I, Bhoomi Vala, hereby submit this work as part of the requirements for the degree of: Master in Community Planning

It is entitled: Proposal of Alternate Route to Mount Auburn Tunnel in Cincinnati by Light Rail

This work and its defense approved by:

Chair: Dr. Xinhao Wang
Dr. Carla Chifos
Prof. John Niehaus
PROPOSAL OF ALTERNATE ROUTE TO MOUNT AUBURN TUNNEL IN CINCINNATI BY LIGHT RAIL

A thesis submitted in partial fulfillment of the requirements for the degree of

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ABSTRACT

In November 1993, the Ohio-Kentucky-Indiana Council of Governments (OKI) proposed light rail in Cincinnati along the six corridors namely I-71, I – 75, Westside alignment along I – 74, Eastside alignment, I – 471, and Crosstown route. Of the six corridors the I-71 light rail corridor was identified as the highest priority transportation corridor and was planned to connect Florence in Kentucky to Kings Mill in Cincinnati, Ohio. The starter segment of the I-71 light rail corridor was planned to connect the Downtown Covington in Kentucky to Blue Ash in Cincinnati.

As the Downtown of Cincinnati and the University of Cincinnati in Uptown are the major employment centers of Cincinnati, the connection of Uptown to Downtown was planned as a part of the I-71 Corridor light rail. A Mount Auburn Tunnel passing under the Mount Auburn neighborhood of Cincinnati was proposed to connect the two employment centers. Due to the high cost and the uncertainties of digging a tunnel, the proposal was rejected by the voters of Cincinnati in 2002. The project of the I-71 Corridor was thus brought to a stand still. My thesis proposes alternative routes to the Mount Auburn Tunnel that connects the Uptown and the Downtown of Cincinnati as a part of the I-71 light rail corridor.

Over the series of chapters you will read how various alternatives were selected that could serve the connection to the uptown and the downtown areas of Cincinnati by light rail and how they were analyzed to propose a routes that will serve as an alternative to the Mount Auburn Tunnel. The document is divided into seven chapters. The first
chapter of ‘Introduction’ that gives the readers the knowledge of the thesis topic, the problem statement, and the limitations of the study. The second chapter of ‘Methodology’ explains the readers the methodology that was adopted to find an alternate route to the existing Mount Auburn Tunnel. This chapter also tells the readers how various maps were prepared for the analysis of the alternative routes. The third chapter of ‘Study Area’ gives the knowledge of the Uptown and the Downtown areas of Cincinnati where the new alignment is to be planned. The fourth chapter of ‘Literature Review’ gives the overview of the light rail in the cities of San Diego and Portland. In the fifth chapter of ‘Criteria for Deciding the Route of the Light Rail’ talks about the various factors that are important for the planning of the light rail. These factors are derived from the literature review of San Diego and Portland, and the interviews conducted by me. The factors described in this chapter thus help to derive the Primary Criteria, Secondary Criteria and the Unique Criterion for the planning of the light rail in Cincinnati. This chapter builds a strong base for the analysis of the routes that are described in Chapter 6 of ‘Assessment of Alternate Routes’ where each alternative route is discussed in detail for the primary criteria and the secondary criteria. In the final Chapter 7 of ‘Comparison of Alternate Routes’, the final route is decided that can connect the Uptown and the Downtown areas of Cincinnati by light rail.
ACKNOWLEDGEMENT

I would like to express my gratitude to all those who helped me, encouraged me, and motivated me to do the thesis. I am greatly indebted to my thesis chair Dr. Xinhao Wang for his continuous guidance and suggestions in the thesis. I want to thank him for encouraging and motivating me to do the best. I would also like to thank my thesis faculty Dr. Carla Chifos and my thesis reader Prof. John Niehaus for their suggestions in the thesis. Lastly, I would like to thank my family, friends and especially my parents for supporting me with the research.
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CHAPTER 1
INTRODUCTION
1.1 PROBLEM STATEMENT

The Ohio – Kentucky – Indiana (OKI) Council of Governments estimates that by the year 2020 the regional freeway system will fail to move people and goods. Thus, there arises the need to improve the transportation system in the city. According to Fred Craig, Engineer for I-71 with Parsons Brinckerhoff in Cincinnati, Ohio light rail is a better alternative for the transportation expansion as it is quite, smooth and fast and can carry about 300 to 350 people in two-car set at a speed of up to 55 miles per hour. In addition, rail transit alignments only require narrow rights-of-way that can penetrate the congested corridors that are difficult for the highway expansion (Light Rail Cincinnati 2003).

Of the six light rail corridors proposed in November 1993 by the OKI to improve the region’s mobility and to meet the regional air quality goals, the I-71 light rail corridor was identified as the highest priority transportation corridor (Metro, TANK, OKI, and BRW 2001). In Cincinnati, the Downtown is the largest employment center and the Uptown where the University of Cincinnati is located is the second largest employment center. Hence, it becomes very important to connect the Downtown and the Uptown of Cincinnati by light rail as a part of the regional light rail corridors (Wormald, Reynolds, and Schneider 2007).

A tunnel through Mount Auburn was planned to connect the Downtown to the University of Cincinnati in the Uptown neighborhood of Cincinnati. The tunnel was planned to start in Over-the-Rhine with its south portal at the Mulberry St. and its north portal at the
Corry Street near the University of Cincinnati campus in the Corryville neighborhood (Mecklenborg 2006). The total cost of the segment of the light rail under the Mount Auburn neighborhood (N2 segment) was $155,961,000 in the 1996 dollar value. Of the total cost of the segment under Mount Auburn, the cost of tunnel comprised of $66,183,000 in the 1996 dollar value (Burgess & Niple, Limited, BRW, Inc., KPMG Peat Marwick LLP, Manuel Padron & Associates, Hogan, Nolan & Stites, R. L. Banks & Associates, Cambridge Systematics, Inc., Gray and Pape 1998, 5.7). The Mount Auburn Tunnel along with the bridge over the Ohio River into the Northern Kentucky formed the significant capital investment for the I-71 light rail corridor project (Metro, TANK, OKI, and BRW, 2001). In June 2002, the plan of building a Mount Auburn Tunnel as a part of the I-71 light rail corridor in Cincinnati was abandoned by the voters of Cincinnati.

According to Fred Craig, it would be advisable to go for an “above-ground” route which might be significantly cheaper and the cost of building will be more certain than to go for an underground solution like the Mount Auburn Tunnel that are often fraught with unknowns as one gets into them (Monk and May 2002).

1.2 RESEARCH QUESTION

My thesis concentrates on the starter segment of the I-71 Corridor light rail that aims to connect the Downtown and the Uptown of Cincinnati by light rail. I have studied various routes that could serve as and alternate to the Mount Auburn Tunnel to connect the Downtown and Uptown, as a part of the entire I-71 Light Rail Corridor.
I have focused my study to the “spatial analysis” of the Cincinnati’s “uptown” and the “downtown” areas and explored the alternative routes on the basis of various planning criteria that at the same time proved to be less expensive compared to the Mount Auburn Tunnel and were not subject to the uncertainties like digging the tunnel. I checked the various alternatives for their cost and studied them against the Mt. Auburn Tunnel.

Connecting the uptown and the downtown areas of Cincinnati will serve as a starter line to the commencement of light rail. At present, due to the disapproval of the Mount Auburn tunnel, the light rail project in Cincinnati has come to a stand still. My proposal of the routes that could connect the uptown and the downtown areas of Cincinnati will help the planners, engineers, politicians and the investors to decide the future routes of light rail in Cincinnati.

When the alternate route by light rail is proposed from the Uptown to Downtown areas of Cincinnati, it will influence the land use pattern of the city to a great extent. There is even a possibility that the city may look into the ‘Transit Oriented Development’. Apart from this, since a great number of people commute daily between Uptown and Downtown areas of Cincinnati, it may boost the public transportation leading to the sustainable development in the city.

‘Proposal of the Alternate Route to Uptown and Downtown areas of Cincinnati by Light Rail’ is a vast area of study that might include the study in the fields of politics,
economies, environmental impacts, etc. Considering all the factors for the proposal of the alternate route were beyond the scope of study; hence, my thesis focuses solely on the “physical” and “spatial” planning for the alternative route to the Mount Auburn Tunnel.

1.3 WHY IS IT IMPORTANT TO FIND THE ALTERNATE ROUTE TO MOUNT AUBURN TUNNEL?

The study conducted in 1996 by the University of Cincinnati in collaboration with a committee studying the transportation alternatives for the I-71 Corridor in Cincinnati showed that 60,000 people commute in and out of Uptown area daily and proposed light rail tunnel passing through Mount Auburn as the link between Uptown and Downtown connecting the areas of Clifton, Corryville, Avondale and Mount Auburn. John Schneider, the then Chairman of Downtown Cincinnati Inc.’s Transportation Committee, mentions that a link between Uptown and Downtown would be a boon to Cincinnati as it would solve the parking problems for UC and the cost of such a light rail system which was estimated to be at $30 million (as per 1996 $ value) which would be cheaper than adding a highway lane along the parts of I-71 (Monk 1996).

The preliminary studies on the I-71 light rail corridor shows that about 31,000 people will be riding light rail by the year 2020 and the number of riders can increase to 248,000 by adding a car to the train and simultaneously increasing the frequency. The study also shows that the light rail will increase public transit ridership in the area by 28% and there will be an increase of 47% riders along the I-71 Corridor (Frank 1998).
Thus, without the piece connecting the Uptown and the Downtown areas of Cincinnati, the I-71 Corridor will be incomplete and it becomes important to find the alternate route to Mount Auburn as a part of the entire I-71 Corridor Plan.

1.4 CONTRIBUTIONS

After the rejection of the Mt. Auburn Tunnel, planners started thinking about the alternatives to connect the Downtown and the Uptown areas of Cincinnati and thus complete the entire I-71 Corridor Plan for Light Rail (Monk and May 2002). As an alternative to the existing I-71 Corridor, the revised alignment of the I-71 light rail corridor was proposed by the SORTA (this alignment is discussed in detail in Chapter 6). This alignment however was not decided as the final proposal for the I-71 Corridor light rail alignment (Reynolds 2007). Hence, the local transit planners are studying to realign the I-71 light rail line in a manner that will eliminate the expensive Mt. Auburn Tunnel (Monk and May 2002). My study will propose the alternatives to connect the Uptown and the Downtown areas of Cincinnati by light rail as a part of the I-71 Corridor (for the purpose of selecting the alternatives even the Revised I-71 Corridor alternative is considered).

Connecting the uptown and the downtown areas of Cincinnati will serve as a starter line to the commencement of light rail. At present, due to the rejection of the Mount Auburn tunnel that was proposed to connect the uptown and the downtown areas of Cincinnati, the construction of the light rail in Cincinnati is bought to the hold. My proposal of the route that could connect the uptown and the downtown areas of Cincinnati will help the planners; engineers, politicians and the investors help decide the future routes of light
rail in Cincinnati. Such a kind of project (where various alternatives were explored and analyzed) is not yet explored by the planners and engineers hence; it will make my study a unique project in itself. When the best route of light rail is proposed from the Uptown to Downtown areas of Cincinnati, it will influence the land use pattern of the city to a great extent. There is even a possibility that the city may look into the ‘Transit Oriented Development’. Also, since a great number of people commute daily from Uptown to Downtown areas of Cincinnati, it will give a great boost to the public transportation. This will lead to the sustainable development in the city.

1.5 LIMITATIONS

‘Proposal of the best route for light rail to connect Uptown to Downtown areas of Cincinnati’ covers the wide areas of politics, spatial analysis and economic development. Considering all the factors for the proposal of the best route will become the individual topic of research in itself. Hence, my thesis will not consider the politics of the light rail transit in Cincinnati. Thus, my thesis will be focusing solely on the physical and spatial planning for the proposal of best route to connect uptown and downtown of Cincinnati through Light Rail.

1.6 OVERVIEW OF THE DOCUMENT

I divided the research into ‘Literature Review’, ‘Map Making’, ‘Interviews’ and ‘Analysis’. ‘Literature Review’ of my thesis concentrated on studying and analyzing the materials written on the light rail system in San Diego (CA) and Portland (OR), Uptown and Downtown of Cincinnati, and Mount Auburn Tunnel for Light Rail in Cincinnati. I
referred to various public documents, newspaper articles, journals, and books to build my understanding of the subject. The literature review of the San Diego and Portland light rail concentrated on the factors that were considered during the planning of the light rail in these regions; the literature review of the ‘Uptown’ and ‘Downtown’ areas of Cincinnati concentrated on the study of the “ridership”, “population”, “employment centers”, “redevelopment projects”, “vehicle and home ownership”, “income level”, and “age distribution”, for the Uptown and the Downtown areas of Cincinnati; the literature review of the Mount Auburn Tunnel concentrated on the location planning of the tunnel, the planning criteria that were considered while proposing the tunnel and the reasons for its failure. The literature review thus gave me the understanding of the criteria that are important for the design and planning of the light rail

‘Map Making’ part involved preparing the ‘Base Maps’ and the ‘Analysis Maps’ for the Uptown and the Downtown areas of Cincinnati. The base maps in GIS were prepared for “land use”, “existing and projected population”, “existing and projected employment”, “redevelopment projects”, “slope”, and “income group”. After the preparation of the base maps, the advanced GIS tool of ‘Spatial Analysis’ was used for the analysis of the various criteria for the planning of the light rail (methodology of the spatial analysis is explained in chapter 5). Thus, the map making gave me different areas and routes that had high potential for the planning of the alternate light rail routes.

‘Interviews’ were the major part of finding the alternate route to the mount Auburn Tunnel. Much of the research for the proposal of the alternate route to the Mt. Auburn Tunnel by Light Rail in Cincinnati that was done after the rejection of the Mt. Auburn
Tunnel was not published or documented. Hence, I needed to conduct interviews with
the planners and engineers involved in the planning of the I-71 light rail corridor to get
the data for the alternate routes to the Mt. Auburn Tunnel. The participants in the
interview were asked specific questions regarding the planning and the various criteria
for planning the light rail in Cincinnati. They were also asked about an alternate route to
the Mt. Auburn Tunnel in Cincinnati. The participants are referenced in the thesis
document with their permission.

I was the Principal Investigator (PI) of my research team and my thesis chair Dr. Xinhao
Wang was also Principal Investigator (as I was a student) in the research. I e-mailed
the consent letter for the interview to the various participants and after receiving their
consent, I conducted an interview with them at the location of their choice. The entire
process of the interview was done in compliance with the rules and regulations laid by
the IRB (Institutional Review Board).

The request to participate in the form of the consent letter was sent to the people who at
some time were involved in the planning of the I-71 light rail corridor in Cincinnati.
These people were either the employees of the public or the private agency or were
working for the non-profit organization. Participation in this interview was strictly
voluntary. The participants who were willing to participate in the interview signed a
consent letter and these consent letters were kept safe with me in a locked cabinet. No
sensitive personal information about the participant in the form of their social security
number or the home telephone or address was asked from the participants. Only the
name and the role of the participants in the planning of light rail in Cincinnati were asked apart from the interview questions. The interviews were conducted at the time and place of participant’s choice and the participants had the choice to leave or skip a question during the interview.

‘Analysis’ part concentrated on the analysis of the primary and the secondary criteria that were considered for the planning of the alternate route. These primary and the secondary criteria were obtained from the literature review off the San Diego and Portland light rail. The difference between primary criteria and secondary criteria is that the primary criteria are “imperative” in nature and can not be generated or modified while the secondary criteria are important for the purpose of planning but can be modified or generated. The important factor considered for the planning of the light rail is cost. Here the alternatives to the Mount Auburn Tunnel are very cheaper compared to the tunneling cost of the Mount Auburn Tunnel. Hence, it is an important factor that was considered but not the criteria of planning. The motive of finding the new alignment was not finding the cheapest route; but to find the alternative route that works the best.

Based on the primary criteria, I sorted various routes that seemed to be potential alternate routes to the Mount Auburn Tunnel in Cincinnati by Light Rail (these routes were obtained from the interviews with various lead transportation planners and proponents and a few routes were decided by me on the basis of my analysis of the areas). The routes were then checked for the secondary criteria. Thus, an alternate
route was decided on the basis of the route that scored maximum points of the total points from the primary and the secondary criteria.
CONCLUSION

This chapter discusses the problem statement, research question, and gives the overview of the chapters in the document. This section thus prepares the readers to build the general understanding of the topic and how I went about finding the solution for the existing problem.
CHAPTER 2

METHODOLOGY
2.1 GIS DATA AND DATA SOURCE

The data for the preparation and the analysis of the maps was collected from Cincinnati Area Geographic Information System (CAGIS) that was updated for the year 2006, the Ohio – Kentucky – Indiana data that was updated for the year 2007 and the US Census Bureau that was updated for the year 2006. The data was available in the form of ‘Shapefiles’ and ‘Excel Formats’. As per the requirement, the data was transformed from the excel format to the dbf format that can be used in the shapefiles to prepare the maps.

2.2 SURVEY INSTRUMENT

In order to find the alternate route to the Mt. Auburn Tunnel, I conducted the literature review on the San Diego light rail and the Portland light rail. The literature review gave me the factors that were important for the planning of light rail and that in turn helped me to derive the primary and the secondary criteria for the planning of light rail in Cincinnati. On the basis of this I developed the primary criteria and the secondary criteria for the planning of the light rail. While doing the planning of any infrastructure, it is important to study the area. Once I got the primary criteria, I prepared the base maps of these primary criteria for the Uptown and the downtown areas of Cincinnati. To find the alternate route to the Mt. Auburn Tunnel in Cincinnati, I interviewed various people that were involved in the planning of the light rail in Cincinnati along the I-71 Corridor. It was very important to conduct the interviews with these people as they were already involved in planning and finding an alternate route to the Mount Auburn tunnel.
2.3 REASON FOR SELECTING SAN DIEGO AND PORTLAND

As a part of the literature review, I studied the light rail transit in San Diego and Portland. The reason I chose to study San Diego for its public transit is that San Diego like Cincinnati is one of the most sprawling cities of US. Between 1990 and 1996, the population of San Diego grew by almost 50%. The Sierra Club mentions San Diego as “dishonorable” for the sprawl while on the other hand, Cincinnati ranks fourth amongst the sprawling cities of US (Sierra Club 1998). On the other hand, Portland is a city like Cincinnati (SORTA 2002, 13). Both San Diego and Portland are one of the most successful examples of the light rail transit. Hence, I studied the light rail in San Diego and Portland and implied the planning criteria for the light rail of these cities to the planning of the light rail in Cincinnati. Due to the time constraints, I had to limit my literature review to the two light rail cities of San Diego and Portland. Studying these light rails in details gave me a thorough understanding of the light rail planning. The limitation of choosing the San Diego and Portland light rail is that they are not mid-west cities. If these cities were in mid-west, I could have drawn a direct connection between them and Cincinnati.

The San Diego Trolley started its operation in the summer of 1981 and it represents a unique opportunity to study the impact of light rail transit on the modern urban environment as it is the first light rail system to be built in U.S. after several decades (San Diego Association of Governments 1981, 3). On the other hand Portland is a transit-oriented city and determines to use transit for the urban development. In other words Portland is the “hallmark” of integration of transit and land use (Parsons
2.4 DEVELOPMENT OF PRIMARY AND SECONDARY CRITERIA

The literature review of San Diego light rail and the Portland light rail, and the interview with various planners and engineers that were involved in the planning of the I-71 Corridor light rail helped me to understand the criteria that were important for the planning of the light rail. From the literature review I learnt that not all the factors were equally important for the planning of the light rail. Some factors were more important than the others. The factors that were the most important and imperative in nature, I called them ‘Primary Criteria’ while the factors that were less important and can be manipulated according to the needs; I called them ‘Secondary Criteria’. On the other hand, during the interview, the interviewees were asked which were the most important criteria for the planning of the light rail in Cincinnati and the responses from them were considered for the ‘primary criteria’. The interview and the literature review gave me a criterion that was very important for the planning of light rail; but it could not be completely implied in this research. Hence, I called it a “Unique Criterion” (all the criteria are discussed in detail in Chapter 5).

2.5 SCORING A ROUTE BASED ON THE PRIMARY CRITERIA / ANALYSIS MAP

Once the primary criteria were obtained from the literature review and the interviews, I prepared a single map of these primary criteria and named it ‘Analysis Map’. This map
showed the regions that exhibited “high priority areas” and “low priority areas” for the planning of the rail alignment.

For the purpose of the preparation of the analysis map, the rasters of various primary criteria were prepared. Then, using the ‘Spatial Analysis’ tool of GIS the “unweighted overlay” was performed over the rasters of the primary criteria. Here, “equal weight” was allotted to all the primary criteria as all the primary criteria were of equal importance. Of all the primary criteria, one criteria was checked individually as it could not be used for the preparation of the map. To get the consistent results, the cell size of each raster obtained from the primary criteria was kept constant (the detail construction of each raster of the primary criteria and the construction of the analysis map using these rasters is explained in Chapter 6). The analysis map gave the high and the low priority areas that were used for the analysis of the individual routes. These high and low priority areas were derived by the GIS software on the basis of the weighted sum performed to get the analysis map.

If the given alternative route is falling under the high priority area, it was given ‘2’ points for the analysis of the route, while if the given route was under the low priority area, ‘1’ point was given to that alternate in the analysis of the alternative routes. Under the circumstances, where the route partially fell into the high and low priority areas, the strict score was awarded. This means that the score for the low priority areas was given. In deciding the alternate route, the unique criterion plays a very important role. The value of this unique criterion should be very low (and should be almost equal to the
at-grade solution). Hence, if the alternate route exhibits the value that is equivalent to that of the Mount Auburn Tunnel, then this alternative will not be selected as an alternative that best connects the Uptown and the Downtown areas of Cincinnati by light rail. Thus, the unique criterion is flexible provided its value is comparable to the at-grade solution (that is very low compared to the Mount Auburn Tunnel) but this criterion plays its role when the value of the alternative for judging this alternative becomes very high and equivalent to tend to be equivalent to the Mount Auburn Tunnel.

2.6 SCORING A ROUTE BASED ON SECONDARY CRITERIA

The factors that were less important for the planning were considered as ‘Secondary Criteria’. These criteria were given the points ‘1’ or ‘2’ depending on whether the given route satisfied that criteria or not. If the given route is missing that criterion or if the given route requires modifying or developing those criteria, ‘1’ point was given. On the other hand, if the given route fulfills that criteria, ‘2’ points were given. The point allocations for the various routes were decided by me and my judgment was based on the understanding of the literature review.

Once the score for the primary and the secondary criteria were decided (they are discussed in Chapter 6), a table was prepared that showed the primary and the secondary criteria against the alternative routes. The scores were filled in this table as discussed in Chapter 6 and then the sum of the scores was done. The alternative that showed the highest sum showed that it can best serve the Uptown and the Downtown of Cincinnati by light rail.
2.7 METHODOLOGY

The research was divided into ‘Literature Review’, ‘Interviews’, and ‘Maps’. The literature review and the interviews were used for the selection of the primary and the secondary criteria. After that the maps were prepared for the primary criteria. The alternative routes obtained from the interview and one route was proposed by me. These routes were checked on analysis map and then they were later checked for the unique criterion and the secondary criteria. This assessment of the alternate routes on the basis of the primary criteria, unique criterion, and the secondary criteria finally led to the conclusion of the project where I came up with the proposal of the alternate route to the Mount Auburn Tunnel in Cincinnati by light rail.
Figure 2.1: Methodology Flow-Chart

**Alternate Route to Mount**

**Literature Review**
- Study of San Diego Light Rail
- Study of Portland Light Rail
- Study of Uptown and Downtown Cincinnati

**Interviews**
Interviews were conducted with various planners and engineers involved in the planning of I-71 Corridor light rail in Cincinnati

**Outcomes:**
- A set of factors for LRT route selection
- Reasons for classifying the factors into primary and secondary criteria category

**Selection of the primary and the secondary criteria**
The factors are classified based on literature review and the interviews

**Maps**
Area concentrating on the Uptown and the Downtown of Cincinnati.

**Assessment of alternate Routes**
- How well each route meets the primary criteria
- How well each route meets the secondary criteria
- Compare each alternative route to the Mt. Auburn Tunnel proposal
- Compare alternative routes among themselves
- Rank the alternative routes

**Outcomes:**
- Map of individual primary and secondary criterion
- Map of the composite indicator of weighted primary criteria

**Conclusions**
- Your choice for the alternative route
- Recommendations for each action
- Lessons Learned
2.8 PREPARING THE BASE MAPS
To commence the study, the base maps of the ‘Current Land Use’, ‘Existing and Projected Population for the year 2030’, ‘Existing and Projected Employment for the year 2030’, ‘Household Composition’, ‘Topography’, ‘Major Activity Centers’, and the ‘Redevelopment Map’ were created. Then using the data of the CAGIS, OKI and US Census Bureau, the analysis map was prepared. The analysis map depicted the primary criteria that were important for the planning of the light rail and was based on the literature review of the light rail in San Diego and Portland.

2.8.a LAND USE MAP
The CAGIS 2006 data of “civil boundary”, “river”, “streets”, “railroads”, “parcels”, “major roads”, “slope”, and “jurisdiction” was used for the preparation of the land use map. For the understanding of the various land uses, the parcel shapefile was classified into “unique colors” under the tab of “symbology” where each land use was assigned a unique color.

2.8.b EXISTING AND PROJECTED POPULATION MAP
The CAGIS 2006 data of “civil boundary”, “river”, “streets”, “railroads”, “parcels”, “major roads” and “jurisdiction” was used for the preparation of the population map. The OKI data for the population of 2005, 2010, 2020, and 2030 was used to prepare the map for the existing and the projected population for the Uptown and Downtown areas of Cincinnati. To create the classes in the population map, the population field was given a graduated color in the symbology. The population map is classified with the
difference of 1000 persons. The sequence of the population map shows the areas in the Uptown and the Downtown areas of Cincinnati gaining and loosing populations.

2.8.c EXISTING AND PROJECTED EMPLOYMENT MAP

The CAGIS 2006 data of “civil boundary”, “river”, “streets”, “railroads”, “parcels”, “major roads” and “jurisdiction” was used for the preparation of the employment map. The OKI data of employment for the year 2005 and the year 2030 was used to prepare the existing and the projected employment in the Uptown and the Downtown areas of Cincinnati. The ‘Employment Maps’ shows the number of employees in each neighborhood.

2.8.d SLOPE MAP

The CAGIS 2006 data of “civil boundary”, “river”, “streets”, “railroads”, “parcels”, “major roads”, “jurisdiction”, and “slope” was used for the preparation of the slope map. The slope is classified as 0-10%, 10-20%, 20-30% using the symbology in the GIS.

2.8.e MAJOR ACTIVITY CENTERS MAP

For the purpose of study, the hospitals, businesses, parks, monuments, YMCAs and YWCAs, and schools were considered as the major activity centers.
2.8.f  **REDEVELOPMENT AREAS MAP**

CAGIS recognizes certain areas as ‘Urban design District’, ‘Historic District’, and ‘Redevelopment Areas’. These areas exhibit high potential for the attraction of the people.

2.8.g  **PROFILE OF VARIOUS STREETS**

To create the profile of streets, ‘3D Analyst’ tool in GIS was used. A TIN was created from the spot elevations of Cincinnati using the “create TIN from features” from the 3D Analyst toolbar by choosing the option of ‘Create/Modify TIN’. This TIN is 2D in nature and in order to create the profile of the streets, it needs to be converted to 3D. The heights to the TIN are assigned in ArcScene. For this purpose, the TIN is opened in ArcScene and the TIN is assigned the heights. Here right click on the TIN layer in the layer dialogue box and select the properties. In the properties choose the Base Height tab and select the option “obtain heights for layer from surface”. At this stage, the terrain is a flat surface compared to the elevations of the surface; hence, an exaggerated elevation needs to be added to the surface. To do this, right click on the scene layers and select “scene properties”. Here choose the “general” tab to enter the vertical exaggeration of ‘2’. To visualize the terrain, select the “classified” display in the symbology of the properties of TIN. Now, to create the profile of the desired road/street, open the current TIN in ArcMap and launch the 3D Analyst tool box. To get the profile or graph of the desired line, first draw the street by using “interpolate” button in the 3D Analyst tool bar and once the desired street is drawn, use the “create graph” button to get the profile of the desired streets.
Conclusion

This chapter discussed the methodology adopted by me to find the alternate route to the Mount Auburn Tunnel by light rail. It prepares the readers to understand the discussion of Study Area in Chapter 3, the literature review of San Diego and Portland light rail in Chapter 4, the primary and the secondary criteria that decides the planning of the light rail that are discussed in Chapter 5, and the comparison of alternate routes that is discussed in Chapter 6.
CHAPTER 3
STUDY AREA
3.1 INTRODUCTION

This chapter focuses on the study area comprising of the nine neighborhoods of the Uptown and the Downtown of Cincinnati. It discusses the planning criteria of land use, major activity centers, population, household income, employment, development projects, travel pattern, and trip generation and ridership that influence the planning of the light rail in Cincinnati. For the purpose of clarity, the land use of each neighborhood is explained individually.

3.2 UPTOWN AND DOWNTOWN OF CINCINNATI

The ‘Uptown Transportation Study’ conducted from November 2004 to November 2006 recognizes Avondale, Clifton, Corryville, East Walnut Hills, Evanston, Mt. Auburn, North Avondale, Walnut Hills, Clifton Heights, University Heights, and Fairview (CUF) as the Cincinnati neighborhoods that comprises for the Uptown area (URS Corporation 2006, 1.1).
3.2.a Land use

“The economic benefits of integrating effective land use planning with light rail (LRT) corridors are becoming increasingly obvious (Glick 1992, 75).” Transit has a positive impact near the walking distance of the transit stations as the property values stabilizes or increases near these stations while on the other hand it can create difficulties associated with ownership, financing, liability and operational issues related to the joint development (Burgess & Niple, Limited, BRW, Inc., KPMG Peat Marwick LLP, Manuel Padron & Associates, Hogan, Nolan & Stites, R. L. Banks & Associates, Cambridge Systematics, Inc., Gray and Pape 1998, 4.2).

Avondale

In Avondale, the majority of the land use consisted of residential areas. Of the total land uses, 6% was commercial, 2% - educational, 1% - industrial, 5% - institutional, 45% - residential, 2% - office, 13% - public space, and 21% - vacant (CAGIS 2006).

Figure 3.2: Land Use in Avondale Neighborhood of Cincinnati

Source: CAGIS 2006.
Clifton
The major land use in Clifton consisted of residential area and vacant lots. About 5% land use was commercial, 2% - educational, 26% - institutional, 35% - residential, 1% - office, 4% - public space, and 27% - vacant (CAGIS 2006).

Figure 3.3: Land Use in Clifton Neighborhood of Cincinnati

Source: CAGIS 2006.

Over The Rhine (OTR)

As seen in the land use map, the land use in the neighborhood of Over the Rhine was evenly distributed (CAGIS 2006). The new residential redevelopment in the north of the Central Parkway exhibited a great potential for the development. Over-the-Rhine had some of the finest historic buildings of Cincinnati that gave it a

Source: CAGIS 2006.

Mount Auburn

The major land uses in Mt. Auburn were residential and vacant land. Of the total land uses in Mount Auburn, 39% was residential, 1% - mixed use, 7% - institutional, 2% - industrial, 5% - educational, 25% - vacant, 12% - public spaces, and 6% - office (CAGIS 2006). The high proportion of vacant land exhibited a good potential for the new development projects in this area. Thus a high number of vacant and residential land uses was a positive sign for the transit development.

Figure 3.5: Land Use in Mount Auburn Neighborhood of Cincinnati

Source: CAGIS 2006.
Walnut Hills

Figure 3.6: Land Use in Walnut Hills

As seen in the map, the eastern side of the Walnut Hills neighborhood is predominantly a residential area. Along the eastern side of the I-71 there are number of office spaces, and industrial areas along the I-71. Along the Gilbert Road, there are number of commercial spaces along with the offices and the light industrial development. There is a good number of residential land uses in the Walnut Hills neighborhood (CAGIS 2006).

Source: CAGIS 2006.

Central Business District (CBD)

Figure 3.7: Land Use in CBD

The Central Business district of Cincinnati is the largest employment center in Cincinnati. The initial I-71 corridor light rail alignment was planned on the Walnut Street and the Main Street with the idea to strengthen the existing locations and support the property values (Burgess & Niple, Limited; BRW, Inc., KPMG Peat Marwick LLP, Manuel Padron & Associates, Hogan, Nolan & Stites, R. L. Banks & Associates, Cambridge Systematics, Inc., Gray and Pape 1998, 4.9).
Coryville

The neighborhood of Coryville has a residential land use as a major land use. Of the total land uses in Coryville, about 43% was residential, 31% - public spaces, 1% - educational, 9% - institutional, 1% - office, and 12% - vacant land (CAGIS 2006).

Figure 3.8: Land Use in Coryville Neighborhood of Cincinnati

Source: CAGIS 2006.

CUF

As seen in the map, the major land use in the neighborhood of CUF is residential. The CUF is near to the University of Cincinnati which is the influence of the neighboring land use. The second largest land use in this neighborhood is institutional use with the University Health Alliance in the northern part of it.

Source: CAGIS 2006.
University Heights

Figure 3.10: Land Use in University Heights

The University of Cincinnati in the University Heights neighborhood is the second largest employment center in Cincinnati after the CBD. As seen in the map, the major land uses in the University Heights neighborhood is the public uses and the second largest land use being residential use. At the south of the University Heights, a mixed use development is taking place that comprises of the shopping and living facilities.

3.2.b Major Activity Centers

The major institutions in the Uptown area as recognized in the Uptown Transportation study were University of Cincinnati, Cincinnati Zoo and Botanical Garden, Cincinnati Children’s Hospital, University Hospital, and Good Samaritan Hospital (URS Corporation 2006, 1.1).

For the purpose of study, the major businesses, institutions, recreational centers, schools, offices, and hospitals in the Uptown and Downtown areas of Cincinnati were considered as the ‘major activity centers’. The major activity centers in Mount Auburn were Christ Hospital, three Cincinnati Public School, and three Public Swimming Pools.
along with number of businesses; the major activity center in University Heights were Deaconess Hospital and Cincinnati Public School; the major activity centers in Corryville were V A Medical Center, Children’s Hospital, Shriner’s Hospital, University Hospital with one Cincinnati Public School; the major attraction center in Avondale were Tri State Endoscopy with two Cincinnati Public Schools, one YMCA & YWCA, and one Public Swimming Pool. Apart from this there were number of businesses and monuments that were major activity centers in the Uptown and Downtown areas of Cincinnati that might attract a large number of people (CAGIS 2006).

Figure 3.11: Major Activity Centers in Uptown and Downtown of Cincinnati, OH.

Source: CAGIS 2006.
3.2.c Population

The Uptown area of Cincinnati exhibits an urban setting with the total existing population of 51,132 for the year 2005 and the projected population of 43,726 for the year 2030 (URS Corporation, 2006, 2.2).

Figure 3.12: Population in the different neighborhoods of Cincinnati

The analysis of the ‘Population Map’ for the Uptown and Downtown areas of Cincinnati shows that for the year 2005, the neighborhood of Corryville, CUF, Mount Auburn, North of Avondale, and Southern Clifton are over 2000 persons. The period of 2005 to 2030 shows that the population in the neighborhood of Corryville, southern Clifton, some regions of Northern Avondale remains constant between the categories of 3000 to 4000 persons while in the eastern parts of Mount Auburn and the western parts of Mount Auburn it is declining. The population in the Over the Rhine remains constant. A closer look at the I-71 Corridor shows decline in the population in Walnut Hills along the I-71 corridor (CAGIS 2006 and OKI 2007).

### 3.2.d Household Income

The existing (2000) households in the Uptown areas of Cincinnati were 25,060 in number which reduces by 2,034 to 23,026 for the year 2030. The employment in this area increases from 59,490 in 2005 to 65,648 as projected for the year 2030 (URS Corporation 2006, 2.2). The median income for the neighborhood of University Heights, Corryville, CUF, Avondale, and eastern Walnut Hills was between $20,000 and $40,000. The northern parts of Walnut Hills, Over the Rhine, and some areas of West End had the median income between $0 and $20,000.

![Figure 3.13: Household Income](image-url)

3.2.e Employment

For the year 2005, the highest employment was registered in the northern areas of Corryville, University Heights (i.e. University of Cincinnati), Mount Auburn (along the eastern Vine street) and along the western side of the I-71 Corridor. For the year 2030, the overall employment in the Uptown and the Downtown areas of Cincinnati is increasing. The employment in these areas still remain the highest among the neighborhoods of Uptown and Downtown Cincinnati; but the number of employee in these neighborhoods increases. The employment along the I-75 corridor remains lower than the other areas of Cincinnati but is increasing for the year 2030 (CAGIS 2006 and OKI 2007).

Figure 3.14: Employment in Uptown and Downtown Areas of Cincinnati.

3.2.f Development Projects

The major development projects in the Uptown of Cincinnati as mentioned in the Uptown Transportation Study in Part A are (URS Corporation 2006, 2.4 – 2.8):

- **Cincinnati State Advance Tech & Learning Center** which is 216,000 sq ft classroom and student life center.

- **American Jewish Archives Hebrew Union College** which is an extension to the existing facility.

- **Brunet Avenue Redevelopment Strategy** that is planned to be achieved in five stages and will consist of 95 dwelling units, 220,000 sq ft office, and 60,000 sq ft retail space in first stage of development. In the second stage of development, it is planned to develop 135 dwelling units, 15,000 sq ft retail and 10,000 sq ft civic space. In the third stage of development it is planned to develop 80 dwelling units and 35,000 sq ft retail space. In the fourth stage of development it is planned to develop 30 dwelling units and in the fifth stage of development it is planned to develop 20 dwelling units.

- **Calhoun Street Gateway** which is planned to be a retail and housing development with 100 dwelling units, 150,000 sq ft office space, 50,500 sq ft of retail space and 540 parking spaces.

- **University of Cincinnati’s Calhoun Street mixed use development** that will consist of 744 beds, 37,000 sq ft retail and 1,000 car parking space.
- **University Park in Clifton Heights** at and Calhoun Street Marketplace which is proposed for the development of 758 beds, 35,000 sq ft office space and 399,250 sq ft retail space.

- **McMillan Place development** in Phase I, Phase II, and Phase III that is planned at Clifton Heights and Calhoun Street Marketplace which will develop 240 dwelling units and 53,000 sq ft retail development. The Phase III development will propose 120 dwelling units.

- **The University of Cincinnati Campus Recreation Center** which is a mixed use development with 227 beds and 335,000 sq ft of recreation space.

- **Charleton Place Town homes** which are a redevelopment project planned to propose 12 dwelling units.

- **Children’s Hospital Medical Center Research Tower** that is a project with the proposal of 363,000 sq ft of research facility. It is a 9 story development with the facilities of housing and research laboratory.

- **Good Samaritan Hospital Tower** which is a 175,000 sq ft of medical facility expansion.

- **Highland Place** which is a 5 story of Class A office space with the area of approximately 74,000 sq ft.

- **University of Cincinnati Jefferson Residence Hall Complex** which is an on-campus residence hall development housing 350 beds.

- **University of Cincinnati Joseph Steger Student Life Center** which is a 92,000 sq ft of mixed use development with the spaces for offices, art gallery, computer laboratory and food services.
- **McMillan Manor** which is a six story student housing project in Mount Auburn with 119 dwelling units.

- **University of Cincinnati Medical Sciences Building** that is 239,000 sq ft of development in the east campus.

- **Old Town Parking Garage** which houses 10,000 sq ft of offices and 5,000 sq ft of retail space.

- **University of Cincinnati Richard E. Linder Center** at the Varsity Village which is a 236,000 sq ft of mixed use development.

- **Rockdale Elementary School** which is a new K-8 elementary school on existing site for Cincinnati Public Schools consisting of 3 buildings that covers the area of 86,160 sq ft.

- **Schott Education Center** which is a 33,000 sq ft educational center development.

- **Stratford Heights** which is a 710 beds and 18,000 sq ft of community building development.

- **University of Cincinnati Tangeman University Center** which is a 240,000 sq ft of mixed use development that comprises of classrooms, offices, theater, food court and meeting spaces.

- **University Village** which is a revitalization project proposing 1,498 dwelling units, 58,000 sq ft of office space, 276,300 sq ft of retail space and 2,400 parking spaces.

- **Uptown Crossing/Zoo Area** that is a redevelopment project proposed in three phases. The Phase I proposes the surface parking development, the Phase II proposes 140 Dwelling Units and 12,500 sq ft of retail space. The Phase III
proposes 162 dwelling units with 200,000 sq ft of office and 75,000 sq ft of retail space.

- **University of Cincinnati Varsity Village** which is a recreation and open space development.

- **Village at Stetson Square** which is a redevelopment of a 6 block residential area into a mixed use retail, owner and rental occupied dwelling developing

Figure 3.15: Redevelopment Projects in Uptown of Cincinnati

Source: URS Corporation 2006, 2.9.
The entire neighborhood of Corryville, certain areas of University Heights, certain areas of Avondale, eastern area of Walnut Hills, and the CBD are recognized as Urban Renewal Districts; the neighborhood of Over – the – Rhine, certain areas of Clifton and Mount Auburn are recognized as Historic Districts; the area of Corryville near the Jefferson is recognized as the Urban Design District (CAGIS 2006).

Figure 3.16: Redevelopment Projects, Urban Design District and Historic Districts

Source: CAGIS 2006.
3.2.g Travel Patterns

The Uptown Transportation Study’s Part B document indicates that of the 26,500 residents in the Uptown of Cincinnati, more than 9,500 walk to work while around 7,700 use some means of transportation other than driving alone as a means to travel to work while only about 9,300 residents use drive alone as a mode of travel to work. This is a very low number compared to the other metropolitan areas (URS 2006, 2.8). The daytime population of Uptown area is twice the permanent population as there are approximately 300,000 daily vehicle trips into and out of the Uptown (URS 2006, 21).

In the Uptown neighborhood of Cincinnati, maximum residents either walk or drive alone for the work that consists of 36% and 35% of the total residents respectively. About 10% work at home, 8% use public transit, 5% carpool with two persons, 2% carpool with three persons and 1% of the residents use a cab (URS 2006, 2.10). The University of Cincinnati being the second largest employment center and many residents living in and around the campus, can walk to work in the Uptown area.

Figure 3.17: Mode of Travel for the Uptown Residents of Cincinnati

Source: URS 2006, 2.10
As per the data available from the Uptown Transportation Study Part A, the highest zero car neighborhoods were University Heights, Corryville, Walnut Hills, and Mount Auburn. On the other hand, the lowest numbers of zero car neighborhoods were Clifton and CUF (URS 2006, 2.15). Thus, the neighborhoods of University Heights, Corryville, Avondale, and Walnut Hills exhibit high potential to ride the public transit.

### 3.2.h Trip Generation and Ridership

Of the total riders projected to be traveling the I-71 Light Rail Corridor, 32% are projected to either embark or disembark downtown, 54% will be embarking or disembarking from Cincinnati and 70% would be from Hamilton County. It is estimated
that about 31,000 people will be riding light rail daily along the I-71 corridor by the year 2020 and by increasing the number of car in the light rail from 2 cars to 3 cars and simultaneously increasing the frequency of the rail; the ridership can be increased to 248,000 riders. The light rail system will increase public transit ridership by 28% and along the I-71 corridor, the increase in ridership will be by 47% (Frank 1998).

Table 3.1: Projected (2020) Daily Boardings for Various areas of Cincinnati

<table>
<thead>
<tr>
<th>Station Location</th>
<th>Projected Daily Boardings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government Square</td>
<td>6,820</td>
</tr>
<tr>
<td>Court Street</td>
<td>2,807</td>
</tr>
<tr>
<td>Xavier University</td>
<td>1,499</td>
</tr>
<tr>
<td>Galbraith Road</td>
<td>1,343</td>
</tr>
<tr>
<td>University of Cincinnati</td>
<td>1,196</td>
</tr>
<tr>
<td>Fields Ertel Road</td>
<td>980</td>
</tr>
<tr>
<td>Medical Center</td>
<td>961</td>
</tr>
<tr>
<td>Norwood</td>
<td>788</td>
</tr>
<tr>
<td>Reading Road</td>
<td>706</td>
</tr>
<tr>
<td>Mt. Auburn</td>
<td>690</td>
</tr>
<tr>
<td>Pfeiffer Road / Blue Ash</td>
<td>574</td>
</tr>
<tr>
<td>Cornell Road</td>
<td>552</td>
</tr>
<tr>
<td>Over – the – Rhine</td>
<td>544</td>
</tr>
<tr>
<td>Kings Mill Road</td>
<td>439</td>
</tr>
<tr>
<td>Western Row Road</td>
<td>382</td>
</tr>
<tr>
<td>Cooper Road</td>
<td>281</td>
</tr>
<tr>
<td>Mason</td>
<td>261</td>
</tr>
<tr>
<td><strong>Total – Southwest Ohio</strong></td>
<td><strong>23,265</strong></td>
</tr>
</tbody>
</table>


According to the I-71 Transportation Study conducted in 1998 for the daily boardings of the light rail, the maximum daily projected boarding was at Government Square with the Court Street being second, and Xavier University at third position. The other highest boardings were projected at Galbraith Road and University of Cincinnati.
CONCLUSION

For the planning of any infrastructure in any place, it is very important to know the features of that place. This chapter discusses the various features of the study area like the land use, household composition, household income, vehicle ownership, major activity centers, and the redevelopment projects. It thus prepares the readers for the understanding of the study area and later helps in deciding the alternate route to the Mount Auburn Tunnel by light rail.
CHAPTER 4
LITERATURE REVIEW
4.1 WHAT IS LIGHT RAIL?

“Transit systems, including light rail transit (LRT) systems, exist to move people safely, conveniently, and efficiently (Lutin and Benz 1992, 117).”

Light Rail – The first mechanized form of urban mass transit was introduced in 1880s to feed the expansion of the cities leading to the development of the star-shaped pattern along the lines of the rail (Kuby, Barranda, and Upchurch 2003, 224). The Light Rail Transit is the railway that can operate on a variety of the right-of-way conditions with the modern LRT exhibiting the capacity to carry about 150 to 200 passengers on 80 to 90 feet long vehicle (Burgess & Niple, Limited, BRW, Inc., KPMG Peat Marwick LLP; Manuel Padron & Associates, Hogan, Nolan & Stites, R. L. Banks & Associates, Cambridge Systematics, Inc., Gray and Pape 1998, 2.34). In 1976, the Transportation Research Bureau (TRB) committee on Light Rail Transit adopted the concise definition of Light Rail (Schuman 1989, 9). According to TRB,

“Light rail transit is a mode of urban transportation that uses predominantly reserved, but not necessarily grade-separated, rights-of-way. Electrically propelled vehicles operate singly or in trains. Light rail transit provides a wide range of passenger capacities and performance characteristics at moderate costs (Schumann 1992, 3).”

The American Public Transportation Association (APTA) in 2002 defines Light Rail as “lightweight passenger rail cars operating singly (or in short, usually tow-car, trains) on fixed rails in right-of-way that is not separated from other traffic for much of the way (Kuby, Barranda, and Upchurch 2003, 229).” The Light Rail Vehicles (LRVs) have to be drawn by electric power particularly from an overhead electric line. The light rail is also known as “streetcar”, “tramway”, or “trolley” (Kuby, Barranda, and Upchurch 2003, 229).
In 1970s, there were 11 definable LRT and streetcar system in eight US cities including Toronto and Mexico City and in 1977; virtually all the systems were modernized or refurbished (Schuman 1989, 12). The cities in which light rail has been installed and is a success are San Diego (1981), Buffalo (1985), Portland (inter-urban LRT 1986), Sacramento (1987), San Jose (1987), Los Angeles (1990), Baltimore (1992), St. Louis (1993), Memphis (1993), Denver (1994), Dallas (1996), Salt Lake City (1999), Kenosha (2000), Hudson-Bergen in New Jersey (2000), Tampa (2002), Tacoma (2003), Huston (2004), Little Rock (2004) and Minneapolis (2004). The Light Rail is under construction in the cities of Seattle, Phoenix, and Charlotte and under expansion in the cities of San Francisco, Boston, Philadelphia, Cleveland, Pittsburg and Newark. The other cities where the construction of Light Rail is under evaluation are Tucson, Omaha, Cincinnati (OH), Toledo, Huntington (WV), Richmond, Montgomery (AL), and Charlottesville (VA) (Light Rail Now 2006).

The light rail in Baltimore (MD) is operated by Maryland Transit Administration (MTA), in Buffalo (NY) is operated by Niagara Frontier Transit Metro System (Metro), in Cleveland (OH) is operated by Greater Cleveland Regional Transit Authority (RTA), in Dallas (TX) is operated by Dallas Area Rapid Transit Authority (DART), in Portland (OR) is operated by Tri-County Metropolitan Transportation District of Oregon (TriMET), in Sacramento (CA) is operated by Sacramento Regional Transit District (SRTD), in Saint Louis (MO) is operated by Bi-State Development Agency (BSDA or Bi-State Transit), in Salt Lake City (UT) is operated by Utah Transit Authority (UTA), and in San Diego (CA) is operated by San Diego Trolley (SDT) (Kuby, Barranda, and Upchurch 2003, 229).
Figure 4.1: US Cities with Light Rail Transit and the Timeline they were constructed.

Source: Kuby, Barranda, and Upchurch 2003, 225.
4.2 WHY LIGHT RAIL?

The light rail systems are generally quite, clean and create less vibrations compared to the heavy rail system and at the same time carry a good number of people (but less than what heavy rail can carry). The light rail does not necessarily have to have a designated right-of-way. They can operate in a highway median, or within a downtown street with the light rail stations that can be relatively small and the spacing between them can vary to accommodate the needs of the passengers. The light rail is highly compatible in the urban as well as suburban locations with varied land uses (Burgess & Niple, Limited, BRW, Inc., KPMG Peat Marwick LLP, Manuel Padron & Associates, Hogan, Nolan & Stites, R. L. Banks & Associates, Cambridge Systematics, Inc., Gray and Pape 1998, 4.3).

The LRT receives superior attraction for riders against other transit services due to its high acceleration electric propulsion, higher than average transit speed, larger vehicles than motor buses, exclusive transit lanes at various routes, protection from weather, train signals on exclusive right-of-way, bus transfer privileges, overhead trolley power supply, petroleum conservation and no on-line emission. The passengers prefer LRT as it has no on-board engine noise, no air pollution and unexpected stops along the routes, more interior space per passenger, has fixed and self proclaimed route, smooth ride, it can handle large volumes with its multi-car operation, can provide different transit travel, and can lead to urban development along fixed right-of-way (Tennyson 1982, 46). The Light Rail can be installed using a long, exclusive right-of-way from the Central Business District (CBD) to the other metro centers and the suburbs. Using a short and
densely used right-of-way in the CBD and other metro centers, the routes of the LRT could be directed in the manner to avoid traffic congestion and thus allowing priority streetscape for high-volume lines and providing fast feeders to a heavier rail mode (Tennyson 1982, 47).

The light rail virtually fills the gap between the bus and a metro. The light rail stations can be spaced at a distance of 400 – 600 m while the metro needs the station spacing of at least 800m. With the walking distance being 350 m, a person can virtually walk between the stations of light rail (Topp 1999, 136).

This means that the light rail can service more number of stations in one line than the Metro can. At the same time the light rail can service the lesser number of stations than the bus can. Thus, the light rail can optimize the service of the bus and the regional rail which helps it to gain a speed higher than a bus and a service to the number of stations that is better than a regional rail. Light Rail looks more “urban” and the quietness, smoothness and speed makes it very convenient to ride for various purposes of the trips. Thus, light rail is the better alternative compared to the bus and the regional rail transportation system and bus transportation system.
4.3 CLASSIFICATIONS OF LIGHT RIAL

The light rail system can be classified on the basis of its operating speeds and the spatial configuration.

4.3.a Spatial Classification of Light Rail

Based on the spatial organization the Light Rail System can be classified into “Type A”, “Type B”, and “Type C”.

Type A: These are the exclusive alignments for the light rail. They have a full grade separation for pedestrian crossing facility and thus, the grade crossing and operating facility conflicts are eliminated (Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 15).

Figure 4.3: Exclusive Right-of-Way (Type A) Light Rail Alignment.

**Type B:** These are the “semi exclusive” alignments that use the limited grade crossing. As the right-of-way is fenced or has a substantial barrier that separates the light rail vehicles from the automobile, bicycle and the pedestrian traffic. Here, the crossing is provided only on the places where it is not avoidable. The speed of the Light Rail is reduced in the Type B alignment compared to the Type A alignment, yet in the places where the right-of-way is fenced or protected, the speed of the light rail can be increased. The speed of the vehicles in the adjacent right-of-way is the governing factor for deciding the speed of the light rail in the Type B alignment. The Type B kind of alignment can be further divided into ‘B1’, ‘B2’, ‘B3’, ‘B4’, and ‘B5’ (Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 14 - 16).

**Type B1** is a semi-exclusive right-of-way with the crossings for the motor vehicles, pedestrians and bicycles at designated locations only. Here the right of way at the crossings is protected by the fencing or the barriers and generally the crossings are provided at grade level (Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 15).

Figure 4.4: Semi – Exclusive Right-of-Way (Type B1) Alignment.

*Source: Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 15.*
Type B2 is the semi-exclusive right of way where the motor vehicles and the pedestrians cross the right of way at designated locations and the tracks for the LRT are separated by the 6 inch high curbs and fences (Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 15).

Figure 4.5: Semi – Exclusive Right-of-Way (Type B2) Alignment.


Type B3 is a semi-exclusive right of way within the streets that is protected by 6 inch curb and the motor vehicles and the pedestrians can cross the light rail right-of-way at a designated crossing only. In this kind of alignment, there may be a fence in between the tracks (Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 15).

Figure 4.6: Semi – Exclusive Right-of-Way (Type B3) Alignment.

Source: Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 16.
Type B4 is the semi-exclusive alignment that is separated by the mountable curb on the street right of way and at the same time allows the pedestrian and vehicular traffic at designated locations (Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 15).

Figure 4.7: Semi – Exclusive Right-of-Way (Type B4) Alignment.

Source: Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 16.

Type B5 is the semi-exclusive alignment generally located near the malls and the pedestrian walkways. In this case, the right of way is parallel to the roadways and separated by 6 inch or higher curb. In this case, the pedestrians cross the LRT tracks at any location but the vehicular traffic cross the LRT tracks at the designated locations only (Korve Engineering Inc. 1996, 17).

Figure 4.8: Semi – Exclusive Right-of-Way (Type B5) Alignment.

Source: Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 16.
**Type C**: These are the “non exclusive” alignments that share the right-of-way with the pedestrians and motorists. These kinds of alignments often result in higher conflicts and lower speeds of the LRT and hence are feasible in the areas where speed is not the vital feature of the transportation. These kind of alignments are generally found in higher density areas like the downtown, transit mall, shopping mall, etc (Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 13). The ‘Type C’ alignment can be further classified into ‘C1’, ‘C2’, and ‘C3’ depending on their location and use where C1 is called Mixed Use, C2 is specified for the transit malls and C3 is specified for the pedestrian malls (Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 17).

**Type C1** is considered as “Mixed Traffic Operations / Surface Street” where the motor vehicles and the bicycles share the surface road and there is no clear demarcation between the roadway the LRT tracks (Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 17).

Figure 4.9: Non – Exclusive Right-of-Way (Type C1 / Mixed Traffic) Alignment.

*Source: Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 16.*
Type C2 is considered as “Transit Mall” non-exclusive alignment. Here the LRT that is parallel to the roadway traffic is mainly used for the embarking and disembarking the passengers that are separated by the raised curb (Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 17).

Figure 4.10: Non – Exclusive Right-of-Way (Type C2 / Transit Mall) Alignment.

Source: Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 16.

Type C3 is also called as “LRT / Pedestrian Mall” alignment where the pedestrians share the right of way and motor vehicles and bicycles are prohibited from operating on or adjacent to the LRT tracks. Here the motor vehicles cross the LRT tracks at the designated locations (Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 17).

Figure 4.11: Non – Exclusive Right-of-Way (Type C3 / Pedestrian Mall) Alignment.

Source: Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 16.
4.3.b Classification of Light Rail based on the Operating Speeds

Based on the operating speeds, the light rail can be classified as Group I, Group II and Group III (Schuman 1989, 13).

**Group I:** The average operating speed ($V_{avg}$) for Group I rail is greater than 15mi/hr or 24km/hr. The cities of Calgary, Cleveland, Edmonton, Newark, Philadelphia, Portland, Sacramento, San Diego, and San Jose have this kind of light rail (Schuman 1989, 13).

**Group II:** The average operating speed ($V_{avg}$) of this group of rail is between 10mi/hr to 15mi/hr or between 16km/hr to 24km/hr. The cities of Boston, Buffalo, Fort Worth, Philadelphia, Pittsburg and San Francisco have this kind of light rail (Schuman 1989, 13).

**Group III:** The average operating speed ($V_{avg}$) of this group of rail is less than 1mi/hr or less than 16km/hr. The cities of New Orleans and Philadelphia have this kind of light rail (Schuman 1989, 13).

### 4.4 LIGHT RAIL IN CINCINNATI

Light rail being efficient and reliable option to move large number of people, smaller cities similar to Cincinnati like Denver, St. Louis, Dallas and Portland are developing and expanding light rail. Light rail is a good alternative to combat the congestion in Cincinnati because limiting the transit improvements to only highway expansion can be very expensive. Apart from this, light rail provides a better alternative for commuters

Figure 4.12: Light Rail Alignment in Cincinnati

Source: OKI
4.4.a I – 75 Corridor LRT

The I – 75 LRT is a part of the North-South Transportation initiative sponsored by the OKI. It serves the communities of Arlington Heights, Bond Hill, Carthage, Elmwood Place, Glendale, Hartwell, Lincoln Heights, Lockland, Springdale, St. Bernard, Tri-County, Woodlawn, Wyoming and West Chester. The track mileage of I – 75 is 15 miles with 13 miles in Hamilton County serving 9 stations in these communities. The estimated riders per day is 23,000 with 22,000 in Hamilton County and the estimated cost for the construction of the I – 75 corridor is about $610 million with $530 million for construction in Hamilton County (SORTA 2002, 16).

Figure 4.13: I – 75 Corridor Light rail Alignment

Source: SORTA 2002, 16
4.4.b Westside Light Rail

The Westside light rail begins in the downtown of Cincinnati at Central Parkway and connects with I-71 to head west and north along the Central Parkway. It uses the old subway tunnels built in 1920. The main communities or the destinations served by this line are Camp Washington, Cincinnati downtown and riverfront, Cincinnati State, Clifton, Dent, Green Township, Monfort Heights, Northside, University Heights, and West End. The total mileage of this line is 12 miles that is all along Hamilton County only and the number of stations is estimated to be 8. This line will serve about 18,000 riders per day with the estimated cost of building to be about $490 million (SORTA 2002, 17).

Figure 4.14: Westside Light Rail in Cincinnati

Source: SORTA 2002, 17
4.4.c Eastside Light Rail

The eastside light rail shares the route on I-71 from downtown Cincinnati to Xavier University. From I-71 the line turns east on existing tracks past the Rookwood shopping centers and through Hyde Park and Oakley and then on the State Route 32 it runs parallel to reach I-275 and the Eastgate area. The main communities and destinations served by Eastside LRT are Anderson Township, Evanston, Fairfax, Hyde Park, Newtown, Oakley, Xavier University, Eastgate, and Union Township. The Eastside LRT line is 12 miles long with 10 miles in Hamilton county and 5 stations serving these communities. The Eastside LRT is estimated to get 20,000 riders per day by serving the population of 148,000. The estimated building cost for this line is $450 million with $370 million as a building cost in Hamilton County (SORTA 2002, 18).

Figure 4.15: Eastside Light Rail in Cincinnati

4.4.d I-471 Light Rail

The I-471 LRT line was planned to link the downtown Cincinnati and its riverfront to Northern Kentucky communities along with serving the destinations of Alexandria, Cold Springs, Crestview, Ft. Thomas, Highland Heights, Northern Kentucky University, Southgate, Wilder and Woodlawn. The I-471 LRT line is about 10 miles long with only 1 mile in Hamilton County. It is estimated to have daily riders of about 10,000 with about 6,000 from Hamilton County serving the total population of 65,500. The estimated cost of building this line is about $360 million with $50 million in Hamilton County (SORTA 2002, 19).

Figure 4.16: I-471 Light Rail Alignment in Cincinnati
4.4.e  Crosstown Light Rail

The Crosstown line was the addition during the refinement to connect the Eastside line to I – 75. This is 4-mile long line that creates a direct and unique LRT line to allow passengers to travel the breadth of Hamilton County without changing trains in downtown. The Crosstown light rail runs only in the community of Winton Place with a single station that is estimated to get about 11,000 riders par day serving the population of about 228,000 at the estimated cost of $110 million for its construction (SORTA 2002, 20).

Figure 4.17: Crosstown Light Rail in Cincinnati

Source: SORTA 2002, 20
4.4.f  I-71 Corridor Light Rail

As per the I-71 Transportation Corridor Study, the Mount Auburn tunnel served as a direct link from Uptown to Downtown of Cincinnati; but the refined SORTA plan proposes to move the Mount Auburn line to east along the I-71. According to SORTA, this choice reduces the cost of the I-71 starter segment which will go down to $730 million and remove the uncertainty associated with tunneling (SORTA 2002, 21).

Figure 4.18: I-71 Corridor Light Rail in Cincinnati

Source: Light Rail Progress 2001
4.5 I-71 CORRIDOR AND MOUNT AUBURN TUNNEL

The I-71 light rail corridor was planned to connect the CBD of Covington to Kings Mill in Cincinnati. The first segment of the starter line called the ‘Segment S1’ was planned to start on the north side of 19th Street, just west to the CSX railroad corridor in the CBD of Covington in Kentucky to the Riverfront in Cincinnati. It passed through CBX in CBD of Covington, Washington Street, Pike Street and finally turns north on Madison Avenue. This segment of the alignment serves the stations to be located on 19th Street that was planned as a park and ride station, 12th Street Station, Pike Street Station and the Covington CBD station (Burgess & Niple, Limited; BRW, Inc., KPMG Peat Marwick LLP, Manuel Padron & Associates, Hogan, Nolan & Stites, R. L. Banks & Associates, Cambridge Systematics, Inc., Gray and Pape 1998, 2.38).

The second segment called the ‘Segment N1’ of the I-71 light rail corridor connected the riverfront to Over-the-Rhine area in Cincinnati. From the Ohio Riverfront, this segment continued to cross Race Street across Fort Washington Way, then the Third Street to the Main Street or Walnut Street where it was designated as a one-way track. The Main Street was the northbound track while the Walnut Street was the southbound track. Along this segment, the stations were proposed on Riverfront between Mehring Way and Third Street, on Government Square at the Fifth Street, between Ninth and Eight Street and the Over-the-Rhine Station located between the 13th Street and the 14th Street (Burgess & Niple, Limited, BRW, Inc., KPMG Peat Marwick LLP, Manuel Padron & Associates, Hogan, Nolan & Stites, R. L. Banks & Associates, Cambridge Systematics, Inc., Gray and Pape 1998, 2.38 – 2.39).
The ‘Segment N2’ ran from Over-the-Rhine to Reading Road to connect to the Uptown area of Cincinnati. This segment started from Main Street and 14th Street and from Walnut Street and 14th Street (as these were one way tracks) then crossed the Liberty Street to merge on the Main Street on the south portal of the Mount Auburn Tunnel that began at the Mulberry Street. The tunnel then opened up in the Uptown area with its north portal located at the west of Jefferson Avenue at Calhoun Street near the University of Cincinnati Campus. At the Jefferson Avenue, the light rail tracks crosses the Daniels Street and University Avenue where it was at-grade. This alignment then turned to the east and ran northbound to the Martin Luther King Jr. Drive towards the I-71. While running northbound, the track crossed Eden Avenue, underpassed at Bellevue Avenue, Highland Avenue and Brunet Avenue. It again crossed at grade at Harvey Road and then again underpassed at Reading Road. On the ‘Segment N2’ the stations were proposed at Christ Hospital in Mt. Auburn, University of Cincinnati, Medical Center at the University of Cincinnati and one at Reading Road (Burgess & Niple, Limited, BRW, Inc., KPMG Peat Marwick LLP, Manuel Padron & Associates, Hogan, Nolan & Stites, R. L. Banks & Associates, Cambridge Systematics, Inc., Gray and Pape 1998, 2.39 – 2.40).
Figure 4.19: Layout of Mount Auburn Tunnel for Light Rail in Cincinnati

Source: CAGIS 2006, SORTA 2002
4.6 CAPITAL COST FOR LIGHT RAIL ALONG I-71 CORRIDOR

In the I-71 Corridor Transportation Study, for the purpose of calculating the cost of the LRT, the various construction elements were categorized to develop the approximate unit costs. In this case, the “conceptual design” of the LRT alignment was assumed to be consistent with the I-71 Corridor Transportation Study’s LRT Design Guidelines (Burgess & Niple, Limited, BRW, Inc., KPMG Peat Marwick LLP, Manuel Padron & Associates, Hogan, Nolan & Stites, R. L. Banks & Associates, Cambridge Systematics, Inc., Gray and Pape 1998, 5.1).

Table 4.1: Costing for Guideway

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>1996 $ Value of Cost per sq ft</th>
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<tbody>
<tr>
<td>A – 1</td>
<td>At – Grade Double Track</td>
<td>368</td>
</tr>
<tr>
<td>A – 2</td>
<td>At – Grade Double Track with Retained Ballast</td>
<td>322</td>
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<tr>
<td>A – 3</td>
<td>At – Grade Paved Double Track with Street Reconstruction</td>
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<td>A – 4</td>
<td>At – Grade Paved Single Track with Street Restoration</td>
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<td>C – 1</td>
<td>Retained Cut Double Track (1 Side)</td>
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<tr>
<td>C – 2</td>
<td>Retained Cut Double Track (2 Side)</td>
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<td>F – 1</td>
<td>Retained Fill Double Track (1 Side)</td>
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<tr>
<td>F – 2</td>
<td>Retained Fill Double Track (2 Side)</td>
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<td>E – 1</td>
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<td>E – 2</td>
<td>Ohio River Bridge</td>
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<td>T – 1</td>
<td>Cut &amp; Cover Tunnel Double Track</td>
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<td>T – 2</td>
<td>Mount Auburn Tunnel</td>
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Table 4.2: Costing for Systems

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<tr>
<th>Description of Work</th>
<th>1996 $ Value of Cost per sq ft</th>
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<tr>
<td>Traction Electrification (Double Track, Non –CBD)</td>
<td>248</td>
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<tr>
<td>Traction Electrification (Double Track, Tunnel)</td>
<td>368</td>
</tr>
<tr>
<td>Traction Electrification (Double Track, CBD)</td>
<td>368</td>
</tr>
<tr>
<td>Traction Electrification (Single Track, CBD)</td>
<td>276</td>
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<td>Signal Systems (Double Track, Non – CBD)</td>
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<td>Signal Systems (Double Track, Tunnel)</td>
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<tr>
<td>Signal Systems (Double Track, CBD)</td>
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<tr>
<td>Signal Systems (Single Track, CBD)</td>
<td>92</td>
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<tr>
<td>Communications Systems (Double Track)</td>
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<tr>
<td>Communications Systems (Single Track)</td>
<td>83</td>
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<tr>
<td>Fare Collection Systems</td>
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Table 4.3: Costing for Stations

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<tr>
<th>Station Location</th>
<th>1996 $ Value of the Cost</th>
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<tbody>
<tr>
<td>Florence Mall Park and Ride</td>
<td>2,604,831</td>
</tr>
<tr>
<td>Donaldson Highway Park and Ride</td>
<td>3,004,110</td>
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<tr>
<td>Airport Terminal Station</td>
<td>1,084,420</td>
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<tr>
<td>Mineola Park and Ride</td>
<td>3,014,658</td>
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<tr>
<td>Buttermilk Pike Park and Ride</td>
<td>2,010,513</td>
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<td>Kyles Lane Park and Ride</td>
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<td>Nineteenth Street Park and Ride</td>
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<td>Twelfth Street Station</td>
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<td>Pike Street Station</td>
<td>588,040</td>
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<tr>
<td>River Center Station</td>
<td>1,084,420</td>
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<td>Riverfront Station</td>
<td>588,040</td>
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<td>Government Square Station</td>
<td>588,040</td>
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<tr>
<td>Court Street Station</td>
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<tr>
<td>Over – The – Rhine Station</td>
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<tr>
<td>Mount Auburn Tunnel</td>
<td>25,000,000</td>
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<tr>
<td>University of Cincinnati Station</td>
<td>1,060,930</td>
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<td>Medical Center Station</td>
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<td>Reading Road Station</td>
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<tr>
<td>Xavier University Park and Ride</td>
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<td>Norwood Station</td>
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<tr>
<td>Ridge Avenue Park and Ride</td>
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<td>Silverton Station</td>
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<td>Galbraith Road Park and Ride</td>
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<td>Cooper Road Park and Ride</td>
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<td>Pfeiffer Road Park and Ride</td>
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<td>Cornell Road Park and Ride</td>
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<td>Mason Park and Ride</td>
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<td>Western Row Road Station</td>
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<td>Kings Mills Road Park and Ride</td>
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Table 4.4: Costing for Right-of-Way

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<td>Suburban</td>
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<td>CBD</td>
<td>5,300,000</td>
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Table 4.5: Costing for Special Conditions

<table>
<thead>
<tr>
<th>Description of Work</th>
<th>1996 $ Value of Cost per sq ft</th>
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<tr>
<td>Utility Relocation (Double Track, Non – CBD)</td>
<td>46</td>
</tr>
<tr>
<td>Utility Relocation (Double Track, CBD)</td>
<td>552</td>
</tr>
<tr>
<td>Utility Relocation (Single track, CBD)</td>
<td>368</td>
</tr>
<tr>
<td>Roadway Restoration (Conventional)</td>
<td>3.35</td>
</tr>
<tr>
<td>Roadway Restoration (Freeway)</td>
<td>8.28</td>
</tr>
<tr>
<td>Roadway Restoration (Freeway Ramp)</td>
<td>9.40</td>
</tr>
<tr>
<td>Roadway Structure</td>
<td>72</td>
</tr>
<tr>
<td>Railroad structure</td>
<td>300</td>
</tr>
<tr>
<td>Railroad Track Restoration</td>
<td>255</td>
</tr>
<tr>
<td>Traffic Signal</td>
<td>95,000 each</td>
</tr>
<tr>
<td>Grade Crossing</td>
<td>100,000 each</td>
</tr>
<tr>
<td>Traffic Control</td>
<td>10%</td>
</tr>
</tbody>
</table>


Table 4.6: Costing for Vehicles

<table>
<thead>
<tr>
<th>Description</th>
<th>1996 $ Value of Cost per No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low – Floor Light Rail Vehicle</td>
<td>2,500,000</td>
</tr>
<tr>
<td>Transit Bus</td>
<td>250,000</td>
</tr>
</tbody>
</table>


4.7 LIGHT RIAL IN PORTLAND

4.7.a Layout

The light rail in Portland known as ‘Metropolitan Area Express (MAX)’ is operated by TriMet runs 44 miles in Portland with the service to 64 stations. The Portland light rail can be divided in ‘Blue Line’, ‘Red Line’, and ‘Yellow Line’. The four major light rail projects proposed by MAX are ‘Eastside Light Rail’, ‘Westside Light Rail’, ‘Airport Light Rail’, and ‘Interstate Light Rail’ (TriMet 2007).
The Interstate MAX is a 5.8 miles long yellow line project that was opened in May 2004 and services 10 stations. It connects the North and the Northeast of Portland with the Portland City Center and the rest of the MAX light rail system (TriMet 2007). For an Interstate Light Rail project, ‘A design priority was to transform Interstate Avenue into a pedestrian friendly, multi-modal urban street (TriMet 2007, 1).’
The ‘Airport MAX’ is a 5.5 miles long red line that opened in September of 2001 with services to 4 stations. It connects the airport with key destinations of Oregon Convention Center and the Portland City Center.

Figure 4.22: Red Line Light Rail in Portland


The Westside MAX is an 18 miles long blue line project that was opened in September of 1998 with the service to 32 stations. It connects Hillsboro, Beaverton and Portland City Center (TriMET 2007).

Figure 4.23: Westside Light Rail Line in Portland

The Eastside MAX is a 15 miles blue line servicing 30 stations. It was opened in 1986 and connects Gresham and Portland City Center. It is one of the nations’ first light rail system (TriMET 2007).

Figure 4.24: Eastside Light Rail Line in Portland

In the year 1994, of the total 27.1 miles of LRT in Portland, about 10.2 miles were exclusive alignment that is Type A alignment, about 15.8 miles were semi exclusive alignments that are Type B alignment and 1.1 miles were non exclusive alignments that is Type C alignment. Of these total miles of the LRT, 15.1 miles were the mainline routes and of the total LRT miles about 52% of the LRT miles were semi exclusive and non exclusive that operated under 35 MPH (Korve Engineering Inc. 1996, 17).

4.7.b Geography of Light Rail in Portland, OREGON

The light rail service in Portland can be divided into Line Section I (LS-I), Line Section II (LS-II), Line Section III (LS-III) and Line Section IV (LS-IV). MAX in LS-I operates as Oregon Public Utility Commissioner that operates on single-track railroads with the crossing streets and the light rail running at the highest speed of 55 mph. The LS-I
section is protected along the two – directions while the vehicular and pedestrian traffic are regulated by standard railroad crossing signals. In the LS-II section, the MAX travels at a maximum speed of 35 mph in the median of a two-way street. In this section, the vehicular and the pedestrian traffic cross the railroad tracks at designated intersections only. In LS-III MAX operates on a completely separated right-of-way with the rail operating at maximum speed of 55mph. In the section of LS-IV, MAX travels with the maximum speed of 15 to 25 mph. The LS-IV lanes are reserved for the light rail with vehicular and pedestrian traffic crossing the lane at almost every intersection (Colombo 1992, 19).

4.7.c Extension of Portland Light Rail

The Eastside line in Portland carries about 24,000 weekday rides after being in service for 5 years while the Northwest 185th Avenue is being finalized with the extension that includes a 3 miles long tunnel that runs beneath the hills separating the downtown Portland and its western suburbs (Schumann 1992, 9).

4.8.d Issues and Concerns

The safety concerns on the Portland LRT are mainly due to the motorist failing to abide the traffic signs and signals. Of the total accidents that occurred for Tri-MET’s MAX, 41% of the accidents involved the vehicle turn in front of the LRV, 39% involve the right-angle collisions and 15% involve the pedestrians (Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 36 - 37).
4.8 LIGHT RAIL IN SAN DIEGO, CALIFORNIA

4.8.a Layout

Opening of the San Diego light rail in 1981 is considered as a landmark event in the new U.S. LRT system. San Diego adopted a “no-frills, low-budget, and reuse” as a concept for the development of the LRT (Schuman 1989, 33). “The San Diego Trolley, Inc., operates two LRT lines: the East line (from Imperial/12th to El Cahon) and the South line (from County Center to San Ysidro) (Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 41).”

Figure 4.25: Light Rail Transit Layout in San Diego, CA

Source: Whal, and Humiston. 1992. 279
4.8.b  Classification of Light Rail in San Diego

The trolley in San Diego is categorized as Blue Line, Orange Line, Green Line and Red Line. There is a trolley interchange station at Old Town where all the Blue Line, Orange Line, Red Line and the Green Line trolleys met. The common thing about this line is that it connected all the major activity centers. The blue line ran along the Friar’s Road and connected the Mission Valley Mall, Rio Vista – a mixed use structure that included residences, offices, shopping, and recreation. Then it went along the Friars Road to stop at Fashion Valley Shopping Mall, then to Morena Linda Vista which was residential and office area. The blue line terminated in the Old Town which was the historic district of San Diego. Hence, I feel that it is very important to connect all the major activity centers in any transit planning.

In the 1994 of the total 66 miles of LRT, there were no exclusive or Type A and non exclusive that is Type C alignments. All the alignments of the LRT in San Diego were semi exclusive or Type B in nature. Of the total miles of LRT in San Diego, about 11% of the miles operated less than 35 MPH and 33 miles of the total miles were mainline routes (Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 15).

4.8.c  Extension of San Diego Trolley

The San Diego trolley was opened in 1981 with the initial proposal measuring 15.9 miles. Since 1988, two extensions one from Euclid Avenue to El Cajon that was an addition to the East line measuring 11.3 miles and the other from Santa Fe Depot to Trolley Towers by way of City’s new convention center that was a Bay Side extension.
measuring 1.5 miles was opened in mid-1990. The length of the San Diego trolley thus doubled since its opening. The fleet of the trolley was increased to five times with the initial weekday boarding of 11,000 increasing to 53,000 weekday boarding (Schumann 1992, 9).

4.8.d Planning Criteria for San Diego Trolley

For the proposal of the starter line for San Diego Trolley, the San Diego Association of Governments (SANDAG) formed the following principles (Larwin and Powell 1992, 31):

- The corridor should be relatively long distance.
- The line should provide opportunity for high speed.
- The line should lead to low capital cost.
- The line should be preferably at grade
- The line should preferably have exclusive right-of-way.
- The system should have low operating cost.
- The system should be able to meet the operating cost.

4.8.e Issues and Concerns of San Diego Trolley

The two major problems involving the accident issues of LRT in San Diego were the concerns resulted from the motorists driving on the LRT tracks and the motorist turning left across the LRT median transit lane thereby violating the ‘NO LEFT TURN’ signs. There were occasionally incidences of the motorist turning right in front of the LRVs. The accident analysis from the period of July 1981 to June 1994 shows that 85% of the
accidents involved the vehicles and 15% of the accidents involved pedestrians (Korve, Farran, Mansel, Levinson, Chira-Chavala, and Ragland 1996, 43).
CONCLUSION

This chapter gives the overview of the light rail in Cincinnati and talks about the light rail in the cities of San Diego and Portland. It thus forms the base for the further discussion of the factors that are important for the planning of the light rail (the factors are discussed in Chapter 5). The factors that are important for the planning of the light rail and forms the primary and the secondary criteria to decide the alignment of the light rail in Cincinnati are derived from the literature review of San Diego and Portland. The discussion of the factors that influences the planning of the light rail is discussed in the coming chapters.
CHAPTER 5
CRITERIA FOR DECIDING THE ROUTE OF THE LIGHT RAIL
5.1 FACTORS THAT INFLUENCE THE PLANNING OF THE LIGHT RAIL

The literature review of San Diego and Portland light rail gave me various criteria that influence the design and planning of the light rail. Some criteria are vital while others are less important. The various criteria that influence the planning of light rail are discussed as under:

5.2 Right – Of – Way

Depending on the cost, availability, and conditions the Light Rail services can choose six different types of right – of – way namely

- The center street operating as transit lane
- Park strip, median or the boulevard’s right – of – way to be used for the transit lines
- Light density railroad tracks for the transit lines
- Power lines or the abandoned railroad lines
- Aerial structures at highway crossings with the private right - of – way
- Subway for the right – of – way (Tennyson 1982, 47)

At times, choosing the available right – of – way might not give the satisfactory solutions for example choosing a center street in the CBD for the operation of the LRT might reduce its speed and thus deteriorating the quality of the transit. Though subways and below-grade alignments look ideal alignments to the planners they are undesirable due to their high cost. Apart from this, the passengers dislike the underground alignment of the LRT (Tennyson 1982, 47 – 48).
5.3 Land Use

The light rail boarding and transit information collected from the 1990 census, Federal Transit Administration (FTA), 1993 National Transit Database and transit agencies on 11 light rail cities in United States having 19 lines shows that residential densities have a significant influence on rail transit station hoardings (Parsons Brinckerhoff Quade & Douglas, Inc., Cervero, Howard/Stein – Hudson Associated, Inc., and Zupan 1996, 1).

With the case studies of six light rail cities of Huston, Texas; Washington, D.C; Portland, Oregon; Vancouver, B.C, Canada; Ottawa-Carleton, Ontario, Canada and Curitiba, Brazil, it was found that in order to have regions with successful transit development, it should have a good connection between the region’s activity centers and the developing corridors and there should be high quality transit service (Parsons Brinckerhoff Quade & Douglas, Inc., Cervero, Howard/Stein – Hudson Associated, Inc., and Zupan 1996, 2):

Transit is most successful in the regions with high density. Hence, near the CBDs’ of any city, transit is the most successful. However, over the time, the suburbs developed and with the development of the suburbs, the city started growing into multi center settlement. Thus, in the recent times, it becomes important to connect all the important centers of the city. Further in these multi nuclei cities; there are various residential and non-residential uses that will prove attractive and competitive for the alignment of the transit lines (Parsons Brinckerhoff Quade & Douglas, Inc., Cervero, Howard/Stein – Hudson Associated, Inc., and Zupan 1996, 2).
To find an at-a-grade solution, many times planners align the rail tracks on the existing rail tracks that are active or abandoned. In case of the abandoned rail tracks, they generally pass through the industrial areas or the land uses that typically include the warehouses, abandoned industrial buildings or the vacant land which in turn out to be poor trip generators. These lands uses thus fail to provide adequate ridership to the transit system that the variable land uses have the potential to provide. Apart from this these abandoned industrial property may be contaminated and pose a health and environmental hazard. Another implication of laying out the rail alignments in the industrial corridor is that it is distant from the residential areas. This makes it inhospitable for the residential population to access the rail when the users have to pass through the vacant and abandoned properties. Apart from this, at times the stations are not at the walkable distances hence, all these conditions make the rail almost obsolete (Lutin and Benz 1992, 120). “In these instances the LRT planner should examine the relationship between residential areas and station sites at micro level. Although using an industrial corridor is very appealing, other alignments may be needed that pass closer to the residential areas to be served if the maximum benefit to riders is to be obtained (Lutin and Benz 1992, 120).”

The chief factor that influences the land use impact of transit is the “decision to develop the land”. The factors that influence the decision to develop the land are ‘Attractiveness of Site for Development’, ‘Availability of Developable Land’, ‘Other New Nearby Land Investments’, ‘Commitment to Specific Improvements’, ‘Implementation of Transit

The factors that influence the attractiveness of site are ‘Physical Character’ comprises of the access to the property, blight conditions, compatible land uses and ‘Social Character’ that comprises of crime, and social character of the neighborhood. The characters of infrastructure capacity, ease of private assembly, cost of land and site preparation, and public assembly activities influence the availability of developable land. The projects of private development, urban renewal and public facilities influence the new development and investment. The criteria of ‘Commitment to Specific Improvement’, ‘Implementation of Transit Improvement’, and ‘Improvement in Accessibility’ are inter-related that influence the land use impact. Neighborhood attitudes, incentives for zoning and development, and goals of larger community for the growth and social character influences the local land use policies and other government policies. The regions demand for new development is based on the national and the regional economy (Knight and Trigg 1977).

Land use and light rail in San Diego

Lawrence Dallam and Natalio Diaz of Metropolitan Council of the Twin Cities Area and David Rubin of COMSIS Corporation evaluate the feasibility of Light Rail Transit in the cities of San Diego and Sacramento in California on the basis of “Qualifying” and “Nonqualifying” criteria. They described the Qualifying Criteria as the previously established regional goals that must be met to meet the feasibility of the Light Rail
Transit project. On the other hand, the Nonqualifying Criteria are established to decide the hierarchy among the alternatives for the implementation of the selected alternative. The Qualifying and the Nonqualifying criteria can be grouped into the criteria of “Physical impact criteria”, “Transportation criteria” and “Economic criteria” (Dallam, Diaz, Metropolitan Council of Twin City Area, Rubin, and COMSIS Corporation 1982, 36-37).

Land–Use is the most important and complex factor for the evaluation of the development of the Light Rail Transit. The land use factors that influence the development might be in the form of neighborhood disruption, housing dislocation, disruptive use of park land, proximity to the elementary schools, etc that are negative impacts to the community. At times, the LRT lines in the neighborhood will be completely unacceptable as it creates visible barriers. These neighborhood barriers should be avoided in the design of the LRT lines as they may lead to realignment of the LRT lines rather than eliminating them. To eliminate the major problems of acquiring the neighborhood property for the alignment of the LRT, the LRT alignments should be limited to major streets and rail rights-of-way. The positive land use impacts as a qualifying criterion for the evaluation of the LRT is that the LRT should serve at least one of the two foci of the entire transit system. These foci could be the two downtowns or the major activity centers of the city or the two centers of the city. The purpose for putting this criterion is that the LRT being considered as the most accessible transit mode, the regional goals require that it should connect the two downtowns or the metro centers and not “detract” from them. The other positive land use factor as a nonqualifying criterion is that the LRT should serve the secondary land uses. The
purpose for putting this criterion is that the LRT should provide access between the major population centers and the metro centers that would feed the LRT and serve the centers. The nonqualifying factor that raised a considerable discussion was that the LRT planning and local metropolitan plans for the development and redevelopment should be mutually supportive as the LRT planning and the land development planning for the city or the region are mutually dependent (Dallam, Diaz, Metropolitan Council of Twin City Area, Rubin, and COMSIS Corporation 1982, 37 – 38).

Land use and light rail in Portland

Portland’s transportation policy and land use planning are viewed as highly innovative (Glick 1992, 75). Portland’s ‘Transit Station Area Planning Program (TSAPP)’ that was initiated in 1980 by the Metropolitan Service District and funded by the Tri-County Metropolitan Transportation District (Tri-Met) was the initiative to coordinate regional land use planning relative to a specific transportation program. Banfield light rail project (also called Eastside line) was the first line to coordinate transportation to land planning with the goal of building five more LRT corridors to complete a seven-corridor regional system by the year 2010 (Glick 1992, 78).

The main aim of the Banfield light rail project was to connect the downtown of Portland, East Multnomah County, and the city of Gresham to the east by providing the regional mass transit that help shape the development. The jurisdictions of these three counties planned to use light rail as the tool to create a restructured zoning code that will shape the growth of these counties and thus new zoning ordinances and development policies
were implemented before the construction of the light rail. This action lead to the transit oriented development during both the planning and construction of the light rail projects. In the period between 1986 to 1992, these jurisdictions saw more than $800 million development in the private and public sector that is either adjacent to the line or within a block or tow of the system (Glick 1992, 78). “Transit-related design with a spirit of pedestrian activity has resulted in the Portland region, fostering high density residential growth and higher intensity commercial development. Such an approach is seen as necessary for successful implementation of future light rail lines, adding to the initial successes of the Banfield Project (called MAX in operation for Metropolitan Area Express) in the areas of both corridor design and transit oriented land use planning (Glick 1992, 78).”

Generally the transit oriented development is planned to fit the higher density projects into the existing development or re-creating the neighborhood structures that such an approach is feasible. In Portland, the plan led to the optimization of the development and revenue generation (Glick 1992, 78).

Based on the interviews with the senior members of Portland’s development Community the ERA found that LRT has a positive influence on residential, retail and office construction. The real estate brokers and the developers started to advice the local residents and the investors to purchase the property along eh Banfield line in the anticipation of the higher values while the developers believe that LRT will enhance the retail activities in downtown. The developers also related the Banfield line’s positive
influence on the Gresham core as there was availability of vacant land that exhibited a good ability for the development (Tri MET & Portland State University 1985, 75).

5.4 GRADE

It is most feasible to find an at-a-grade and continuous line, as at-a-grade lines are less expensive than the subway tunneling or aerial structures (Lutin and Benz 1992 in TRB, 120). The Light Rail can operate smoothly and without any difficulty at the grade up to 6. Up to this grade, the ascending of the Light Rail to the stations and the descending to accelerate can happen without any difficulty (Tennyson 1982, 48). Yet, at shorter distances, more than 5 percent grade can be allowed (Burgess & Niple, Limited, BRW, Inc., KPMG Peat Marwick LLP, Manuel Padron & Associates, Hogan, Nolan & Stites, R. L. Banks & Associates, Cambridge Systematics, Inc., Gray and Pape 1998, 2.34). According to Fred Craig of Parsons Brinckerhoff, “An above-ground route is going to be significantly cheaper and more certain in cost than a tunnel. Tunnels are often fraught with unknowns as you get into them (Monk and May 2002).”

5.5 MAJOR ACTIVITY CENTERS

In the study of the hypothetical corridor for the light rail transit, it is observed that as the distance to the CBD increases, the daily boardings for the transit decreases. The highest daily boardings of approximately 4000 passengers were projected near the CBD with the assumption of the CBD having 200 employees per acre. Apart from this, it can be inferred from the study that the daily boardings for the light rail is directly proportional
to the number of employees in the CBD (Parsons Brinckerhoff Quade & Douglas, Inc., Cervero, Howard/Stein – Hudson Associated, Inc., and Zupan 1996, 13).

**Light Rail connecting major activity center in San Diego**

Figure 5.1: Hypothetical light rail station boardings by distance to CBD and employment density

![Graph showing hypothetical light rail station boardings by distance to CBD and employment density.]


The transportation and land planning integration in San Diego is driven by the issues of air quality, traffic congestion, and urban sprawl (Glick 1992, 75). In San Diego, the transit connects all the major activity centers of the convention center, shopping malls, recreational areas, downtown and the major institutional areas. The light rail running along the ‘Friars Road’ services the Fenton Mall and the residential areas near the mall and along the Friars Road, Rio Vista which is a mixed use development, Mission Valley Shopping Center, Fashion Valley Shopping Center, and Morena Lind Vista which is an office and residential area.
The MTS/James R. Mills Building at the Imperial and 12th Transfer Station is located where three trolley lines and several major transit bus lines converge is regarded as a model development project for integrating LRT and commercial or office development. This 10 storey facility featuring creative design spanning the trolley tracks and a 15 storey clock tower adds to the architectural presence to the place (Glick 1992, 75).

The America Plaza located on the Bayside Line can be considered the hub of all public transportation including the trolley, bus, rail and air due to its proximity to the waterfront and walking distance to hotels and other retail centers. The other important developments near the America Plaza are a 34-story 565,000 ft² office tower and 15-story, 272 room luxury all-suite hotels (Glick 1992, 76).

The coordination of the land use planning and light rail transit varies greatly from region to region with San Diego exhibiting the land use and light rail integration that ranges from large, high-quality mixed-use and institutional development while Portland exhibiting the coordination of state, regional and local layers of opportunity within the
Major Activity Centers with scattered growth

In some areas the institutional and commercial growth has taken place in the suburban locations. In such a situation, the offices, and institutions are located in a campus that houses a number of buildings. In such a case, the user of the rail is exposed to long walking towards the buildings. Thus, the planners should strive to minimize the walking distance in the campus locations in the suburban developments. In the situations where the plans of the development are not complete, the planners must strive to develop the cluster of the buildings near the LRT stations. In the conditions where the development has already occurred, the LRT stations should be planned in a manner that it has its proximity to maximum buildings in a way that the walking distance is reduced (Lutin and Benz 1992, 120).

5.6 HOUSEHOLD COMPOSITION
According to Keith Lawton, a Metro transportation planner who is leading a federally funded study of travel habits says that the single parent or the spouse of the double wage household or single parent household take the public transit (Oliver 1994).

Historically, the ‘Work to Home’ trips constituted the major trip generation while in the recent times, the changing life styles and family compositions has led to various trip generations. Traditionally, rail transit connected the high density residential areas to the high density job sector. In recent times, the number of house holds with dual workers and the ones with single parents has increased that greatly affects the trip generation. The dual worker household generates the “home-drop spouse-work-pick up-spouse-home” trip pattern where one spouse drives to work while the other takes the public transit that will increase the “kiss-and-ride” access to the stations where the spouse drops the partner at the arterial streets near the station. Thus, these changing patterns of the trip generation require convenient drop-off points near the stations (Lutin and Benz 1992, 119, 120).

People make trips to various locations to meet their daily requirements and it is seen that the maximum trips are generated in the areas that have varied use making them the areas with the heaviest travel demand. Thus, for the success of the future LRT line, the alignment should be provided in a manner that connects various land uses and the activity centers where the people make trips (Lutin and Benz 1992, 119, 120).
The trip pattern has changed over the time. Traditionally, when one spouse remained at home, the other spouse who is working made home-work-home trips while in the recent times when the household composition has changed to dual-worker, they do not have the time to shop. Hence, the shopping time is accommodated on the way to home from work. Thus, the traditional work-home trip generation has changed to work-shop-home. At times due to the dual worker nature of the households, this trip pattern often becomes to work-daycare-home, work-shop-daycare-home, work-shop-eat meal-home, or work-shop-daycare-eat meal-home. Thus, for any transit system to be successful, it becomes important to locate the station in the areas that cover multiple land use types (Lutin and Benz 1992, 120).

The single parent household composition has created the trip pattern of work-daycare-home or work-daycare-eat meal-home where the parent requires to pick the child from the daycare or school. If under such circumstances the stations are planned away form these key locations, the riders will find it very inconvenient to synchronize their daily activities (Lutin and Benz 1992, 120).

“The essence of these examples is that station locations in a proposed LRT corridor should be planned to link sensible destinations that correspond with contemporary travel needs of the expected user population (Lutin and Benz 1992, 120).”

The transit ridership is greatly influenced by the demographics of the area. The general characteristic of transit ridership in San Diego based on the South Bay area shows that
the ridership reflects the demographic characteristic in the area (San Diego Association of Governments 1982, 12). Along the light rail corridor there were about 53.2% of females. The median age of the people along the transit corridor was 28.9 years and the median income of the people as per the 1980 dollar value was $9.9. The Hispanics formed 18.8% of the transit corridor while the whites formed 58.5%. About 46.2% of the total population was dependent on the transit (SANDAG 1981, 12).

5.7 STATION LOCATION & PLANNING AND FEEDER CONNECTIONS

“Rail transit frequently confers a value premium on residential properties near stations (Parsons Brinckerhoff Quade & Douglas, Inc. 1996, 26).” Station locations and planning plays a vital role for the passengers to access the transit system. The light rail planning focuses on the alignment of the tracks to maximize the availability of the right-of-way and in doing so often the criteria for the selection of the stations becomes secondary (Lutin and Benz 1992, 117). “Ideally, station sites should be planned first, and the alignments should be developed to connect the stations (Lutin and Benz 1992, 117). The principles that guide the planning of the stations are:

- Plan the stations before the alignment.
- Station spacing should be such that it optimizes the travel speed and in turn thus attracts the passengers to increase the ridership.
- The alignment of the light rail tracks should be preferred in the residential areas over the industrial areas.
- Pedestrian access should be considered in the panning stages of the light rail.
• The walking distance to the stations should be tried and reduced. This could be achieved by planning clusters of the buildings around the stations that leads to high density near the stations and thus reducing the walking distance with the increased ridership (Lutin and Benz 1992, 117).

The main principles of station planning are:
• Station Spacing
• Station Location and Trip Purposes
• Land Use Environment for Stations
• Pedestrian Access
• Station Layout and its relations to operations (Lutin and Benz 1992, 118 - 124)

Station Spacing

“Transit-oriented development depends upon having station with development potential (Parsons Brinckerhoff Quade & Douglas, Inc. 1996, 35).” With the case studies of six light rail cities of Huston, Texas; Washington, D.C; Portland, Oregon; Vancouver, B.C, Canada; Ottawa-Carleton, Ontario, Canada and Curitiba, Brazil, it was found that in order to have regions with successful transit development, Transit stations should be located in the areas that support the public transit to increase the ridership and consequently decrease the operational cost of the transit per person (Parsons Brinckerhoff Quade & Douglas, Inc., Cervero, Howard/Stein – Hudson Associated, Inc., and Zupan 1996, 2).
LRT can be successful if it can provide less or competitive travel time to the passengers from their home to destination. Hence, station spacing plays an important role as it decides the speed of the rail. Decreased spacing between the stations leads to decreased speed of the rail and consequently increased travel time. Apart from this, almost every household in America has an automobile and at times there are more than one automobile available per households. Hence, if the travel time of the LRT is not competitive, people will not ride the rail and it will lead to decreased ridership making the operation of the LRT difficult. The LRT stations at the same time need to be at the walking distance to the passengers to attract the ridership. Hence it becomes very important to balance the station spacing and at the same time maintain the optimum speed of the rail (Lutin and Benz 1992, 118).

If the major goal of the transportation planning is to improve the service for the existing transit, then closer spacing of the stations could be provided by using the feeder bus for transportation to the longer distances. In such cases, the stations spaced as close as 0.25 mi of each other can work. On the other hand, if the goal of the transportation planning is to attract the riders from the freeways or the automobile riders, then the stations should be kept to 1 mi distance to maintain the required mileage. If the station planning is done for CBD, it is good to locate the stations at 0.25 mi distance where most of the people are walking while if the station planning is done for the suburban area, then the aim of the stations is to attract the riders at the same time maintain the mileage. Hence, in this circumstance, more distance spacing of the stations can be used with the park-and-ride facility (Lutin and Benz 1992, 119).
Depending on the function and the location, the LRT station spacing varies with the spacing of 1 to 2 mile (1.6 to 3.2 km) intervals in relatively low land-use intensities and the spacing decreasing to ¼ to 1 mile interval for the higher density neighborhoods or near employment centers. The stations that serve the CBD are generally located ever four to five blocs to serve large business (Burgess & Niple, Limited, BRW, Inc., KPMG Peat Marwick LLP, Manuel Padron & Associates, Hogan, Nolan & Stites, R. L. Banks & Associates, Cambridge Systematics, Inc., Gray and Pape 1998, 2.35).

*Feeder Connection at Stations*

In the Banfield Light Rail alignment in Portland, 25 stations of three distinct configuration were planned serving the downtown, Old Town, Memorial Coliseum, Lloyd Center, Hollywood Gateway, Hazelwood, Rockwood and Gresham with the east side of the rail serving schools, neighborhoods and the businesses (Tri MET & Portland State University 1985, 6).

The potential for the development of offices near the LRT stations in Portland ranges from 50 feet to 400 ft; that for the retail ranges from 10 feet to 700 feet; and for residences, it ranges from 50 feet to 250 feet. Thus, of all the three, the offices have the highest potential of development near the stations (Tri MET & Portland State University 1985, 60). Thus, while proposing a route for the light rail, stations should be planning in the areas with the highest employment density or the ones that have the highest potential for the supporting the employment while the second highest priority should be given to the residential areas.
Figure 5.4: Potential Development of Offices near LRT Stations in Portland

Source: Tri MET & Portland State University 1985, 60

Figure 5.5: Potential Development of Retail near the LRT Stations in Portland

Source: TriMET & Portland State University 1985, 60

Figure 5.6: Potential Development of Residences near the LRT Stations in Portland

Source: TriMET & Portland State University 1985, 60
5.8 PEDESTRIAN ACCESS

“Pedestrian access is crucial to the success of any light rail line in terms of patronage (Lutin and Benz 1992, 121).” At least one end of the trip involves a walk to the passengers and about 90 percent of the people walk less than 6 minutes that accounts for about 1500 feet distance while 50 percent of the people walk less than 3 minutes. A quarter mile distance consider as the walkable distance where a person can reach his destination most comfortably (Lutin and Benz 1992, 121).

Figure 5.7: Area within a normal 5 minute walk.

“The pedestrian access area is defined by the pedestrian network serving the stations, usually the street grid. In the typical rectangular street grid network, the pattern of all points lying within 0.25 mi walking distance of a station is described by a square rotated 45 degrees from the axes of the street grid, with sides approximately 1,870 ft long (549 m), covering a total area of 80 acres (32.4 ha) (Lutin and Benz 1992, 121).”

The station locations should be designed in a manner that it is able to attract passengers from all the sides. Hence, in doing so the physical barriers like river, valley, freeway, park, etc that restricts the movement of the passengers towards the stations should be avoided. The safety of the passenger is also important issue while
considering the pedestrian access to the stations. The pathway of the passenger should be secured by providing adequate lighting during the night time, avoiding mixing of walk-on with the park-and-ride and kiss-and-ride vehicle flow (Lutin and Benz 1992, 121).

Walking as a mode of access reduces the vehicle trip at the same time improves air quality by eliminating the vehicle trips that are substantial. According to Untermann (1984), most people are willing to walk 500 ft, with 40 percent willing to walk 1,000 ft and only 10 percent people willing to walk half a mile and people will be more willing to walk to their destinations if there is a pleasant environment. Thus, the 500 ft walking distance can be stretched beyond. (Parsons Brinckerhoff Quade & Douglas, Inc., Cervero, Howard/Stein – Hudson Associated, Inc., and Zupan 1996, 9).

The research on 27 California stations served by rail, Cervero (1993a) concluded that neighborhood proximity and neighborhood density were the most influential factors in the transit planning were people are more driven by the proximity of the transit than by the density Parsons Brinckerhoff Quade & Douglas, Inc., Cervero, Howard/Stein – Hudson Associated, Inc., and Zupan 1996, 9). According to me, density of the neighborhood is the more driving factor for the operation of the transit than for the people to ride the transit.
5.9 POLICIES THAT SUPPORT THE LIGHT RAIL

With the case studies of six light rail cities of Huston, Texas; Washington, D.C; Portland, Oregon; Vancouver, B.C, Canada; Ottawa-Carleton, Ontario, Canada and Curitiba, Brazil, it was found that in order to have regions with successful transit development, the local government should support and encourage the transit system and at the same time, there should be respected and trusted public investment firms that the citizens might be willing to make contributions to (and these contributions can be used for the development of the transit system) (Parsons Brinckerhoff Quade & Douglas, Inc., Cervero, Howard/Stein – Hudson Associated, Inc., and Zupan 1996, 2).

Figure 5.8: Mediating Influences on the transit urban form relationship

Source: Parsons Brinckerhoff Quade & Douglas, Inc. 1996, 3

Policies should be adopted that support the transit oriented development. These policies should support ‘Transit-Supportive Housing Policies’, ‘Transit-Supportive Shopping Center and Major Public Facility Siting Policies’, and ‘Transit-Supportive Tax Policies’. The government should integrate transit-land use planning and its

“Employment and residential density are the most important factors associated with transit ridership at either end of the trip (Parsons Brinckerhoff Quade & Douglas, Inc., Cervero, Howard/Stein – Hudson Associated, Inc., and Zupan 1996, 28).” Hence, the policies should be planned that increases the employment and residential densities near the stations. It is observed that the neighborhoods with the mix of land uses tend to have relatively high employment and residential densities and the work related trips in these areas from the urban and the suburban locations are increased. These kinds of neighborhoods are also appealing and pedestrian friendly. Hence, along with planning for the higher densities near the station areas, mix of land uses should be encouraged in these high density areas (Parsons Brinckerhoff Quade & Douglas, Inc., Cervero, Howard/Stein – Hudson Associated, Inc., and Zupan 1996, 28, 29).

Figure 5.9: Transit Development Relationship

Source: Parsons Brinckerhoff Quade & Douglas, Inc. 1996, 3
5.10 INFRASTRUCTURE FOR THE LIGHT RAIL RELATED ACTIVITIES

The suburban residents using the LRT for their daily commute to work in the CBD prefer to use the park-and-ride service near the suburban stations. Near the CBD, the traffic congestion leads to the higher travel time for the passenger hence, many times people making trips to CBD prefer rail transit as they are quicker. Apart from the park-and-ride lots, the “intercept” lots should be located at major commuter roads at points just before traffic congestion begins to provide choice to the riders to switch to the rail transit (Lutin and Benz 1992, 120).

5.11 RIDERSHIP AND TRIP GENERATION

Figure 5.10: Light Rail Station Boardings with respect to CBD

The light rail station boarding is highest near the CBD. The figure shows that there are highest boardings between 5 and 10 miles of the CBD and the number of boardings ranges from 0 to 1000 persons. Thus, overall the number of boardings between 0 to 10 miles of CBD is maximum and is about 0 to 2000 persons (Parsons Brinckerhoff Quade & Douglas, Inc., Cervero, Howard/Stein-Hudson Associates, Inc., Zupan 1996, 13).
The concept of the “no frills” transit in San Diego along with the improvements in the initial South Line and on East line as a phase two improvements increased the ridership during the weekday from 11,000 in 1981 to 27,000 in 1988. Along with the improvements, the extension of the Eculid Avenure that opened in March 1986 played a vital role (Schuman 1989, 33).

As per the evaluation of Tri-MET, at the opening of the light rail in Portland in 1986, it will carry 15,000 to 20,000 riders per day during the first year and the ridership will increase to about 42,500 riders per day by the year 1995. Of the total number of rider for the year 1995, the light rail will carry approximately 6,800 passengers in the rush hour. In Portland the freeway can carry 119,000 riders per day and with the light rail the total number of passengers in the transportation corridor will increase to 161,500 (Tri MET 1985, 6).

5.12 OPERATION AND MAINTENANCE COST

The qualifying economic criteria for LRT states that the annual operating cost per passenger should be less than the annual cost per passenger of existing or proposed transit alternatives while the nonqualifying criteria states that the proposed LRT line shod be more cost-efficient than either the existing transit alternative (Dallam, Diaz, and Rubin 1982, 39).

“Light rail transit cannot be economical in low-volume markets (Tennyson 1982, 47).” If the length of the line is longer and the speed is higher, the traffic volume need can be
assured for its economical viability like in San Diego the peak volume of the passengers was 1200 for one way per maximum hour and still it is economical due to its steady use all the day (Tennyson 1982, 47). “Shorter lines with less speed opportunity need more volume to justify investment in LRT (Tennyson 1982, 47).”

The Operation and Maintenance Cost for light rail can be calculated as the sum of the ‘Non Labor Cost’ and the ‘Labor Cost’. To calculate the labor cost of the light rail, it is very important to calculate the labor required for the operation and maintenance of the light rail. The formula for the calculation of the non labor cost, labor requirement and the labor cost for the operation and maintenance of the light rail is as under (Parsons Brinckerhoff Quade & Douglas, Inc., Cervero, Howard/Stein-Hudson Associates, Inc., Zupan 1996, 56.)

Table 5.1: Calculations for the Operating Cost of Light Rail

<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-labor cost ($ million) = 1.342 + (1.441 x annual revenue vehicle-miles (millions))</td>
<td></td>
</tr>
<tr>
<td>Light Rail Transit O &amp; M Labor Requirements = -107.75 + (0.492 x Annual Revenue Hours of Service x 1,000) + (3.85 x Number of Track Miles) + (35.61 x Number of Track Miles per Vehicle in Fleet) + (1.93 x Number of Vehicles in Maximum service) + (0.884 x Number of Vehicles in Fleet) + (0.667 x Annual Revenue Miles (in 1,000s) per Vehicle in Fleet) + (-2.81 x Average Vehicle Speed (mph)) + (61.41 if the average station spacing is less than ½ mile)</td>
<td></td>
</tr>
<tr>
<td>Light Rail Transit O &amp; M Labor Cost (1993$)= $66,004 x Total Light Rail O &amp; M Labor Requirements.</td>
<td></td>
</tr>
</tbody>
</table>

5.13 CAPITAL COST

The capital cost for light rail can be calculated as the sum of “cost per route-mile” and “cost per vehicle”. On the basis of the study conducted on twelve light rail systems, the following equation was derived to calculate the capital cost for the light rail can be calculated as under:

Table 5.2: Calculations for the Capital Cost of Light Rail

<table>
<thead>
<tr>
<th>Capital costs (in 000s of 1993$) for light rail =</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.41 x (6,440 x track-miles + 1,220 x number of stations + 1,920 x vehicles in fleet)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Capital cost (in 000s of 1993 $) for light rail =</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.41 x (2,940 x track-miles + 2,350 x at-grade track-miles + 6,250 x elevated track-miles + 25,680 x subway track-miles + 160 x number of stations + 890 x number of at-grade stations + 5,440 x number of elevated stations + 40,860 x number of subway stations + 1,920 x number of vehicles in fleet)</td>
</tr>
</tbody>
</table>


5.14 TRAVEL TIME

The ‘Transportation Criteria’ for the design and planning of LRT addresses the issue of accessibility, ridership, and coordination and integration of transportation mode. The qualifying criteria for the accessibility for San Diego states that the travel time for a transit system should not be more than 45 minutes in either peak or off-peak periods from any part of the urban service area to other metro centers. This criterion should qualify for 90% of the residents of the urban service area. The nonqualifying criteria for the LRT planning for San Diego (and Sacramento) states that the LRT line should meet peak ridership demands and that the LRT should increase the overall transit usage in the region over the existing transit system. The LRT should serve multiple boarding
areas in the metro center to distribute the movement of the passengers. Apart from this, the LRT should integrate with other travel options without seriously disrupting or degrading the existing transportation system (Dallam, Diaz, and Rubin, 38, 39).

According to Judi Craig, the then OKI’s light rail project manager, “Ridership is very sensitive to time.” If a light rail line is proposed from Blue Ash to connect the Uptown and Downtown, it will take about seven to nine minutes to travel from downtown to Blue Ash (Monk and May 2002).

5.15 HOUSEHOLD POPULATION

For light rail 5 minute peak headways is required for the residential density of 9 dwelling units per residential acre that comes to about 25 to 100 sq mi corridor (Holtzclaw 1994, 15). Population density is a very import factor to be considered while planning a transit. It is observed that the residential densities associated with the lower incomes and lower vehicle ownership attracts more people to opt for the public transit (Parsons Brinckerhoff Quade & Douglas, Inc., Cervero, Howard/Stein-Hudson Associates, Inc., Zupan 1996, 5).

5.16 PLANNING CRITERIA FOR THE MOUNT AUBURN TUNNEL

While deciding for the alternate route to the Mount Auburn Tunnel for light rail in Cincinnati, it was very important to know the planning criteria that were considered for the Mount Auburn Tunnel. As this data was not documented, I had to conduct
interviews with the various key personnel that were involved in the planning of the light rail in Cincinnati.

The interview with David Wormald – the then Project Engineer of I-71 Corridor Transportation study was conducted at the URS Office in Cincinnati, the interview with Tim Reynolds – the then lead planner was conducted at the METRO Office in Cincinnati, the interview with John Schneider – the then Chairman of Alliance for Regional Transit was a lunch time interview at Mount Adams Restaurant, and the interview with Bob Koehler who mentioned that personally he was not involved in the project of the I-71 Corridor light rail was held at his office at OKI. The interviews were conducted at the location of the participants’ choice, and were strictly voluntary in nature. The participants were allowed to leave the interview any time they want or could skip the question. The data of the interview is tabulated as follows:

<table>
<thead>
<tr>
<th>Table 5.3: Interviews</th>
</tr>
</thead>
</table>

1. **What were the “planning criteria” taken into consideration for the proposal of Mt. Auburn Tunnel during the planning for Light Rail in Cincinnati?**

<table>
<thead>
<tr>
<th>David Wormald</th>
<th>The design of the light rail in Cincinnati was guided by Transit Cooperative Research Cooperative Research Program (TCRP) Report No. 52, Handbook for Light Rail Design, and National Fire Protection Association (NFPA) Code 130 for fire life safety for fixed guideway transit system. The planning criteria were the desire to serve the Christ Hospital and its vicinity, serving the University of Cincinnati at the North end and connect to Over – The – Rhine in the south end. The other important planning criterion was to have a minimum impact on the neighborhood in terms of neighborhood relocation and environmental impacts. The alignment started from Main Street. Three points were fixed for the alignment. The curves and the grade were tried to</th>
</tr>
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<tbody>
<tr>
<td></td>
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</table>


<table>
<thead>
<tr>
<th>Name</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tim Reynolds</td>
<td>Cost comprising of the capital cost and operating cost, Construction Feasibility/Ability, length of the tunnel, impacts on traffic at either end, noise and vibration, light rail speed, stations within the tunnel, and impacts of construction on surrounding neighborhood, serving the Uptown and Downtown areas of Cincinnati were the planning criteria considered during the planning of the light rail in Cincinnati. During the planning of the light rail, land use was not considered as criteria. The stations were planned in the locations where the zoning could be revised. While proposing the alternate route to the Mount Auburn Tunnel in Cincinnati, providing service to the second largest employment and activity center of Cincinnati was one of the major criteria. Further up in the north service to service to Xavier University was considered.</td>
</tr>
<tr>
<td>John Schneider</td>
<td>According to John Schneider, the original alignment of the I-71 Corridor light rail was designed as suburb to suburb from Airport to Mason. He thought it was the omission of the second largest employment center that is the University of Cincinnati. The Mount Auburn alternative was proposed as a connection to the two major employment centers of Cincinnati.</td>
</tr>
<tr>
<td>Bob Koehler</td>
<td>The planning criteria that reveals from the I-71 Transportation Corridor report were ‘determining station location based on proximity to the employment’, and ‘operation cost’.</td>
</tr>
</tbody>
</table>

2. **What criteria should be considered while proposing the alternate route for the light rail in Cincinnati that will serve as alternate route to Mt. Auburn?**

<table>
<thead>
<tr>
<th>Name</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>David Wormald</td>
<td>The Blue Ash route does not directly serve the University of Cincinnati and Uptown areas and requires to serve downtown to the west. This segment planned to use the abandoned rail road tracks near I-71. The Blue Ash alignment is cheaper than the Mount Auburn tunnel but it won’t have enough ridership and will not serve Mount Auburn area and the University of Cincinnati directly. University of Cincinnati was a strong supporter of the tunnel under Mount Auburn.</td>
</tr>
<tr>
<td>Tim Reynolds</td>
<td>Cost, travel time from Uptown to Downtown, and neighborhood impacts are the major planning criteria that should be considered while planning of the alternate route to the Mount Auburn Tunnel in Cincinnati. The Mount Auburn Tunnel had the highest cost; hence there was a pressure to reduce the cost. Apart from that, the travel time is longer from Blue Ash by Mount Auburn Tunnel.</td>
</tr>
<tr>
<td>Name</td>
<td>Response</td>
</tr>
<tr>
<td>--------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>John Schneider</td>
<td>One of the primary criteria that were considered was to move the workers. The light rail in Cincinnati was designed to connect the two largest employment centers of the Downtown and the University of Cincinnati in Uptown. The light rail then went further up to the Xavier University and to Rookwood following Danna Ave to Wasson Ave at Airy Ave in Cincinnati.</td>
</tr>
<tr>
<td>Bob Koehler</td>
<td>Looking at the cost consideration of the Mount Auburn Tunnel, the alignment of the Mt. Auburn Tunnel was decided to be moved (from I-71 Corridor Transportation Study Report)</td>
</tr>
</tbody>
</table>
| 3. Of the various criteria considered in planning of the Light Rail Transit in Cincinnati, what according to you should be given the highest priority and why? | David Wormald: Ridership should be given the highest priority during the planning. Ridership is based on population density, population close to the employment centers. The second and the third priority should be given to travel time and cost & environmental impacts respectively.  
Tim Reynolds: For the planning of the light rail, the highest priority should be given to the route that can generate highest ridership, that allows construction feasibility, and has a reasonable cost.  
John Schneider: Land Use, Vehicle Ownership, Activity Centers  
Bob Koehler: The thoughts of the board mentioned that cost, economic development opportunity, relief of traffic congestion, and transportation options for residences should be considered for the planning. |

5.17 PRIMARY CRITERIA

The primary criteria that were considered for the planning of the light rail in Cincinnati are:

- Land Use
- Number of Vehicles
- Household Composition
- Household Income
Household Population

Grade

5.17.a  Land Use
Of the various land uses, the transit works best in residential and employment centers. On the contrary the transit is least affective in the industrial areas. Hence, when planning the transit, care should be taken that it services the maximum residential areas, commercial areas, institutional and educational areas and the office areas. In Portland as well in San Diego, the transit served the major residential, commercial and mixed use areas.

5.17.b  Number of Vehicles
The interview suggest that vehicle ownership is important criteria for the planning of the light rail. Lower the number of vehicles per household is higher the tendency of the people to take transit.

5.17.c  Household Composition
It is seen from the literature review on San Diego and Portland that light rail or for that matter any public transit woks best in the areas that have high density. The household composition plays a very important role in generating the ridership for the transit. The most probable users of light rail are teenagers, single parent household, and old generation. The residents who are most probable to use the transit are low income and
middle income people. A fixed monthly income might not make possible for this section of the community to buy individual vehicles and thus, they travel by public transit.

5.17. d Household Income
The San Diego study shows that the low and the medium income people exhibit high tendency to ride public transit.

5.17.e Household Population
Transit is most successful in highly populated areas as it decreases the operating cost. The transit becomes more affordable in the areas with high population density. In the areas with high population density the operating cost per rider is lowered than the areas with lower population density.

5.17.f Grade
Topography plays a very important role in deciding the routes for any transit system. It is most feasible to align the transit especially the light rail along the at-grade areas. Doing so will remove the expenses of constructing subways and high rise structures. San Diego’s primary aim while planning the light rail route was to plan it along an at-grade route as it works out to be cheaper.

The analysis map of the Uptown and Downtown neighborhoods of Cincinnati shows that the highest priority for the transit should be given to the areas of northern CUF, University Heights, Corryville, Northern Avondale, Avondale, eastern areas of Mount
Auburn, eastern areas of Walnut Hills, and the northern areas of the CBD (See Appendix Maps). For Cincinnati, ‘Grade’ is also a very important criterion. As the grade of every street cannot be used for the analysis using the GIS, I have analyzed each street separately for the grade.

5.18 SECONDARY CRITERIA

Right-of-way, feeder connection, trip generation and ridership, station location and planning, pedestrian access, infrastructure for LRT activities, and travel time are the secondary criteria as they can be modified as per the requirement. The right-of-way if not available can be purchased or modified for the purpose of laying out the transit; the feeder connection in terms of bus or tram can be provided if not available; the trip generation is important criteria and is very much dependent on the location of station and the location of the station is dependent on the land use, thus the trip generation criteria can be modified by either providing a feeder bus connection or a shuttle connection; the pedestrian access if not appropriate can be enhanced or modified; the travel time of the light rail can be modified by increasing the speed of the vehicle or by skipping the stations in certain connections; and finally the environmental impacts can be mitigated by using the appropriate and sophisticated construction technology.

Hence, this is the way the secondary criteria of right-of-way, feeder connection, trip generation and ridership, station location and planning, pedestrian access, infrastructure for LRT activities, and travel time were selected compared to the primary criteria.
5.19 UNIQUE CRITERION

The interviews and the literature review show that cost is the important factor that should be considered during the planning of the light rail. For the purpose of study, I have named “cost” as the unique criterion as any alternative for the Mount Auburn Tunnel has to be cheaper than the tunnel (Mount Auburn Tunnel was rejected for its very expensive tunneling cost). An alternative to the mount Auburn Tunnel might be an “at-grade” solution that makes the alternative cheaper. Hence, the cost amongst the alternatives need not be compared (this means that if one alternative is cheaper than the other, it will not be proposed solely on the basis of cost. It will be studied for other criteria too).

5.20. ANALYSIS MAP

The ‘Analysis Map’ shows the combination of primary criteria that were imperative for the planning of the light rail. The primary criteria that were used for the preparation of the analysis map were “land use”, “number of vehicles”, “household composition”, “household income”, and “household population”. The primary criterion of “grade” was not used for the preparation of the analysis. This criterion was individually checked for each alternative (see Chapter 7).

The data of “land use” was available from CAGIS that was updated for the year 2006; the data of “number of vehicles”, “household composition”, and “household income” was available from US Census Bureau that was updated for the year 2000; and the data of “household population” was available from OKI updated for the year 2007.
The analysis of the primary criteria for the planning of the light rail was done using the “unweighted overlay” in the “Spatial Analysis” tools in the ArcTools of GIS. To do this, first the entire vector based shape files of the individual primary criteria were converted to the raster by doing weighted overlay over them. The steps were as follows:

- The land use shapefile was converted to the raster with the field of ‘Exclucode’. During the conversion of the vector file to the raster, the cell size was kept 50 (many other cell size of 500, 300, 200, 20, and 10 were tried but they did not give sufficient results). The ‘Spatial Analyst Tools’ was used to reclassify the landuse. Here the land use of Institution, Single Family, Commercial, Transitional Family, Multi Family, Mixed Use, Educational, Office, Public Utility, and Commercial Housing were given the rank ‘1’; the land uses of Public Spaces, and Parks and Recreation were ranked at ‘2’; while the land uses of Vacant, Not Available, High Industrial, and Light Industrial were ranked at ‘3’. The rank of ‘1’ was considered as most favorable while the rank of ‘3’ was considered as least favorable.

- To analyze the data of the median income along with other primary criteria, it was necessary to convert the shapefile of the median income into raster. While converting the files into raster, the cell size of each file was kept at a constant of 50. After converting each shapefile into raster, they were “reclassified” using the ‘Reclass Tool’ in the ArcTool box to get three categories in one raster. The median income level from $0 – $40,000 was ranked as ‘1’, the median income of $40,000 – 70,000 was ranked as ‘2’, and the median income of $70,000 - $110,000 was ranked as ‘3’. The rank ‘1’ was the most favorable condition while the rank ‘3’ was the least.
favorable condition. This reclass median income was used for the analysis of the primary criteria map.

- The other factor that was considered for the primary criteria is ‘Number of Vehicles’. The information for the number of vehicles in each neighborhood was available on the basis of number of persons. This means that the data for number of vehicles was available in different files and they needed to be brought into one file for the analysis. To do this each shapefile was required to be converted into raster. While converting the shapefiles into raster, the cell size of each file was kept 50. After converting the data into different rasters, ‘Weighted Sum’ which is an ‘Overlay Tool’ in the ArcTool box was applied to these rasters. During weighted sum, the households with 0 or 1 vehicle were ranked as ‘1’, the ones with 2 vehicles were ranked at ‘2’, while the ones with 3 or more vehicles were ranked at ‘3’. The rank ‘1’ indicated the most favorable condition while the rank ‘3’ indicated the least favorable condition.

- The data for the household composition that comprises of the age groups was available in different shapefiles. Hence, it was important to get all the data into one shapefile or in a single file. To do so, all the shapefiles containing the data for the age group were converted into raster. While performing the conversion, the cell size for the raster was kept at 50. After this, ‘Weighted Sum’ was performed from the ‘Overlay Tool’ in the ArcTool box. While performing the “weighted sum”, the persons with the age of 60 and over, 5 to 9, 10 to 14, 15 to 19, and 20 to 24 were ranked as ‘1’; the ones between 55 and 59 were ranked as ‘2’; and the ones with the age of 25 to 34, 35 to 44, and 45 to 54 were ranked at ‘3’. The ones with the rank of ‘1’ were
considered as the most favorable while the ones with the rank of ‘3’ were considered as the least favorable.

Thus, the maps of the individual primary criteria were available in the form of different maps and they need to be converted into single map of individual primary criteria by converting them into rasters and then reclassifying them using the “weighted sum”. While performing the weighted sum, they were given different weights (weights were decided by me). Thus this gave a map of the single primary criteria. To make the Analysis Map, the unweighted overlay of the Spatial Analysis Tool was used. While performing this application, the cell score of ‘9’ was selected that classified the map into High and Low Priority areas. This means that the cell with the score of ‘9’ or higher will be selected to exhibit the ‘High Priority’ areas while the ones with the cell score lower than ‘9’ will exhibit ‘Low Priority’ areas. To maintain the consistency in the map, the cell size of ‘50’ was selected.

Thus, the procedure of getting a single analysis map involved the making of the individual primary criteria map and then adding them to get the analysis map.
CONCLUSION

This chapter gave me a very good understanding of the positive and the negative factors that influences the planning of the light rail. The study of the various factors that influences the planning of the light rail helped me in deriving the “primary criteria” and the “secondary criteria” for planning.
CHAPTER 6

ASSESSMENT OF ALTERNATE ROUTES
6.1 DISCUSSION OF ALTERNATE ROUTES

After the rejection of the Mount Auburn Tunnel for the connection of the Uptown and Downtown areas of Cincinnati by Light Rail as a part of the I-71 Corridor, the planners and transportation engineers started to think for the alternate route. I interviewed various planners and engineers to derive the alternate routes to the Mount Auburn Tunnel. As a resident of Cincinnati I also had the notions about the alternative routes which I have suggested in the document. The various alternatives routes to the Mount Auburn Tunnel are as follows:

Table 6.1: Interviews

<table>
<thead>
<tr>
<th>4. What could be the alternate route to the Mt. Auburn Tunnel for the Light Rail in Cincinnati?</th>
</tr>
</thead>
<tbody>
<tr>
<td>David Wormald</td>
</tr>
<tr>
<td>Tim Reynolds</td>
</tr>
<tr>
<td>John Schneider</td>
</tr>
</tbody>
</table>
that it is far in the east.

Reading Road on the other hand is narrow, has good employment sites, and has more traffic. Hence, if the Reading Road alternative is chosen then the restructuring of the I-71 corridor needs to be worked out.

In both the alternatives of the Reading Road and the Gilbert Ave, the route to University of Cincinnati needs to be worked out.

| Bob Koehler       | Tunnel could still be a better option as it serves the Uptown and the Downtown directly. |

5. How could the cost of the alternate route to the Mount Auburn Tunnel for Cincinnati by Light Rail reduced?

| David Wormald    | - |
| Tim Reynolds     | The cost of the alignment can be reduced by not building the station at the Christ Hospital if the Mount Auburn Tunnel is built. The other alternative is to build an at-grade alignment |
| John Schneider   | While planning of the alternative route, there is a tradeoff between the cost and the ridership. Gilbert Avenue is less expensive but Mount Auburn Tunnel is a better alternative as it will serve the I-71 and the I-75. |
| Bob Koehler      | - |

Source: Author

6.1.a Revised I-71 Corridor Light Rail (Blue Ash Segment)

Introduction

This route was proposed by METRO. The proposed route of the I-71 light rail ran from 12th Street in CBD of Covington to the Riverfront in Cincinnati crossing the Ohio River. After having passed through the downtown of Cincinnati on the Main Street and the Walnut Street, the LRT would swing east beside Reading Road where it would begin to parallel I-71 freeways. Then it would pass near the Xavier University to like with the eastside of I-75 lines to follow the Reed Hartman Highway in the northeast and terminates near Cornell Road. Then, the line could further go to the Kings Island area.
along I-71 and I-75 in two branches where one serves the Florence Mall while the other goes to the Airport (SORTA 2002, 15).

The new alignment of the I-71 LRT corridor will be 44 miles long with 20 miles in Hamilton county serving the communities of Avondale, Blue Ash, Cincinnati downtown and riverfront, Columbia Township, Deep Park, Evanston, Kenwood, Montgomery, Norwood, Pleasant Ridge, Silverton, Sycamore Township, Symmes Township, Walnut Hills, and Xavier University. This I-71 LRT line will serve 29 stations, the chief among them are Cincinnati / NKY Airport, Covington, Crescent Springs, Deerfield Township, Erlanger, Ft. Mitchell, Ft. Wright, Florence and Kings Island. It will serve the estimated population of 320,000 including 158,000 in Hamilton County and will produce a ridership of 34,000 per day with 23,000 in Hamilton County. The estimated cost of the starter line is $1.8 billion with $730 million in the 19-mile starter line (SORTA 2002, 14).

The revised I-71 Corridor line runs on the Main and Walnut Streets as a one way line, and then turns to the Central Parkway to run northward parallel to Reading Road. It then crosses I-71 on an existing abandoned railroad bridge to continue north parallel to the east side of I-71 to cross under the Dr. Martin Luther King Jr. Dr. It then comes

**Figure 6.1: Revised I-71 Corridor Alignment for Light Rail**

*Source: Reynolds 2007*
back to the west side of I-71 on another abandoned railroad bridge, just north of MLK (SORTA 2002, 31).

According to Tim Reynolds, the light rail line that connects the Uptown and Downtown areas of Cincinnati could run along the I-71 using the abandoned rail lines near the I-71. This line will pass through the Walnut Hills and as this area has a good population; it can serve the wider section of the community. Apart from this, the construction in this area is feasible and the cost of construction will be reasonable (Reynolds 2007).

**Analysis of the route based on the Primary Criteria**

From the analysis map prepared by choosing the primary criteria of Land Use, Number of Vehicles, Household Composition, Household Income, and Household Population, the area of the revised I-71 Corridor falls under low priority area. Hence this criteria will score ‘1’ point for the analysis map.

**Grade**

As this alignment uses the abandoned rail alignment, the solution is “at-grade” and thus this criterion qualifies for the criteria of grade. Hence ‘2’ points were given for this route in the analysis of the route to get the final results

**Feeder Connection**

If a line is planned along the abandoned rail lines, feeder connection will be required to transfer the passengers from the station to the University of Cincinnati. Hence, for these criteria ‘1’ point was given.
Right-of-Way
The line would run along the Reading Road which is about 80 feet wide with the available right of way. The line would then run along the I-71 which has a good right-of-way. In this case, the line running along Reading Road and I-71 may face the heavy motor traffic. Hence for this criteria ‘2’ points were allotted.

Trip Generation and Ridership
This alignment of the light rail runs along the Reading Road to further run along the I-71 Corridor. In such a scenario, pedestrian access to the stations located either on the Reading Road or on the I-71 may not be able to generate sufficient ridership. This may affect the trip generation. Thus, for these criteria of trip generation and ridership ‘1’ point was allotted.

Station Planning and Pedestrian Access
If the line is running along the Reading Road and I-71, then the station might be planned along the Reading Road. The Reading Road does not exhibit the potential for the park and ride or the kiss and ride stations. This criterion scored ‘2’ points.

Travel Time
The revised I-71 Corridor light rail alignment is approximately one half mile shorter than the original tunnel alignment with the MLK alternative. Hence, the travel time will be reduced. This criterion scored ‘2’ points.
Cost Estimation

The rail alignment will be chiefly running along the Reading Road and the I-71 Corridor. It is an at-grade solution to the I-71 light rail corridor. Hence, the capital cost of this alignment will be lower than the Mount Auburn Tunnel.

Connection to the entire I-71 Corridor light rail

The revised I-71 corridor light rail alignment uses the abandoned rail along the I-71 and once it reaches the Martin Luther King Dr, it merges with the original I-71 corridor light rail to serve the north of Cincinnati.
6.1.b Alternate Tunnel in the Mt. Auburn Neighborhood

Introduction

David Wormald suggested building an alternate tunnel under the Mount Auburn as an alternative to the existing (proposed) Mount Auburn Tunnel. According to him, it is very important to connect the Christ Hospital and the University of Cincinnati in the Uptown areas. Hence, an alternate tunnel, which is shorter than the proposed Mt. Auburn Tunnel, could serve as an alternate route. Instead of giving a curve to the tunnel under the Mount Auburn neighborhood, the new tunnel can be planned in a manner that its alignment is straight and thus reduces the distance. The new tunnel opens near the University of Cincinnati and connects to the Reading Road to form the part of the I-71 light rail corridor (Wormald 2007).

Analysis of the Route based on the Primary Criteria

According to the analysis map, the Mount Auburn neighborhood falls under the high priority areas. Hence, planning the light rail line along this route will be beneficial and it will cover the two important employment centers namely the University of Cincinnati and the Christ Hospital. Hence this criteria scored ‘2’ point for the analysis of the route.

Source: Wormald 2007
**Grade**

The drawback of this alternative is that digging the tunnel is an expensive option and it does not strive to solve the problems related to the previous alternative (original plan of building a tunnel). Hence, the score of ‘1’ is given for this criterion.

**Feeder Connection**

If a tunnel is planned under Mount Auburn, then the stations might be located at the Christ Hospital and the Jefferson to serve the University of Cincinnati. Hence, no feeder connection will be needed to serve these employment centers. This criterion scored ‘2’ points for the analysis.

**Right-of-Way**

Tunneling under Mount Auburn does not create the problems related to the right-of-way; and as it covers important employment centers, this route will be effective for trip generation. This criterion scored ‘2’ points for the analysis.

**Travel Time**

As the tunnel is the direct connection from the Uptown to the Downtown of Cincinnati, it will have the lowest travel time. The approximate distance between the Downtown and the Uptown of Cincinnati by using the abandoned rail tracks is approximately 3.5 miles. Thus, assuming two stations on the route, the approximate travel time with the speed of 15 miles per hour will be 8 minutes. This criterion scored ‘2’ points for the analysis.
Cost Estimation

Building a new tunnel as an alternative to the existing tunnel will reduce the travel time; but the questions of the expensive tunneling and the uncertainties during the tunneling are unanswered. Hence, the new tunnel might be less expensive than the proposed tunnel but it will be more expensive than at-grade solution. When the station is planned at the Christ Hospital, it will have to be planned underground and that increases the cost of the route. Eliminating the station at the Christ hospital (as another thought during the revision of Mt. Auburn Tunnel) will lead to decreased trip generation that will ultimately lead to the higher operating cost of the route. Hence, if the alternate route is planned under Mount Auburn, then selection has to be made between the higher capital cost and the higher operating cost.

Station Planning and Infrastructure Facilities

If a tunnel is built under the Mount Auburn, it will serve as a direct connection from the Downtown and Uptown areas of Cincinnati. It directly connects the two important and largest employment centers of Cincinnati of the Central Business District and the University of Cincinnati. Hence, the infrastructure facilities like the feeder bus or the shuttle connection that transfers the passengers from the station area to the destination will not be needed. If the tunnel is planned under the Mount Auburn, the stations will be located at the Christ Hospital and the Jefferson. The station at Jefferson is very near to the East and the West Campus of the University of Cincinnati. Hence, no feeder connection will be needed. This criterion thus scored ‘2’ points for the analysis of the route.
6.1.c Line along the I-75

Introduction

David Wormald suggested building the light rail along the I-75 Corridor as an alternative to the existing Mount Auburn Tunnel for the light rail in Cincinnati. The light rail lines in this alignment will be using the abandoned subway tunnels built in the 1916. The drawback of using the subway tunnels is that in the downtown, the new tunnels need to be built that will serve as a continuous connection for the entire light rail corridor. Moreover, building new tunnels in the downtown will be expensive as well as it will require a large number of infrastructure relocation. This idea of the light rail along the I-
75 corridor was in the end of the interview with David Wormald was turned down by himself (Wormald 2007).

Station Planning and Infrastructure Facilities
If the light rail is planned along the I-75 corridor then the stations will be planned either along the McMillan Street to connect to the University of Cincinnati. For this the feeder connection will be required.

6.1.d Vine Street
Introduction
Vine Street is a direct connection for the Uptown and Downtown of Cincinnati. Hence, if the light rail can pass along the Vine Street it will be a very good alternative. The stations along the Vine Street will be planned at the University of Cincinnati west campus and then the light rail will run eastward on the Martin Luther King Drive to further join the connection of the I-71 light rail corridor.

Analysis based on the Primary Criteria
The Vine Street falls under the low priority areas for the planning of the light rail as a connection to the Downtown and Uptown areas of Cincinnati as a part of the I-71 Corridor. Hence, for the analysis of the route, the alternative of the Vine Street was given ‘1’ point.
Grade

The analysis of the data obtained from CAGIS shows that the steepest slope on Vine Street is about 9% which is very steep for the light rail. This slope is very steep compared to the 7% allowable grade for the light rail. Hence, for the light rail to travel on the Vine Street, either the light rail vehicles with sophisticated brakes have to be use or the grade have to be brought down to the optimum grade. Hence for the purpose of analysis, the score of ‘1’ point was given to this criterion.

Figure 6.6: Profile of Vine Street to Jefferson

Source: CAGIS 2006.
**Feeder Connection**

If the light rail is planned along the Vine Street, then the stations might be located at University of Cincinnati’s West Campus. This will serve as a direct connection to the Downtown and the Uptown of Cincinnati and thus, no feeder connection will be needed. Hence this criterion was given ‘2’ points during the analysis of the route.

**Right-of-Way**

The width of the Vine Street with the available right-of-way is approximately 60 feet (CAGIS 2006). This width is too narrow for laying the two tracks of the light rail. Hence, this criterion was given ‘1’ point for the analysis.

**Trip Generation**

There are number of residences along the Vine Street. Apart from this, the neighborhood near the Vine Street exhibits medium to high statistics for the people having less private vehicles. This combination can lead to good ridership. hence, this criterion was given ‘2’ points for the analysis.

**Station Location and Planning, and Pedestrian Access**

For light rail along Vine Street the stations shall be located at the University of Cincinnati for the Uptown neighborhood and the other stations in the downtown will be located near the Over-the-Rhine neighborhood. Hence no park and ride or kiss and ride facilities will be needed. Hence, this criterion was given ‘1’ point for the analysis of the route.
Travel Time

The length of the Vine Street as a connection from Downtown to Uptown from Over-the-Rhine to the University of Cincinnati is approximately 8500 feet which is approximately 1.6 miles. Assuming that there will be no stop from Over-the-Rhine to the University of Cincinnati, the total travel time from Downtown to Uptown at the speed of 15 miles per hour will be approximately 6.4 minutes. Hence, this criterion was given ‘2’ points for the analysis of the routes.

Cost Estimation

Assuming that there will be two stations on the Vine Street, and the vehicle will operate in three fleet, the total capital cost of this route as calculated from the formula provided by Parsons Brinkerhoff Quade and Douglas will be approximately $260,90,000 (1993 value) which is about 26 million dollars.

Connection to the I-71 Corridor

If the light rail alignment is planned along the Vine Street, the alignment moves along the Jefferson Ave where it further moves north to merge into Martin Luther King Drive. Along the Martin Luther King Drive, it moves east to merge into the original alignment of the I-71 Corridor.
6.1.e Reading Road

Introduction

John Schneider mentioned Reading Road as an alternative to the Mount Auburn Tunnel for light rail in Cincinnati. Reading Road has a good grade for the light rail but at the same time it is narrow. There are good employments sites along the road and with the I-71 traffic interchange; it can be a good alternative for the light rail. The Reading Road can be further connected to the University of Cincinnati through Martin Luther King Drive or Taft Road (Schneider 2007). For light rail along the Reading Road, a small loop can service the University of Cincinnati and then this loop can further join the Reading Road to be a part of the I-71 light rail corridor.
Analysis based on the Primary Criteria

From the analysis map we can see that the Reading Road partially falls under the high and low priority areas for the planning of the light rail. Strict scoring for the analysis map has been adopted. Hence, these criteria were given ‘1’ points for the analysis of the alternatives.

Grade

On the basis of the analysis of the data obtained by CAGIS, the steepest grade along Reading Road is about 4.8% (CAGIS 2006). This is considered as an at-grade and the light rail can pass along this route without any difficulty. Hence this criterion was given ‘2’ points for the analysis of the routes.
Right-of-Way

The width of Reading Road with the available right-of-way is approximately 80 feet (CAGIS 2006). This right-of-way is sufficient for the planning of the two track light rail lines. The draw back of Reading Road is that due to heavy traffic, the available right-of-way might not prove to be sufficient (Schneider 2007). Hence, this criterion was given ‘2’ points for the analysis of the alternatives.

Feeder Connection

The Reading Road can connect to the University of Cincinnati by Martin Luther King Drive where it can reach up to the East Campus of the University of Cincinnati. Thus, in this way it can serve both the East and the West Campuses of the University of Cincinnati. The drawback of this connection from the Downtown to Uptown areas of Cincinnati by light rail is that, this connection can not go further to the Clifton to serve the other areas of the Uptown. This means that the route has to deviate from Martin Luther King Drive to Jefferson and then run towards the McMillan to go to other areas of Uptown or the route has to go in the interior of the East Campus and then go to the north from there. Hence, this criterion was given ‘2’ points for the purpose of analysis.
Trip Generation
The land use along the Reading Road is residential, institutional, and commercial. Apart from this, according to the data available on the number of vehicles, the neighborhoods of the Reading Road fall under medium to high priority areas for the transit. This combination will boost the ridership in the area. Hence, this criterion was given ‘2’ points for the analysis of the alternatives.

Station Location and Planning
With the Reading Road alternative, the stations can be planned at maximum two locations along the Reading Road. As the area exhibits good residential and activity centers, station location along this alignment will generate good ridership. Hence, this criterion was given ‘2’ points for the purpose of analysis.

Travel Time
As per the literature review, I would recommend semi-exclusive rail alignment with the average operating speed of about 15 miles per hour for the Reading Road alternative. Thus with the total distance of about 16,000 feet which is about 3 miles, it will take 12 minutes to travel non stop from the north end of the CBD to the junction of Martin Luther King Drive and Jefferson Road. In this case if two stations are provided with the stops of 3 minutes each, then the travel time from the CBD to the University of Cincinnati will be 18 minutes. The travel time between the Uptown and the Downtown can be still reduced by decreasing the stop over time at the stations and in turn increasing the frequency of the trains. Hence, this criterion was given ‘1’ point for analysis or routes.
Cost Estimation

Assuming that the Reading Road alternative will have 3 stations and will operate in 3 fleet vehicles, the capital cost for constructing light rail over Reading Road which is 3.03 miles long is $39075612 ($39 million) as per 1993 $ value.

Connection to the I-71 Corridor Light Rail

Figure 6.11: Connection of Reading Road to I-71 Corridor

if the alignment is planned along the Reading Road then the alignment moves in the north to merge into Martin Luther King Drive where it services the University of Cincinnati and then from the east of the Martin Luther King Drive joins the original I-71 corridor light rail.

Source: Author

6.1.f Gilbert Avenue

Introduction

According to John Schneider, Gilbert Avenue could be another alternative to connect the Downtown and Uptown areas of Cincinnati by light rail. Gilbert Avenue is a straight road with shallow grade. It has many vacant lots in its vicinity that will prove a good
opportunity for future development projects if light rail is developed along this line (Schneider 2007).

**Figure 6.12: Analysis of Gilbert Ave**

*Analysis based on Primary Criteria*

The neighborhoods along the Gilbert Road partially fall between high priority areas and the low priority areas. Due to the strictness in the scoring of the criteria, these criteria were given ‘1’ points for the purpose of the analysis of the alternate routes.

*Source: Schneider 2007*

**Grade**

According calculations from the data available from CAGIS, the steepest slope on the Gilbert Avenue is 6.5% for a short distance of approximately 1000 feet (CAGIS 2006). The slope in the rest of the street is about 2.5% which is considered “at-grade” for the planning of the light rail. Hence, this criteria was given ‘2’ points for the purpose of analysis.

**Figure 6.13: Profile of Gilbert Ave.**

*Source: CAGIS 2006.*
Feeder Connection

When a light rail line is planned along the Gilbert Ave, it needs to connect to University of Cincinnati by Martin Luther King Dr. alike the Reading Road alternative, as the light rail can not go further beyond the Martin Luther King Drive to connect to the Clifton, it will require to deviate to Jefferson Ave or go further Uptown from the East Campus of the University of Cincinnati. Gilbert Ave to Martin Luther King Dr. is a good alternative for the connection of Downtown to Uptown areas of Cincinnati by light rail as using this route the passengers will get a direct connection with the service to the two major employment centers in the city. Hence, this criterion was given ‘2’ points for analysis.

Right-of-Way

The right-of-way at Gilbert Road is good and two tracks of light rail can be laid. Hence, this criterion was given ‘2’ points for the purpose of analysis.

Trip Generation and Ridership

There is a commercial corridor along the Gilbert Road that has a good potential for generating the ridership. Apart from this, there is good number of residences that
supports the transit. The vehicle ownership along the Gilbert Road is observed to be of the medium range. Hence, this criterion was given ‘2’ points for the purpose of analysis.

*Station Location and Infrastructure Planning*

As there are number of vacant lots along the Gilbert Road, there is a good possibility to have park and ride or kiss and ride stations. In such cases transit can have intermodal facilities. Hence, this criterion was given ‘2’ points for the purpose of analysis.

*Travel Time*

The total distance of the Gilbert Avenue to Martin Luther King Dr alternative is approximately 19,000 feet which is about 3.5 miles. On the basis of the literature review, I will recommend Type B to Type C kind of light rail with Grade II operating speed. Thus, with the assumption that the light rail in this alternative will have the average operating speed of 15 miles per hour, the total travel time will be 14 minutes. If two stations are proposed on this alternative with the stopping time of 7 minutes on each station then the travel time will increase to 28 minutes. Hence, this criterion was given ‘1’ point for the purpose of analysis.

*Capital Cost*

The length of the route from Gilbert Ave to MLK is approximately 19000 feet which is approximately 3.5 miles. If 3 stations are planned at the Gilbert Ave and the light rail operates with 3 fleet, the approximate capital cost for Gilbert Avenue alternative will be $45063600 ($45 million) as per 1993 $ value.
**Connection to the I-71 Corridor Light Rail**

If the alignment is planned along the Gilbert Road, it moves north on the Gilbert Road to merge into Martin Luther King Drive. Along the Martin Luther King Drive, it moves west to service to the University of Cincinnati and then near the University of Cincinnati it joins the original I-71 Corridor Light Rail.

Figure 6.15: Connection of Gilbert Ave to I-71 Corridor Light Rail

*Source: Author*
CONCLUSION

This chapter discussed the various alternatives that could serve as an alternative route the proposed Mount Auburn Tunnel in Cincinnati by light rail. In this chapter, I discussed in detail each alternative for the primary and the secondary criteria for planning. Also, the point allocation for each criterion is discussed that creates the base for the coming chapter to propose an alternate route. This chapter thus helped me find the alternate route to the Mount Auburn Tunnel in Cincinnati by Light Rail.
CHAPTER 7
COMPARISON OF ALTERNATE ROUTES
7.1 CONCLUSION

The various routes that were studied as an alternate route to the proposed Mount Auburn tunnel in Cincinnati by light rail were ‘Revised I-71 Corridor (using the abandoned rail lines)’, ‘Alternate Tunnel in Mount Auburn’, ‘Line along I-75’, ‘Vine Street’, ‘Reading Road’, and ‘Gilbert Road’.

In the alternative of the Revised I-71 Corridor Line, the light rail passes along the Reading Road and then it moves along the I-71. Reading road is too narrow to handle the multimodal traffic of the light rail as well as the vehicular traffic. At the same time, if the light rail operates along the I-71, then it has to share the right of way with the vehicular traffic of the I-71.

If an alternate tunnel to Mount Auburn is selected as an alternative from Uptown to Downtown then the issue of digging an expensive tunnel remains unsolved. Thus this alternative does not satisfy the unique criterion of “cost”. Apart from this, the tunneling is prone to the uncertainties of the rocks of Mount Auburn. This alternative increases the capital cost of the project and hence, it does not serve as a good alternative.

If the light rail is operated along the abandoned lines of the I-75 route, then it passes through the neighborhoods that do not generate sufficient ridership. Hence, in the lieu of reducing the capital cost of the project we might end up increasing the operating cost of the project.
Vine Street is the direct connection from Downtown to Uptown but the grades of Vine Street does not qualify if for the preliminary criteria of grade for selecting this alternative. Vine Street might be able to generate good ridership as it is near to important activity centers in the Uptown of Cincinnati and also qualifies the criteria mentioned in the Analysis Map. Apart from this, the right-of-way in the Vine Street might not be sufficient to lay two track rail lines.

The Reading Road is a good alternative for the light rail from Uptown to Downtown. The flaw with Reading Road is that there is heavy traffic from I-71 entering and exiting from the Reading Road. The other drawback of Reading Road is that it falls under the low priority areas. On the contrary, this alternative qualifies for the primary criteria of grade and the unique criterion of cost. The right-of-way in the reading road will prove to be narrow for the light rail. The Reading Road qualifies for the primary and the secondary criteria for the planning of the light rail.

The Gilbert Road is also a good alternative. The flaw with Gilbert Road is that it is far west and falls under the low priority areas; but at the same time, the travel time from Reading Road and Gilbert Road is not very different. This alternative qualifies for the primary criteria of grade and the unique criterion of cost. Gilbert Road takes just slightly more time than Reading Road which could be overcome by increasing the speed of the vehicles or reducing the stopping times at the stations.
The following table describes the strengths and weaknesses of each alternative. Here, the preferable option is given higher points (i.e. Suitable conditions are given higher points of 2 or 3 based on the condition while the less suitable or the unsuitable conditions are given the points of 1 or 2).

Table 7.1: Table showing alternative to Mt. Auburn Tunnel in Cincinnati by Light Rail

<table>
<thead>
<tr>
<th>Description</th>
<th>Revised I-71 Corridor</th>
<th>Alt. Tunnel in Mt. Auburn</th>
<th>Line along I-75</th>
<th>Vine street</th>
<th>Reading Road</th>
<th>Gilbert Road</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PRIMARY CRITERIA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analysis Map High (2) and Low (1)</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Grade</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>SECONDARY CRITERIA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feeder Connection Yes (1) and No (2)</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Right – Of – Way Good (2) and Bad (1)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Trip Generation and Ridership Good (2) and Bad (1)</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Station Location and Planning Favorable (2) and Unfavorable (1)</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Pedestrian Access Good (2) and Bad (1)</td>
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<td>2</td>
<td>2</td>
<td>2</td>
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<td>2</td>
</tr>
<tr>
<td>Infrastructure for LRT Activities Required (1) and Not Required (2)</td>
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<td>2</td>
<td>2</td>
<td>2</td>
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<td>2</td>
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<tr>
<td>Ridership Good (2) and Bad (1)</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Travel Time Less (2) and More (1)</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total of Primary and Secondary Criteria</strong></td>
<td><strong>16</strong></td>
<td><strong>18</strong></td>
<td><strong>14</strong></td>
<td><strong>17</strong></td>
<td><strong>18</strong></td>
<td><strong>18</strong></td>
</tr>
</tbody>
</table>
From the table we can see that the alternatives of ‘Alternate Tunnel to Mount Auburn’, ‘Reading Road’, and ‘Gilbert Road’ scores the highest points. While choosing between these alternatives, the planners, investors and the politicians will have to choose between the high priority areas and the cost. For the city of Cincinnati, cost is a very important factor. Hence, the alternatives of ‘Reading Road’ and ‘Gilbert Road’ should be preferred over the ‘Alternate Mount Auburn Tunnel’. The analysis also shows that Reading Road has a narrow right-of-way while the Gilbert Road has good right-of-way. Apart from this, the travel time from Gilbert Road to the University of Cincinnati is almost the same as that of the Reading Road. Hence, the alternate route to the Mount Auburn Tunnel can be chosen as ‘Gilbert Road’. When Gilbert Road is developed as the alignment of light rail, the vacant lots near the Gilbert Road can be developed and thus the low priority areas of the Gilbert Road can be turned to the high priority areas. These vacant lots thus exhibit the potential for the transit oriented development.

7.2 LESSONS LEARNT

Light rail is the very effective means of public transportation as it is quite, smooth, and can travel at a higher speed compared to the bus. Light rail works the best in high density and the mixed use areas. While deciding the alignment of the light rail it is very important to connect the major activity centers of the city or a place. Generally the major activity centers in any place are the biggest employment centers of the city or the town. In Cincinnati, the biggest employment centers are the Downtown and the University of Cincinnati in the Uptown. Hence, it becomes very important to connect the Downtown and the Uptown.
The light rail construction is cheaper if the alignment is planned at-grade; but under certain circumstances like the unavailability of the right of way or very high difference in altitude between two destination points, planners have to design the under-grade or the above-grade alignment. Under such circumstances, care should be taken that the under-grade or the above-grade solution meets the construction feasibility and supports enough population to lower the operation cost of the light rail. The light rail is very effective in areas with high population density, the middle to lower income neighborhoods, and the neighborhoods with zero to one car ownership.

I believe that the citizens of Cincinnati should support the idea of light rail because transportation is one of the most important features for urban planning that can bring about a positive change in the development of the city. If a city has good transportation, it attracts more people to live and work in that city. Today, when Cincinnati is declining, and facing the issues of sprawl, an effective public transportation like the light rail can help bring more jobs to Cincinnati. The light rail can bring about compact communities in Cincinnati and thus make the city more environmentally friendly.
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APPENDIX MAPS
Source: CAGIS 2006, OKI 2007
2030 Population
Cincinnati, OH

Primary Roads
Neighborhood Boundary
Ohio River

2030 Population
Number of Persons
- 0 - 1000
- 1001 - 2000
- 2001 - 3000
- 3001 - 4000
- 4001 - 5000

Source: CAGIS 2006, OKI 2007
Number of Vehicles
Cincinnati, OH

Analysis
Value
