploy bikes, similar to Germany’s Call-a-bike system (Shaheen et al., 2010). One of the principal cost factors of a bike sharing system is the docking stations (NICHEs, 2010) and eliminating this might just help cut the running costs of future bike sharing systems.

Technological advancements can also help bike sharing systems to integrate seamlessly with public transit systems through the use of smart cards allowing people to use the bike together with other modes of transport like the train, bus and shared car. This system sounds great as a concept but will only work out if there is proper coordination between the various agencies operating the different modes of transport (Shaheen et al., 2010).
The human powered bikes are effective in bringing people around in places with shorter journeys and a flat terrain. However, in less hospitable areas with hilly terrain and long distances, an electric bike might reduce the physical requirement needed for the ride and still enable the bike to be used. (DeMaio, 2009).

4.4 Existing extent of work done

From the brief overview of current research, it shows that most of the work compiled is merely a compilation of some B+R observations, but not much in-depth analysis of specific case studies.

For instance, most of the emphasis for Pucher and Buehler is on the infrastructure required for the interface between the bike and public transit. Even though they highlight that one of the main measures to promote bike-transit integration is having bike paths leading to public transit stations, they do not elaborate further about how this is done specifically in any of the case studies in that article.

The recordings (by Christensen and Jensen, Böhmer and Pitrone) of mode share in relation to trip length provides a basic understanding on people’s threshold levels for different modes of transport, but do not go further to use specific cities as examples.

Martens and Rietveld discuss about difference in the level of access and egress cycling trips, but do not use a specific city as an example to try to understand why the differences
exist. The existing literature on bike sharing mostly covers an overview of the evolution of bike sharing rather than its specific contribution to B+R in specific cities.

Hence, this thesis will attempt to take the discussion a step further by looking at how the trends and findings in the existing literature can help to explain how B+R can be a sustainable mode of transport for cities.

Before jumping right into studying these specific cases, it will be useful to first look at the research methodology and the rationale for choosing the case studies.
CHAPTER 5 - METHODOLOGY

5.1 Overview

The preceding chapters have attempted to provide theories to understand how B+R works from a transport perspective. Since B+R comprises more than one transport mode, the literature compiled was intended to provide us with some background on trends observed in the field of B+R and its individual components. This chapter outlines how the thesis will build upon the earlier chapters to analyze how B+R is carried out in two cities and distill some important lessons for Singapore.

5.2 Case study approach

The case study approach has been chosen to study how B+R can be promoted as a sustainable mode of transportation. When using the case study approach to identify best practices, there is often a danger that cities may attempt to replicate successful ideas at one location to another location with little regard of the context. Hence, the two cities were carefully chosen to ensure that they had something in common with Singapore. To illustrate this, some of the earlier theories and concepts discussed will be brought in to explain the choice of cities.

In planning effectively for transport mobility and access, it has been earlier established that a multi-dimensional approach involving transport supply management, transport demand management and land use management is required (refer to Figure 1). Singapore has taken an integrated approach to urban and transport planning and this will be
discussed in a later chapter on Singapore. However, what is interesting to note is that despite taking an integrated approach, Singapore’s mode share of cycling seems to be relatively low in comparison to cities also taking a similar integrated approach to development. So, this thesis attempts to find cities that have taken an integrated approach to planning and have managed to achieve a high cycling mode share. Two such examples include Copenhagen in Denmark and Munich in Germany.

The details of the various transport management strategies will be outlined in later chapters, but a summary of these strategies will be highlighted here to provide some insights into how the cities were chosen as case studies because they have some things in common with Singapore. Both Copenhagen and Munich have integrated land use and transport planning to meet the larger needs of urban development in the region. Both cities have an extensive network of public transit coverage. Both cities employ strategies to reduce demand for automobile use through policies (eg. high automobile related taxes) that make automobile use unattractive.

The statistics compiled in Figure 8 below provides some key indicators on the automobile and public transit in the three subject cities. One trend worth noting is that although Singapore’s automobile ownership is much lower than Munich’s and Copenhagen’s, automobile usage appears higher. Based on the figures below, high automobile ownership does not immediately imply high automobile usage. The figures for Copenhagen and Munich show that having higher car ownership numbers and freeway length per capita does not necessarily mean that people will choose to use the automobile and ignore other
modes of transport such as public transit and the bicycle. The mode share for public transit and bicycle for Copenhagen and Munich in Figure 9 bears testimony to this. One of the possible reasons why the use of public transit and cycling are still quite common in Copenhagen and Munich is the city’s policies which provide infrastructure supporting cycling and public transit use. The relatively high cost of car use as reflected by the private motorized passenger km is also another possible reason.

<table>
<thead>
<tr>
<th>Key Indicator / City</th>
<th>Singapore</th>
<th>Munich</th>
<th>Copenhagen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cars per 1,000 people</td>
<td>116</td>
<td>469</td>
<td>275</td>
</tr>
<tr>
<td>Length of freeway per capita</td>
<td>44</td>
<td>45</td>
<td>119</td>
</tr>
<tr>
<td>Cost of one private motorized passenger km for the traveler (0.01 EUR)</td>
<td>43</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>Total public transit vehicles per million in habitants</td>
<td>1,300</td>
<td>1,280</td>
<td>1,110</td>
</tr>
</tbody>
</table>

*Figure 8 - Key indicators for automobile and public transit in the 3 subject cities (Source: Kenworthy and Laube, 2001)*

<table>
<thead>
<tr>
<th>Mode / City</th>
<th>Singapore</th>
<th>Munich</th>
<th>Copenhagen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automobile</td>
<td>45.5%</td>
<td>42.3%</td>
<td>32%</td>
</tr>
<tr>
<td>Public transit</td>
<td>49.6%</td>
<td>32%</td>
<td>19%</td>
</tr>
<tr>
<td>Cycling</td>
<td>1.1%</td>
<td>8.1%</td>
<td>26%</td>
</tr>
<tr>
<td>Walking</td>
<td>3.8%</td>
<td>17.6%</td>
<td>19%</td>
</tr>
<tr>
<td>Others</td>
<td>-</td>
<td>-</td>
<td>4%</td>
</tr>
</tbody>
</table>

*Figure 9 - Mode share for three subject cities (Sources: MVA, 2005; City of Munich, 2006; City of Copenhagen, 2010)*
The purpose of introducing the statistics is to illustrate how cities like Copenhagen and Munich strike a balance between managing traffic supply (providing freeway capacity and public transit facilities), managing traffic demand (making car ownership expensive) and managing land use through integrated transport and urban development. The figures also show that Singapore attempts to balance supply, demand and land use, but cycling mode shares still remain relatively lower than Copenhagen and Munich. There are many reasons that account for these differences, ranging from the climate differences to the way society views the status of cars, bikes and public transit. One possible reason could also be that transport policies in Copenhagen and Munich support non-motorized traffic and this is something that Singapore possibly lacks. Hence, using Copenhagen and Munich as case studies may help provide some insight into what Singapore can do to encourage more cycling and B+R.

Since the intent of this thesis is to look at how B+R can be implemented for Singapore as a whole including the city centre and its satellite new towns, the larger Copenhagen and Munich areas will also be considered in the discussion so as to draw a parallel of how B+R can work for both the city centres and their suburbs.
CHAPTER 6 - COPENHAGEN AS CASE STUDY

6.1 Chapter overview
In this section, the thesis will look at how people who live in the larger Copenhagen metropolitan area make use of B+R to commute daily between the suburbs (more than 10km away) and the city centre. The case study will show how all developments within Copenhagen suburban new towns were designed within a 2-3km radius from the transit stations. The proximity of these developments to the station together with a well developed network of cycling paths linking homes with the station make B+R possible. To get a better understanding of how this is done, a brief history of the urban and transport development of Copenhagen will be discussed and a suburban new town will be chosen to provide more detailed insights on how B+R is carried out.

6.2 A coordinated approach to mobility and access for Ballerup
The urban development of the Greater Copenhagen area is strongly tied to the Finger Plan of 1947 (refer to Figures 10 and 11). In an attempt to control urban sprawl resulting from a rapidly increasing population around Copenhagen city centre, this plan was designed to concentrate any future urban development in the greater Copenhagen area along the regional train lines (S-train) which run the length of each of the “fingers” between Copenhagen city centre and the five provincial towns at the end of the “fingers”. Figure 12 below illustrates how the S-train network is developed along the “fingers” of suburban Copenhagen. This plan also ensures that urban development is well contained within areas served by transit, so that automobile dependency is reduced. Furthermore,
the areas between the “fingers” are retained as open spaces to meet the recreational needs of the people (Danish Ministry of Environment, 2007).

To supplement the land use management strategies, Copenhagen also incorporates some demand management strategies aiming to make the use of automobiles less convenient. The traffic lights along one stretch of Copenhagen city centre used to be coordinated in favour of cars (based on car traveling speeds), but they have recently been coordinated in favour of cyclist in such a way that cyclists moving at a speed of 20km/h can ride through a wave of green lights without stopping (City of Copenhagen, 2009). The city also reduced speed limits on junctions prone to accidents. Furthermore, some heavy goods vehicles have been forbidden along some roads to avoid collisions between lorries and cyclists (City of Copenhagen, 2010). Automobile ownership is also made more expensive by taxes and fees that are about triple the cost of the automobile purchase price (Cervero, 1998).
Figure 10 - Finger Plan of 1947
(Source: Danish Ministry of Environment, 2007)

Figure 11 - Urban development along fingers
(Source: Danish Ministry of Environment, 2007)
Figure 12 - S-train network in Greater Copenhagen Area following the alignment of the fingers
(Source: Danish State Railways, 2010)
To get a better understanding of how the land use management strategies have facilitated B+R, we turn to Ballerup - a new town located along one of the “fingers” (refer to green circle in Figure 13). Ballerup is located about 12km from Copenhagen city centre and served by four suburban train stations along the S-train line (refer to red dots in Figure 14). Ballerup is mostly a residential town with a population of about 47,000 inhabitants, but it also has a relatively large industrial estate providing jobs for both residents and non-residents. Just like any other new towns developed under the Finger Plan, most developments are located within about 2-3 km from any one of the four train stations in Ballerup.

In Figure 14 below, a distance bubble indicates the distance of the developments from the train stations. Based the average commuter cyclist speed of 20km/h, a 2km bike ride should take approximately 6 minutes. In the earlier theoretical discussions on people’s choice of transport for different distances, distances of 2-3km are well suited for cycling. Hence, cycling is definitely a suitable mode of transport feeding people in Ballerup into the S-train system.

Transport planners have stated that the goal is to make cycling an attractive alternative to the car (Ballerup Municipality, 2010). The approach that Ballerup has taken is in line with the multi-dimension approach mentioned in the earlier chapter where there was mention about how mobility and access management has to take into consideration demand management, supply management and land use management. The land use management aspect is mostly clearly seen from this example because the city makes an
effort to ensure that its development areas are within close proximity to the train stations.

The following discussion will focus on how the town attempts at regulating transport supply and demand management.

Figure 13 - Location of Ballerup

(Source: Danish Ministry of Environment, 2007)
Figure 14 - Circles indicating areas within 2km from train stations in Ballerup
(Source: Ballerup Municipality, 2010)

6.3 Network of bike paths

Everyday, about half of the residents and workers in Ballerup depend on the S-train to get to Copenhagen City Centre. Four out of five walk, ride a bike or take a bus to the train station (Cervero, 2003). The city takes on an interdisciplinary approach to biking where biking is promoted to achieve a range of goals such as having a cleaner environment and a healthier population. In order for them to do this, the city worked towards the goal of having people choose the bike as part of their daily transportation routine to work, school or recreation (Ballerup Cykelby, 2010). This approach won the town the award of ‘Cycling City of Denmark’ in 2009. Hence, Ballerup is a perfect candidate to showcase how a Greater Copenhagen new town has put in place efforts to ensure that there is a comprehensive network of bicycle paths that link the whole town together.
Ballerup believes in reducing the CO₂ levels over the years and there is a strong push for the use of public transport and bicycles as an alternative to the automobile. A 42km network of cycling paths has been set up to make it easy for people to get around by bicycle (Ballerup Municipality, 2010). The pictures below were taken on a site visit organized by one of Ballerup’s urban and transport planners. These pictures were taken along a network of bike paths linking two of the S-train stations (Ballerup in Figure 15 and Malmparken in Figure 16) to various parts of the new town including residential areas (Figure 17), schools and offices (Figure 18), alongside major road ways (Figure 19) and within open spaces and recreational areas (Figure 20).

The provision of the bike network is an example of a transport supply management strategy aiming to provide the necessary infrastructure to support a land use strategy which promotes developments close to train stations that can depend on a combination of the bike and train for mobility and access.

Figure 15 - Cycling path linking directly into underpass leading to train platform at Ballerup Station
Figure 16 - Cycling path directly under Malmparken Station

Figure 17 - Cycling paths beside homes
Figure 18 - Cycling paths near schools and offices

Figure 19 - Cycling path alongside major road in Ballerup
6.4 Cooperation with employers

In addition to the facilities the town makes available for access trips to train stations in Ballerup, the town also puts in efforts to make bikes available for egress trips in Ballerup since people from other parts of Copenhagen come to Ballerup to work in the relatively large industrial estate.

To make it easier for people to get from the train station to their work place, the town is considering a station cycle centre providing rental bikes for people who come from other parts of Copenhagen by train to just pick up a bike and cycle to work. The town intends to cooperate with a city hire company to provide this service. The city will charge each person DKK100 (equivalent to US$18) a month and the city will work with local companies to deduct the amount from the salary of all participating cyclists (Ballerup Municipality, 2010). Providing the cycle station at the train stations will certainly help to ease the transition from train to bike in the morning and vice versa in the evenings.
This is an example of how the town tries to reduce any possible missing link since studies discussed earlier in this thesis have shown that transfers and waiting times are perceived negatively. The town has also made it very convenient for Ballerup office workers to participate in the cycle station program by just deducting the money from their pay. This low cost program for users and ease of participation by cooperation with the employers are examples of demand management techniques used to generate more demand for biking by making it cheap. Working with employers is also an example of an employer support program under transport demand management (see Figure 1). The town’s proposal for a cycle station will definitely help reduce any potential disutility generated from the inconvenience of transferring from train to bike. By keeping the cost low, another potential disutility of cycling is eliminated.

6.5 Bike sharing to support B+R in downtown Copenhagen

Users who take the trip from Ballerup to Copenhagen have the option of either parking their bikes at the train station or bringing them on board the trains headed for the city centre. For those who do not bring their bikes on board the train, the current bike sharing system in downtown Copenhagen makes bikes available for the egress trip. According to Gardner (1998), a Danish newspaper reported that it tracked a shared bike and found that it spent merely 8 minutes waiting at the bike stand for new patrons. This probably indicates that the bike sharing system is very well utilized.
One of the strategies that the city is adopting is to work closely with DSB to offer bike rental services at bigger train stations in Central Copenhagen (DSB, 2010). Copenhagen is also currently trying to revamp its public bicycle sharing system and held a competition less than a year ago. In this competition, one of the objectives is for the bicycles to be integrated with public transit and made available at train stations. According to the jury’s report, the winning entry was chosen because it offered a flexible and innovative bike sharing system available for pick up and drop off at any location in the city including train stations (City of Copenhagen, 2009). Since this system has yet to be implemented, we turn to Munich where a similar flexible public bike sharing system run by the public transport authority has been in operation for almost 10 years.
CHAPTER 7 - MUNICH AS CASE STUDY

7.1 Chapter overview

This chapter will focus more specifically on the efforts that Munich has put in place to get people from the suburban areas into downtown through a combination of bike parking facilities at the suburban station and providing shared bikes at the destination city.

7.2 A coordinated approach to mobility and access for Munich (Land use management)

Munich’s more recent urban development planning has been strongly guided by the motto of ‘compact-urban-green’. In this motto, new housing development areas are established within walking distance to the train stations (City of Munich, 2006). Hence, this makes cycling between the home and transit station very manageable. The ‘compact-urban-green strategy sets a vision for a city which is compact, urban and green. This vision is achieved by minimizing the use of land by concentrating high-density developments around public transit stations, maintaining mixed land use to provide a mix of facilities within close proximity to homes and work places, and lastly incorporate green areas next to the housing areas (Koppen, 2007). In so doing, the city hopes to develop into a ‘city of short journeys’ (Munich City Council, 2010) where people do not need to rely heavily on the automobile to get around, but can instead depend on walking, cycling and public transit to get around.
In addition to the compact urban green strategy, a more specific Transport Development Plan was approved in 2006 to guide Munich’s transport development in accordance to the vision of a ‘compact, urban and green’ Munich. This plan aims to reduce, shift and manage traffic. Under this plan, the city gives priority to measures aimed at increasing the use of ecologically sustainable means of transportation such as walking, biking and public transit. The public transit network will be further developed and extended to decrease dependence on the automobile. Traffic management strategies will also be used to minimize traffic congestion (City of Munich, 2006).

Since 1986, Munich’s cycling plans were guided by its ‘Transport Development Plans – Bicycle Traffic’ (VEP-R). The initial focus to encourage cycling was to build bikes lanes and cycling tracks. However, this was not effective enough to make cycling a part of people’s everyday commute choice. Since the 2002 VEP-R, Munich has taken an integrated approach to bike planning by taking into consideration the door-to-door needs of both daily and leisure bikers (Munich City Council, 2010). Munich’s experience bears testimony to the earlier theoretical discussion about how bike planning should be seen as a door-to-door mobility system in order to rival the automobile. In fact, the German National Cycling Plan 2002-2012 advocates ‘cycling as a system’ to ensure that it can encourage a mode shift (Cox, 2008).

On top of all these strategies to make cycling and public transit an attractive mode of transport, traffic demand strategies are also employed to keep the transport demand to a manageable level. Munich restrains the demand for automobile use through strategies like
higher automobile taxes and registration costs which make automobile use less popular than public transit (Cameron et al., 2004; Pucher, 1997).

All these probably demonstrate how a multi-dimensional approach has been taken towards planning for the mobility and access of Munich. The city attempts to control the transport demand by making automobile use less attractive and creating a land use policy encouraging developments near transit stations, hence generating less need for longer distance travels not feasible on bikes. In tandem with demand management and land use management, transport supply management strategies are also adopted in the form of increasing the capacity of public transit lines and network of bike paths.

7.3 B+R widens public transit catchment – analysis from utility travel behaviour theory viewpoint

Unlike the suburban rail system in Copenhagen which grew in tandem with the surrounding developments, the suburban rail system in Munich only came into operation in the 1970s (Cameron et al., 2004). To ensure public transit accessibility for these areas, the city has continued to extend its transit lines to ensure that many of these lower density areas are still within reach of the public transit system.

As a result of this, not all developments in the larger Munich area are within the walking catchment of the train stations. Figure 21 below shows that the immediate catchment of the rail system covers a significant portion of the grey built up areas. However, some places are still not covered and they depend on buses, trams and the automobile which act
as feeders into the main rail system. However, if the train stations in the larger Munich area provide appropriate and adequate biking infrastructure, their catchment areas can increase. Figure 22 below shows how the catchment area of the U-bahn (metro train system) and S-bahn (suburban train system) stations area increased from 500m (represented by green circle) to 3,000m (represented by red circle). The bike has extended the catchment to cover all the built-up areas in the larger Munich area. In fact, many of the station catchments even overlap and this gives B+R users the option to cycle to more than one train station within biking distance from their homes. So we will look at the strategies employed by the city to ensure that B+R can successfully encourage more cycling and public transit use.
Figure 21 - Catchment area of public transit system (rail)
(Source: Koppen, 2007)
Figure 22 - Catchment of public transit system (rail) by foot versus bike
(Source: Bickelbacher, 2007)

Bike parking facilities at train station

To better understand the needs of B+R users, a study was commissioned by MOBINET and relevant agencies like the Munich Transport and Tariff Association (MVV). This study analyzed users’ needs in order to develop customized B+R facilities to cater to users’ needs. Kieferngarten station along the U-bahn U6 line was selected as a case study station (refer to Munich rail system map in Figure 23). Some of the key findings of the study included safe bike parking facilities, providing a roof to cover parked bikes, providing sufficient bike stands and better accessibility of the B+R facility from the road network. In response to this feedback obtained, a sheltered double-decked parking facility was implemented in 2003 at the Kieferngarten station offering 300 new bike stands of which 54 were located with a secure area requiring card access. The pictures in Figures 24 and 25 illustrate how the parking area looked like before and after the construction of the new facilities (Haller, 2007).
Figure 23 - Munich's rail system map

Figure 24 - Bike parking facilities at Kieferngarten Station before MOBINET study (Source: Haller, 2007)
The Transport Division of the Strategic Planning Projects Department conducted a survey to find out more about people's motives for using B+R and also find out how people would react to improved B+R facilities such as having high quality and safe B+R facilities at every station. People's reactions to improved B+R facilities are recorded in Figure 26 below. 15% of respondents who previously did not use B+R would switch to B+R. This shows that improved conditions play a very important role in facilitating B+R. Out of this 15%, 25% substituted rides by car with B+R, 14% substituted rides by bike with B+R, 9% substituted rides by both bike and car with B+R, 39% substituted walking or bus connections to the station with B+R if there was no change in fare while 13% would use B+R to cross a fare zone to get to a station (König, 2007). One interesting trend is the 13% (represented by red slice of pie chart) who used to walk or take the bus to the train station. For these people, the bike has given them the freedom to cycle a slightly longer distance to cross a fare zone to another station to avoid paying extra for crossing a fare zone in the train system. They were previously not able to cover this
distance on foot or there was no bus connection to this further station. Based on this, we can see that cycling as an access mode to stations definitely widens the station’s catchment area. Another positive trend is the conversion of about 34% (represented by two of the three green slices of pie chart in Figure 26) who stopped using the automobile because they can depend on B+R as an alternative. This of course translates to reductions in CO₂ emissions.

This example also clearly illustrates the how the transport utility theory can be used to explain the positive results of B+R. The reason why people chose to cycle a longer distance was to save money on their fares. By so doing, the disutility of cost has been lowered and this gives people a higher overall net utility. Another disutility lowered is inconvenience especially for the 13% of people who used to either walk or take the bus. Previously, walking or taking a bus to get to a further station would prove too inconvenient, possibly because no bus covered the route and it was too far for walking. Hence, with a fall in disutility in convenience and cost, people are willing to trade it off with a slightly longer travel time.
Figure 26 - Survey results of people's reactions to improved B+R facilities  
(Source: König, 2007)

7.4 Availability of bikes for egress trips

For suburban stations, providing parking facilities works because it accommodates B+R users who park their bikes after completing their access journey. These are journeys that users would accomplish everyday because they have to go home everyday. Space limitations at many railway stations put limits on the amount of bike parking facilities available (Munich City Council, 2010). Hence, the city has opted for a bike sharing system (Call-A-Bike) to cope with the egress trips from the train stations in the city centre. This helps to address the typical asymmetry in the availability of bikes at the egress end of a B+R journey.

*Bike sharing system in city centre*

Call-A-Bike (CAB) is a public bicycle sharing system that began in 2001 in Munich, Germany. Deutsche Bahn (German Railway) runs this bike sharing system with the objective to close the gap in the pre-trip and post-rail sectors and to provide door-to-door
accessibility for rail customers (Uhl, 2007). The benefit of such a model is that Deutsche Bahn’s top priority is to provide useful transit service, rather than generating revenues as with the public bicycle sharing systems supported by advertisements (DeMaio, 2009). CAB initially started as a private company, but went bankrupt shortly after it started. Deutsche Bahn took over its assets and operations, and has been running the bike sharing system ever since. In 2001, Deutsche Bahn said it would take them two or three years to make profits and in 2003 they were reported to be well on their way (Ollivier, 2003; DeMaio, 2004). CAB is available at inner city road intersections and train stations as shown in Figure 27 and 28. The customer base of CAB has also increased substantially as indicated by the magenta line in Figure 29.

Figure 27 - Call-A-Bike is found at train stations and road intersections within the inner city
(Source: Deutsche Bahn, 2007)
Users of the CAB system only need to register once to start using the system. Users call a service centre to obtain a 4-digit code for unlocking the bike. The user can lock up the bike temporarily at any location using the same code. At the end of the use, the customer leaves the bike at any train station or road intersection within the inner city. No docking
stations are required. Before parting with the bike, the user calls the service centre to obtain a return code that locks up the bike. The location of the bike is entered into the system so that other users in the vicinity looking for a bike will be able to locate it. Figure 30 below provides a summary of the process. Users with a Bahncard get a discounted rate of 5c/min while other users are charged 7c/min. This discount makes the use of bikes more attractive for public transit users and facilitates the use of the bike for the egress trip from the destination station. Based on Deutsche Bahn’s (2007) statistics, 29.5% of the CAB users in Munich are Bahncard holders. This shows that the train system and the bike sharing system complement one another and there is a possibility that people do use CAB as an extension of the rail system. The potential disutilities of inconvenience and cost are reduced by having a bike sharing system linked with the public transit system.

**How it works**

- **Entrance / Billing**
  - simple registration over a call center, the internet or a local selling partner
  - minute-exact billing
  - deduction over credit card or bank account
- **Central server**
  - Controlling and processing of all transactions and data
  - Efficient logistics, flexible account
  - Control
- **Receipt code**
  - Announcement of junction
- **Opening code** (Computer announces)
  - Coded transmission of customer number and bike number
- **Use**
  - Unrestricted use
  - Locking and reopening with the opening code possible at any time
- **Return**
  - Return at any larger junction
  - When locking, return „YES“ receipt code will appear
  - Call number visible on the lock
  - Confirm the return by pressing the key „1“ on the telephone
  - Enter receipt code into the telephone keyboard
  - Record the junction - finished!

**Figure 30 - Using Call-A-Bike**
(Source: Deutsche Bahn, 2007)
7.5 Flexibility of bike sharing system

The system does not rely on bike racks and docking stations – both of which are part of the principal cost components of a public bike sharing system (NICHERS, 2010). This flexibility of placing the bike any location within the inner city makes it a popular choice of transportation for various uses at different times of the day. The flexibility of either leaving it at a train station or a street intersection gives a B+R user arriving at the destination station the option of both using it as an egress mode of transport and a mode of transport within the city as shown from the typical usage of CAB bikes throughout the day. In fact, the main users are the morning commuters who extend a public transit trip by bike and in the afternoon and evening, it is mostly used by people for shopping trips or visiting the cinemas (Osmose, 2005). Figure 31 shows that most of the users of the system are actually occasionally users. For these users, bike sharing makes it possible for them to use a bike which they otherwise would not have access to since they are not likely to park a bike at the station because they only need the bike occasionally.
Figure 31 - Frequency of usage per customer per year for Call-A-Bike
(Source: Deutsche Bahn, 2007)
CHAPTER 8 – APPLYING B+R IN SINGAPORE

8.1 Chapter overview

Before looking at how relevant the above projects are to Singapore, we need to better understand the urban and transport development of Singapore and also the role of the bike as a mode of commuting in Singapore at the moment.

8.2 Urban and Transportation Planning in Singapore

Singapore is a city state with a land area of 700 sq. km and currently has a population of about 4.9 million. Being a very small country, there is only one city centre which can be treated as the inner city while the satellite new towns outside the inner city together with the inner city can be considered as the metropolitan area.

Urban and transportation takes on a very integrated approach in Singapore. Similar to the Copenhagen Finger Plan, Singapore has a long-term strategic plan called the ‘Concept Plan’ (refer to Figure 32). The Concept Plan is reviewed every 10 years and sets out broad guidelines regarding the kind of uses allowed at different parts of the country in a period of 30-40 years. Since Singapore has no other cities or municipalities, the next level of plan would be the Master Plan which is reviewed every 5 years (refer to Figure 33). The Master Plan provides the detailed land use zonings and intensity of each plot of land for the next 10-15 years.
Figure 32 - Concept Plan 2001
(Source: URA, 2010)
One of the core planning principles of both the Concept Plan and Master Plan is the planning of urban development areas around a network of transit lines. In an earlier version of the Concept Plan drawn up as shown in Figure 34, the intention was to plan satellite new towns scattered along a future network of rail lines. In the 1991 Concept Plan, a decentralization approach was taken to have a core inner city area in downtown Singapore connected by radial rail lines to a series of regional and sub-regional centres designed to decentralize the population throughout the country and prevent overcrowding in the city centre (refer to Figure 35). This approach led to the development of self-sufficient new towns where the vast majority of Singapore’s population resides in. These new towns are generally located within close proximity to a transit station so that residents can depend on public transit to get to work. All these planning strategies eventually shaped Singapore to its current urban form as shown in Figure 36 where the
urban development areas are clustered around the mass rapid transit (MRT) rail lines (represented by coloured lines in Figure 36) with green space in between for recreational use.

Figure 34 - Concept plan for Singapore in the 1970s
(Source: Ministry of National Development, 1988)
Figure 35 - Decentralization plan for Singapore in Concept Plan 1991
(Source: Sim et al., 2001)

Figure 36 - Singapore today
(Source: Google Maps, 2010)
8.3 Cycling in Singapore

The Urban Redevelopment Authority (URA) functions as the national planning agency coordinating all the planning and redevelopment efforts in Singapore. The URA also takes the lead to review both the Concept Plan and Master Plan. At this point in time, there is no bicycle master plan nor is there a department taking care of bicycle related issues. Most of the cycling related matters are taken up jointly by the URA, the National Parks Board (NParks) and the Land Transport Authority (LTA).

Based on the most recent 2008 Master Plan coordinated by the URA, one of the four strategic thrusts is to develop Singapore into an 'exciting playground' by providing quality recreational facilities such as the Round Island Route (RIR) for cycling and jogging as shown in Figure 37. Although this is a step forward to encourage more people to cycle, it is more likely to facilitate recreational cycling instead of commuter cycling. The 150km RIR is planned as a recreational route through recreational venues such as parks, reservoirs and nature trails. Based on the current plans, the RIR will only pass through about 8 out of the 79 transit stations in Singapore, making any hopes of combining the public transit with the RIR for B+R very slim.
Although the URA comes up with proposals such as the RIR, it is actually the NParks who design, build and maintain the RIR. As the national park planning agency, the NParks role is mainly to conserve, create, sustain and enhance Singapore’s green infrastructure. In addition to the RIR, NParks is the agency that takes care of the national park connector network (PCN). The PCN is a series of cycling and jogging paths that aim to link up parks around Singapore. In Figure 38 below, the coloured lines are the park connectors which link up all the parks around the country into a continuous network of green and open space for recreational purposes.
It is not uncommon to find a bicycle department within the Transport Planning department if one of the foci of bicycle planning is to promote commuter cycling. However, as seen from the case of Singapore, most of the cycling related infrastructure is related to the park authority and this is telling about the role the bike plays in Singapore. Although the LTA does not have a bicycle master plan, it does recognize the role of cycling in its recently completed Land Transport Master Plan (LTMP) (LTA, 2010). There are three strategic thrusts for the LTMP and one of them is ‘meeting the diverse needs of the people’. Under this thrust, the bicycle is recognized as a non-motorized transport option that can link commuters to major transit stations. The other two strategic thrusts include ‘promoting the use of public transit’ and ‘effective traffic management’. Based on this, the best way for the bicycle to be effective as a mode of sustainable
transport is to combine its use with public transit since one of the strategic thrusts encourages public transit use while the other promotes the bicycle as a feeder mode of transport to transit stations.

8.4 Singapore's cycling report card

Before moving on to look at how B+R can be implemented in Singapore, we will look at some statistics on commuter biking in Singapore and also what some academics and critics have to say about the state of cycling in Singapore.

Statistics

The mode share of cycling for commuting trips is 1.1% while 49.6% of commuting trips are carried out by public transit and 45.5% of trips are carried out on automobiles (inclusive of cars, vans, motorcycles and taxis). The cost of owning a car is relatively high in Singapore and only about 48% of households own at least a car. However, it is interesting to note that most of the cars are owned by a small proportion of the population. In fact, 39% of the cars are owned by the 20% of the population living in private housing (MVA, 2005). Ideally, for cycling and public transit to have a significant impact on the reduction of car use, policies should be targeted at the 20% of the population living in private housing who account for a disproportionately large amount of the car population. Public housing in the Singapore context refers to government subsidized housing and houses 80.5% of the country's population. The other 19.5% of the population lives in market rate private housing developments (MVA, 2005). Public
housing areas tend to be well served by public transit services such as the MRT and buses while private housing areas are not always accessible by public transit.

Official Government position

Based on the earlier background about the role of cycling in Singapore’s urban and transportation planning, it is evident that most of the government’s efforts has so far been placed on recreational cycling facilities. In a 2008 budget debate in parliament, the Minister of State for Transport highlighted that providing a comprehensive set of dedicated cycling tracks or cycle lanes islandwide is not possible given Singapore’s land constraints. Hence, there is a need to make the best use of very limited road space. The government made clear that they recognized cycling as an additional, if not alternative, mode of transport for cycling within new towns and to key transport nodes. The government stands firm on its position and has recently announced in July 2010 that it will facilitate the use of bikes as a feeder mode of transportation to transit stations by investing in dedicated cycling tracks within public housing new towns and bike parking facilities at transit stations. A S$43 million fund has been set aside for bike infrastructure in 7 new towns while S$26 million aside for cycling infrastructure in the new extension of the CBD – Marina Bay (Channelnewsasia, 2010).

Critics & Academics

Barter (2008) gave an overview on the role of bicycles in Singapore and highlighted that the government’s position has typically focused on the mass movement of people during rush hour over longer distances and tended to overlook the potential role that bicycles can
play. Barter pointed out an interesting point in response to the Singapore government’s position that land scarcity should pose an impediment to constructing cycling facilities since international bicycle infrastructure experts tend to view space-efficiency of bicycle infrastructure relative to that of cars. So perhaps instead of constantly investing in increasing the capacity of automobile infrastructure (eg. widening roads), the funds should go towards constructing bicycle infrastructure (eg. building bike lanes) which take up less space than cars. Urban Development academic Shreekant Gupta highlighted that Mercer’s ranking of livable cities gives greater consideration to sustainable issues when awarding scores. Dr Gupta also pointed out that Singapore needs to go beyond first-generation issues such as clean air and water to focus on second-generation issues such as becoming more bicycle- and recycling-friendly (Chew, 2010).

8.5 Implementing B+R in Singapore

The purpose of the earlier paragraphs was not to pick on the shortcomings of Singapore’s planning system or discredit any efforts the government has put in to promote cycling, but is intended to provide some background on the role that cycling plays in Singapore at the moment, the kind of policies shaping the role of cycling and the actors within the government involved. With this background in mind, we will now move on to look at how existing cycling policies can be improved and how existing infrastructure can be built upon to encourage more B+R.

Linking back to the earlier theoretical discussions about how cycling requires a complete seamlessly linked network in order to eliminate any potential disutility so that the bike
can rival the automobile in providing door-to-door accessibility and given the state of cycling development in Singapore, it seems that the best way to rival the automobile is to promote B+R. A bicycle culture and its supporting infrastructure is not built overnight, so it may be good to start small by building infrastructure allowing people to use the bicycle as a feeder mode to public transit so that people can start cycling short distances and open their eyes to the wonders of cycling.

The next section will be dedicated to showcase how the lessons learnt from Copenhagen and Munich can be applied to Singapore by looking at two MRT stations – one at a suburban new town in Ang Mo Kio and another at a sub-regional centre on the fringe of the inner city in Paya Lebar Central.

8.6 Ang Mo Kio – Background

Ang Mo Kio is a new town with a mix of both public and private housing. Out of the 179,000 people who live in Ang Mo Kio, 16,000 live in private housing while 163,000 live in public housing (Pang, 2009). The town is located about 10-14km from the city centre and is served by the North-South line of the MRT system linking the city centre with the two MRT stations in Ang Mo Kio – Ang Mo Kio MRT Station to the south and Yio Chu Kang MRT Station to the north (refer to Figures 39 and 40). In Figure 39, the areas coloured brown are public housing areas while the areas coloured blue are private housing areas and the purple coloured areas represent other land uses such as industry and education.
Figure 39 - Location map for Ang Mo Kio New Town
(Source: HDB, 2010)
Ang Mo Kio has been chosen to illustrate how bicycle infrastructure can be implemented in a new town to facilitate biking as a mode of transport for access trips to the MRT station. The lessons learnt from Ballerup New Town in the larger Copenhagen area would be applied to Ang Mo Kio New Town, where appropriate. Ang Mo Kio and Ballerup are both about 10km from the city centre, both are well-served by a rail network bringing commuters directly into the city centre, both have developments located within about 2-3km radius from the train stations (refer to Figures 14 and 39), both have a multi-modal transport hub at the town centre housing a rail station, bus station and shopping centre. One of the stark differences is the absence of bicycle infrastructure in Ang Mo Kio as
opposed to Ballerup’s 42km of bike paths and abundance of bike parking facilities at the train stations.

8.7 Increasing catchment of public transit stations to cover automobile dominant areas (utility theory approach)

Based on statistics gathered from the 2004 household survey, about 52% of people access MRT stations by walking while about 18% access the stations by bus (MVA, 2005). The high numbers of people walking owes to the fact that Singapore’s planning strategy has always been to locate the highest density residential developments closest the MRT stations to encourage the use of the MRT. While it is good to expand the catchment area to cover more of the public housing areas, it is more important to reach out to the people living in private housing who make up the minority of a typical new town, but own and use the most number of cars. These people are located about 2-3km away from the train stations. Hence, they are not within walking distance from train stations and neither can they access MRT stations by bus because the feeder buses mainly serve the public housing areas. However, 3km is not too far to cycle to the MRT station. In fact by extending the 500m catchment (see green bubble in Figure 39) to 3km (see red bubble in Figure 39) with the implementation of cycling as a feeder mode of transport to the MRT station, these private housing areas would potentially be included in the catchment of the station.

Even though biking or public transit is possible for people living in private housing areas in Ang Mo Kio, at present the disutility of time and inconvenience are way too high for
people living in private housing. Having bike routes and including them within the public transit catchment helps increase the net utility of B+R by decreasing the disutility of time and inconvenience.

8.8 Providing seamless transition from homes to trains

The private housing areas are mostly low-density single-family homes served by local access roads with mostly internal circulation traffic. Hence, dedicated paths may not be necessary along these roads as bikes can share the road space with the automobiles. However, once bikers reach the public housing area, housing densities rise rapidly and roads tend to be more congested, hence dedicated bike lanes should be constructed to link the MRT station right to the fringe of the private housing areas. In this way, it not only benefits the public housing dwellers, but also the private housing dwellers who have to cycle through the public housing areas to get to the private housing areas. Building dedicated cycle paths through public housing areas is less of a problem because all public housing developments have to be set back a certain distance (known as set back area) from the road. This set back area can be used to house the dedicated cycle paths. In fact, a pilot park connector was built in Ang Mo Kio along one of these set back areas in 2002 to link two parks in the new town (Tan, 2006). This park connector shown in Figures 41 and 42 is quite well used on weekends for recreational use, but its potential can be further exploited beyond its current recreational function to a commuting function by extending it to link up with the MRT station.
Ang Mo Kio
MRT Stn

Ang Mo Kio
Park Connector
(built in the
set back area
between road
and public
housing
buildings)

Figure 41 - Ang Mo Kio Park Connector
(Source: HDB, 2010)
8.9 Bike parking facilities

Bike parking facilities can also be implemented at Ang Mo Kio MRT Station. Today, there are no secure bike parking lots and all the unsecure ones are also full during the day, indicating that there is a demand for more parking lots. Cycling paths are recommended to come right beside the MRT station, similar like what has been done at
Ballerup Station in Copenhagen. Figure 43 below shows the current situation for bike parking at Ang Mo Kio MRT Station. There are very few bike parking lots and many cyclists end up parking along the railings. There is definitely a need for more parking lots and one way would be to build a multi-storey automated parking lot in front of the station. However, such a parking lot may be costly for the public transit operator. One possible solution is to get some form of private partnership to offset some of the cost of running such a bike parking facility as discussed below.

Figure 43 - Bikes are parked along railings in front of Ang Mo Kio MRT station (Source: Google Maps, 2010)

Such an approach is possible by looking into the possibility of bike parking facilities at the adjacent AMK Hub which is a shopping centre integrated with a bus interchange and linked to the MRT station through an underground walkway. The concept of a multi-modal hub including retail is gaining popularity in Singapore. The high-density mixed use development provides ridership to the transit facilities and the transit facilities in return provide excellent accessibility. Hence, the idea of adding one more mode of transport (bicycle) may further improve the accessibility options of the development. This
implies that there is some incentive for the private developer of AMK Hub to provide some form of parking.

One possible approach is to reduce the car parking requirements whenever a developer gives up a parking lot for bike parking lots. Removing one car park space can accommodate about up to 10 bikes depending on the configuration of the bike parking facility. Figure 44 shows that many bikes can be parked in a conventional car parking space. Currently, the car parking provision requirements of developments within 400m from an MRT station are slightly lower under the range based parking requirements agreed upon by the URA and the LTA (URA, 2005). Likewise, considerations should be made to reduce this parking requirement even lower whenever bike parking lots are provided. B+R users can maximize travel utility in this way because they can accomplish more than just commuting and still do some shopping at the town centre. They can come home from work, do their shopping and then pick up their bike to cycle home.

Figure 44 - Removing one car parking space makes way for plenty of bike parking space
Although Ang Mo Kio has some industrial and commercial space, it is definitely not sufficient to provide jobs for all its residents. The predominant land use in the town is residential. Hence, most cycling trips generated are likely to be between the home and the MRT station or town centre. Hence, this may not be an appropriate place to test out the viability of a public bike sharing system. Instead, another future mixed use development area at the fringe of the inner has been chosen for discussion.

8.10 Paya Lebar Central

Paya Lebar Central is a 12ha mixed use development area located about 5km from the city centre. Paya Lebar Central was one of the locations identified as a sub-regional centre in Concept Plan 1991 (refer to Figure 35). In the latest Master Plan 2008, Jurong East Regional Centre and Paya Lebar Sub-regional Centre were identified as one of the key focus areas for development over the next 10-15 years (refer to Figure 45).

Figure 45 - Plan indicating location of regional and sub-regional centres (Source: Richmond, 2008)
8.11 Using B+R to serve mixed use area

Based on the Master Plan 2008 (refer to Figure 47), this area is planned to be a vibrant commercial hub with a mix of uses including offices, retail, residential and communal public spaces. From the earlier discussion about bike sharing systems in Munich, we gathered that people tend to use the bikes to complete the egress trip from the transit station to the destination and using it to get around the city for recreational activities. The statistics for Munich in Figure 31 also showed that bike sharing is popular with people who are occasional bike users. Hence, Paya Lebar Central is an ideal location to test out the bike sharing system because the place has offices and industrial work places surrounding it for people to use it for the morning commute. Throughout the rest of the day, the shared bikes can be utilized by people visiting the retail developments and many communal public spaces.

Figure 46 - Location map for Paya Lebar Central and Joo Chiat
(Source: HDB, 2010)
8.12 Increasing public transit catchment, reducing short trips and reducing traffic congestion

Currently most of the development area of Paya Lebar Central is within the comfortable 500m walking distance as indicated by the green bubble in Figure 46. However, there are many other potential development areas beyond this 500m but within 3km and they are mainly accessed from Paya Lebar MRT Station by buses or automobiles today. However, with the implementation of a bike sharing system, all these areas would fall within Paya Lebar MRT Station’s bicycle catchment (refer to red bubble in Figure 46).

One of these areas is the Joo Chiat area – well-known for its built heritage in the form of conserved traditional shop houses with an interesting mix of activities ranging from traditional shopping to traditional eateries. This is a location popular with both locals and tourists alike. However, given that there are no MRT stations within close proximity, car
parking shortages along the narrow streets have been a source of tension for residents who find their car parking lots taken up by visitors to the area (see Figure 48). Introducing shared bikes might be a good way of bringing the occasional visitor into the area without aggravating the car park shortage problem. A bike sharing system similar to Deutsche Bahn’s CAB could be implemented at this location. Given the limited space in the area, one of the possible solutions is to replace some of the curb side parking lots with a pedestrian walkway. Not only will this provide more quality public space for human interactions, it will also provide space for shared bikes to be parked. This is similar to how CABs can be found in the vicinity of the pedestrian- and bike-friendly shopping area in downtown Munich (see Figure 49).

Figure 48 - The narrow streets of Joo Chiat flanked by conserved shophouses (Source: Google Maps, 2010)

On top of serving the heritage areas to the south-east of the station, widening the catchment of Paya Lebar MRT Station would be beneficial to people who live and work within the 3km radius from the station. Paya Lebar MRT Station functions as a transport hub because it is the interchange station between the East-West and Circle Lines. As an
interchange, this station would naturally see a lot of commuters passing through to switch lines. For some commuters arriving at Paya Lebar MRT Station, they may merely be changing to another line and travel for one stop to get to their destination. Some commuters may exit the station to connect to a bus or automobile to get to their destination a short distance away. Hence, having bike sharing at Paya Lebar allows people to use the bike to get to these short distances. This has the potential of increasing the overall travel utility for journeys because people can avoid having to make transfers which are viewed negatively and bring down the overall net utility of the journey.

This will also greatly reduce the possible congestion at vehicle pick-up points and bus stops outside the station. As shown from the Munich example, having B+R facilities actually attracts people to cross fare zones to get to another station. Likewise, there are actually two other MRT stations located within the 3km radius of this station (see Figure 46). With a bike sharing system and B+R facilities in place, residents or office workers in this area can bike to Paya Lebar MRT Station instead of waiting for a bus or getting stuck in a traffic jam in a car outside the station.
Figure 49 - Bike parking and outdoor dining area in Munich
CHAPTER 9 - CONCLUSION

9.1 Overview

In the final chapter, this thesis relooks at the initial question of how the lessons learnt from the integration of cycling and public transit in Copenhagen and Munich can be applied to Singapore. A brief recap of several transportation theories established in the earlier chapters will help us to understand how B+R as a concept can be a good alternative to using the automobile. The second part begins by looking at the lessons learnt from Copenhagen and Munich and subsequently goes on to explain how these lessons can possibly help Singapore promote sustainable modes of transportation such as B+R. Finally, some of the shortcomings of this research area will be highlighted and some possible direction for future research proposed.

9.2 Theoretical framework

The earlier discussions have shown that a multi-dimensional approach is crucial to the success of any transport development plan. B+R is just one of the many approaches that need to be well integrated with other transport planning strategies to meet a community’s mobility and access needs. To develop B+R into a good alternative to the automobile, the utility theory is brought in to understand the motive behind people’s travel patterns. A deeper understanding of people’s travel patterns helps us to develop appropriate strategies with the potential to influence people’s travel patterns towards more sustainable modes like cycling and public transit. The activity based approach helps to appreciate how people view the overall travel utility based on a larger sequence of trips.
forming a journey. Since a journey may comprise many trip segments, more than one mode of transport may sometimes be required to achieve the whole journey. Hence, the concept of multi-modalism is brought in to help us understand how people can combine different modes of transport to maximize travel utility.

9.3 Lessons from Copenhagen

The combination of the Finger Plan, the S-trains, automobile restrain policies and presence of bicycling plans have made it less attractive to use the automobile and more attractive to use B+R. The Finger Plan ensures that most developments are within proximity to a train station and this establishes development areas with short traveling distances from the train station. Most importantly, the town of Ballerup has capitalized on the short distances to the train stations by providing appropriate infrastructure in the form of a comprehensive network of cycling paths to facilitate cycling as a feeder mode of transport into the train stations.

9.4 Lessons from Munich

Somewhat similar to Copenhagen, transport demand and supply management strategies have been put in place to make car use less attractive and other more sustainable modes of transport like cycling and public transit more attractive. These strategies are combined with land use planning strategies aiming to create a city of short distances so that bicycling is possible. The Munich example also illustrates the importance of having customized bike parking facilities so that people feel safe parking their bikes at train stations. The flexibility of the Deutsche Bahn’s bike sharing system illustrates how the
bike and rail transit can be combined to facilitate multi-modal journeys. The case of people crossing fare zones in Munich illustrates how using the bike as a feeder mode of transport has allowed people to travel to another station previously too far to reach on foot or not accessible by bus. The bike sharing systems in Munich make better use of limited resources because they reduce the need for parking spaces at train stations and the shared bikes can be utilized by different groups of people throughout the day who visit the mixed use areas in Munich city centre.

9.5 Application to Singapore

Singapore has taken a similar integrated and multi-dimensional approach to meet the country's mobility and access needs, yet the cycling mode share remains low. Some of the earlier discussion about Singapore has shown that this is partly because policies directed at cycling mainly cater for recreational cycling instead of commuter cycling. Hence the network of cycling infrastructure tends to focus around recreational areas like parks. However, since the latest land transport master plan views the role of the bicycle as a feeder mode of transport to the main rail transit system, there is scope to look at the implementation of appropriate infrastructure to facilitate B+R.

The Copenhagen experience has shown that a city with developments located within proximity of transit stations usually has short traveling distances suited for cycling as a feeder mode to public transit as long as appropriate infrastructure like bike paths are put in place. Since Singapore has taken a similar approach to locating most developments
within proximity of transit stations, Singapore can likewise consider facilitating B+R by creating this network of cycling paths linking to transit stations.

Adapting from the Munich example of how using the bike for the access trip to the station widens the catchment areas, the suburban Ang Mo Kio example for Singapore shows that implementing cycling as a feeder mode of transport into the MRT stations widens the catchment of the station to include the private housing areas and there is a potential to convert some of the current automobile users in this area over to the B+R mode.

Adapting from the use of bike sharing systems in mixed use areas in Munich city centre, the Paya Lebar Central area example shows how the introduction of a bike sharing system will benefit mixed use area because a bike sharing system can be utilized by commuters in the rush hours and be used by the occasional travelers like tourists at other times of the day.

9.6 Shortcomings and potential areas for future research

One of the main differences between Singapore and both European cities cited is the climate. Singapore’s hot and humid climate might just reduce the catchment of the bike to less than 3km. Since cycling involves physical effort, the climate might cause discomfort to the individual and impose a disutility. More research will probably have to be done in this area to ascertain how climate might affect B+R.
In the meantime, one of the ways to overcome this disutility is to employ the use of electric bikes requiring less physical effort. The electric bike can also be wired up with mobile and digital technologies that can give real time information about public transit arrival times. This is useful information because it helps a cyclist to time an arrival at a public transit stop just in time to catch a connecting train. Using electric bikes allows people to combine it with information systems that accomplish an array of things like locating bikes, assessing the fastest congestion free route to the station and recording distance traveled or calories burnt during a trip. From the travel utility theory viewpoint, being able to use such devices to time arrival at train stations helps to avoid potential disutility caused from waiting for trains. Being able to record calories burnt on a trip is almost like using the trip on the bike as a visit to the gym. Since people always aim to maximize travel utility by carrying out as many activities as possible, being able to “incorporate” a gym session as part of the morning commute seems like an attractive way of marketing the potential of an electric bike + ride journey.
REFERENCES


Munich City Council (2010) *Bicycle Traffic in Munich*. Munich: Munich City Council.


