Using Twin Cities Destinations and their Accessibility as a Multimodal Planning Tool: Task 3 and 4 Report

Draft Report

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Abstract

This study uses accessibility as a performance measure to evaluate a matrix of future land use and network scenarios for planning purposes. Previous research has established the coevolution of transportation and land use, demonstrated the dependence of accessibility on both, and made the case for the use of accessibility measures as a planning tool. This study builds off of these findings by demonstrating the use of accessibility-based performance measures on the Twin Cities Metropolitan Area. This choice of performance measure also allows for transit and highway networks to be compared side-by-side. A TAZ to TAZ travel time matrix was computed using SUE assignment with travel time feedback to trip distribution. A database of schedules was used on the transit networks to assign transit routes. This travel time data was joined with the land use data from each scenario to obtain the employment, population, and labor accessibility from each TAZ within specified time ranges. Tables of person-weighed accessibility were computed for 30 minutes with zone population as the weight for employment accessibility and zone employment as the weight for population and labor accessibility. The person-weighted accessibility results were then used to evaluate the planning scenarios. The results show that centralized population and employment produce the highest accessibility across all networks.

Keywords: Accessibility, Planning, Minnesota
Contents

1 Introduction 1

2 Data 2
  2.1 Land Use ......................................................... 2
    2.1.1 2010 Land Use .............................................. 2
    2.1.2 2030 Land Use ............................................ 3
    2.1.3 Centralized Population and Employment .................. 4
    2.1.4 Centralized Population, Decentralized Employment ...... 4
    2.1.5 Decentralized Population, Centralized Employment ...... 4
    2.1.6 Decentralized Population and Employment .............. 4
  2.2 Highway Networks ................................................ 10
    2.2.1 Freeflow .................................................. 10
    2.2.2 2010 Highway Network .................................... 10
    2.2.3 2030 Highway Network .................................... 10
    2.2.4 Diamond Lane Network .................................... 10
    2.2.5 Congestion Pricing ........................................ 10
  2.3 Transit Networks ................................................ 11
    2.3.1 2010 Transit Network ..................................... 11
    2.3.2 2030 Transit Network ..................................... 11
    2.3.3 Minneapolis Streetcars ................................... 11
    2.3.4 Rhodium Network .......................................... 11
    2.3.5 Retro Transit ............................................... 11
    2.3.6 Platinum Network .......................................... 11

3 Methodology 14
  3.1 Highway Travel Time Calculations .......................... 14
  3.2 Transit Travel Time Calculations ............................ 14
  3.3 Accessibility Calculation .................................... 15

4 Results 17

5 Conclusion 20

References 21
  5.1 Travel Demand Model .......................................... 22
    5.1.1 Calibration ............................................... 23
    5.1.2 Trip Generation ......................................... 23
    5.1.3 Trip Distribution ....................................... 25
    5.1.4 Assignment .............................................. 25
List of Tables
List of Figures

2.1 2010 Population Density ......................................................... 3
2.2 2010 Employment Density ....................................................... 4
2.3 2030 Population Density ......................................................... 5
2.4 2030 Employment Density ....................................................... 5
2.5 Population Change 2010-2030 ................................................... 6
2.6 Employment Change 2010-2030 ................................................ 6
2.7 Centralized Population Growth ............................................... 8
2.8 Centralized Employment Growth ............................................. 8
2.9 Decentralized Population Growth ............................................ 9
2.10 Decentralized Employment Growth ......................................... 9
2.11 Flowchart of Transit Scenarios .............................................. 12
2.12 2030 Highway Network ....................................................... 12
2.13 Transit Networks ............................................................... 13
4.1 Ratio of Highway to Transit Accessibility: 20 Minutes ................ 19
4.2 Ratio of Highway to Transit Accessibility: 30 Minutes ................ 19
5.1 Figure 1 ............................................................................. 24
Chapter 1

Introduction

Transportation and land use are inter-dependent. The relationship between these two has been used to explain the growth patterns of cities, and continues to be influential in the decisions by businesses and individuals of where to locate in a city. Understanding this relationship is also important for planning future growth. Land use plans and transportation plans are typically conducted independent of each other, but the two need to be compatible if the goals of both are to be realized.

Accessibility is defined as the ability of people to reach the destinations to meet their needs and satisfy their wants, and has been long used in transportation planning [Hansen]. It is a function of both land use and the transportation network and can also be thought of as a measure of the efficiency of a city. This study develops a set of land use and transportation network scenarios, and evaluates accessibility for each combination of the two.

Transportation planning has traditionally focused on improving mobility and reliability measures of congestion across a metropolitan area. While policy based on these criteria can improve access to jobs or labor, they can have negative effects as well. First, mobility improvements, when this means improving the connectivity of outlying areas, tend to shape land use by encouraging decentralization. Second, focusing efforts only on reducing congestion is an automobile-centric policy that ignores and often reduces accessibility for people using other modes. Finally, congestion may not matter much, as [Levinson and Marion] show that accessibility increased across the Twin Cities Metropolitan Area from 1995 to 2005 even as traffic congestion worsened by most network measures. [Levinson and Marion] have made a strong case for the use of accessibility as a performance measure in land use and transportation planning and we will demonstrate its use here by evaluating a series of future scenarios.

The use of scenarios is widespread in planning practice, a comprehensive review and meta-analysis can be found in [2]. Scenarios are not forecasts (though forecasts may be scenarios). Rather we can think of them as hypotheses and examine what happens if the hypothesis bears out. In planning, scenarios have often been used in transportation and in land use models to consider alternative policies, and what might their implications be on outcomes like vehicle miles traveled or air pollution. In this study we consider how different patterns affect accessibility.

The next section describes the 6 land use scenarios, 5 highway networks, and 5 transit networks considered in this study. Land use data is developed for each transportation analysis zone (TAZ). A travel time matrix (TAZ to TAZ) is developed for each network and joined with land use data to find the total employment, labor, or population reachable for each time threshold. After that is a methodology on accessibility, followed by a results section analyzing a quantitative result: person-weighted accessibility calculated for 20 and 30 minute thresholds. We conclude by considering the implications for planning in the Twin Cities and the potential for future research.
Chapter 2

Data

This study analyzes the accessibility of 60 different scenarios, representing each combination of 6 land use scenarios and 10 networks. They are as follows.

2.1 Land Use

2.1.1 2010 Land Use

The 2010 land use (scenario LE) is the existing land use (jobs, households, population by TAZ) in the Twin Cities metropolitan area as of 2010. This is used as a baseline scenario. When paired with the 2010 highway network (N1), this produces the existing accessibility. For all other networks, the 2010 land use is used to show the result of network modifications if the region saw no significant growth in the period 2010-2030. A map of population density by TAZ in 2010 is shown in Figure 2.1, and the equivalent map for employment is shown in Figure 2.2. The highest population densities (over 6000 per $km^2$) are in the neighborhoods just south of downtown Minneapolis. Downtown Saint Paul shows somewhat greater population density compared with the surrounding area. Otherwise, population density is relatively uniform (1500 to 6000 persons per $km^2$) across the central cities and inner suburbs (Richfield, east Bloomington, West St. Paul, South St. Paul, Columbia Heights, St. Anthony Village, Brooklyn Center, Brooklyn Park, Crystal, New Hope, Robbinsdale, Hopkins, and St. Louis Park). Population density in the remaining suburbs is generally less than 1500 per $km^2$. Employment in the region is highly concentrated in downtown Minneapolis, with a much smaller concentration in downtown St. Paul. There are significant employment concentrations at many freeway to freeway intersections, although most of these employment nodes are on the southwest side of the Metro area.
2.1.2 2030 Land Use

The 2030 land use scenario (scenario LF) is the land use predicted by the Metropolitan Council in its comprehensive plan. The bulk of the growth is expected to occur in outlying areas at low densities. Despite this, there are still some interesting changes.

Maps of population and employment density are shown in Figures 2.3 and 2.4 respectively. Maps showing the change from 2010 are given in Figures 2.5 and 2.6. The 2030 population map looks similar to the 2010 map, primarily because the bulk of the growth is expected to occur in outlying areas at low densities. Despite this, there are still some interesting changes, which are easiest to see on the comparison map (Figure 2.6).

The population in both downtowns is expected to increase significantly, which amounts to a prediction that the recent condo boom will continue. South of downtown Minneapolis, the neighborhoods west of I-35W are predicted to grow, while a decline is projected for virtually all neighborhoods between I-35W and Hiawatha Avenue. The areas of highest growth are in Dayton, Hugo, Rosemount, Lakeville, Elko New Market, and unincorporated areas of Carver County. The 2030 employment map is almost the same as the 2010 map in terms of the geographic distribution of employment. Significant increases are projected in downtown Minneapolis and along I-494/694, specifically in Edina, Eden Prairie, Plymouth, and Maple Grove. There is also expected to be significant growth in Shakopee, Apple Valley, Lake Elmo, and Dayton although these are likely to be service sector jobs associated with population growth in those areas.
2.1.3 Centralized Population and Employment

The centralized population and employment scenario (LCC) uses the same metropolitan totals of population, employment and labor as the Metropolitan Council’s 2030 Comprehensive Plan, but concentrates all of the growth (beyond 2010) inside the I-494/694 Beltway. All population and employment outside the Beltway is held constant at 2010 values. This scenario can be used to evaluate the effectiveness of a growth strategy that funnels investment into developed areas.

A map of the centralized population growth can be found in Figure 2.7, and the centralized employment growth is shown in Figure 2.8. These maps show the increase in population or employment, respectively, from 2010 to 2030, broken down by TAZ. This scenario can be used to evaluate the effectiveness of a growth strategy that funnels investment into developed areas.

2.1.4 Centralized Population, Decentralized Employment

The centralized population, decentralized employment case (LCD) is meant to evaluate the impact on accessibility if population growth occurred only within the I-494/694 Beltway and job growth only occurred outside it.

2.1.5 Decentralized Population, Centralized Employment

The decentralized population, centralized employment scenario (LDC) is the reverse of the previous section. All population growth occurs outside the I-494/694 Beltway and all job growth occurs inside it.

2.1.6 Decentralized Population and Employment

The decentralized population and employment scenario (LDD) shifts all population and employment growth outside the I-494/694 Beltway. This scenario can be used to evaluate the changes in accessibility that would result from a full dispersion scenario (i.e. no effort is made to increase population/employment in already...
Figure 2.3: 2030 Population Density

Figure 2.4: 2030 Employment Density
Figure 2.5: Population Change 2010-2030

Difference between 2030 and 2010 population forecasts
Twin Cities, Minnesota USA
2010 Population Total = 3,043,355
2030 Population Total = 3,734,838
Percentage Change = 22.7%

TRAFFIC ANALYSIS ZONES
- Less than 0
- 1 to 500 more
- 501 to 2500 more
- 2501 to 5000 more
- 5001 to 10000 more
- 10001+ more
- Major Highways

Figure 2.6: Employment Change 2010-2030

Difference between 2030 and 2010 employment forecasts
Twin Cities, Minnesota USA
2010 Employment Total = 1,820,072
2030 Employment Total = 2,226,025
Percentage Change = 22.3%

TRAFFIC ANALYSIS ZONES
- Less than 0
- 1 to 500 More
- 501 to 2500 More
- 2501 to 5000 More
- 5001 to 10000 More
- 10000+ More
- Major Highways

Data Sources
- MetCouncil Planning Network
- MetCouncil Employment File
- NEXUS Research Group
developed areas). A map of the decentralized population growth is shown in Figure 2.9, and the decentralized employment growth is shown in Figure 2.10.
Revised 2030 Population Forecasts - Centralized Development

2030 Population Totals = 3,734,838
Population:
Within beltway = 1,999,406
Outside beltway = 1,735,432

TRAFFIC ANALYSIS ZONES

Less than and equal to zero
1 to 500 More
501 to 2,500 More
2,501 to 5,000 More
5,001 to 10,000 More
Greater than 10,000
Beltway
Major Highways

Data Sources:
MetCouncil Planning Network
MetCouncil Population File

Figure 2.7: Centralized Population Growth

Revised 2030 Employment Forecasts - Centralized Development

2030 Employment Totals = 2,226,025
Employment:
Within beltway = 1,453,335
Outside beltway = 772,690

TRAFFIC ANALYSIS ZONES

Less than and equal to zero
1 to 500 More
501 to 1,000 More
1,001 to 2,500 More
2,501 to 5,000 More
Greater than 5,000
Beltway
Major Highways

Figure 2.8: Centralized Employment Growth
Revised 2030 Population Forecasts - Decentralized Development

2030 Population Totals = 3,734,838
Population:
Within beltway = 1,249,342
Outside beltway = 2,485,496

Traffic Analysis Zones

Less than and equal to zero
1 to 250 More
201 to 500 More
401 to 750 More
751 to 1,000 More
Greater than 1,000
Beltway
Major Highways

2030 Population Totals = 3,734,838
Population:
Within beltway = 1,249,342
Outside beltway = 2,485,496

Figure 2.9: Decentralized Population Growth

Revised 2030 Employment Forecasts - Decentralized Development

2030 Employment Totals = 2,226,025
Employment:
Within beltway = 997,092
Outside beltway = 1,228,933

Traffic Analysis Zones

Less than and equal to zero
1 to 500 More
501 to 1,000 More
1,001 to 2,000 More
2,001 to 3,000 More
Greater than 3,000
Beltway
Major Highways

2030 Employment Totals = 2,226,025
Employment:
Within beltway = 997,092
Outside beltway = 1,228,933

Figure 2.10: Decentralized Employment Growth
2.2 Highway Networks

2.2.1 Freeflow

The freeflow network (N0) has no congestion whatsoever and is used to evaluate what the accessibility would be under ideal conditions or if there were some technological advance resulting in greatly increased effective capacity (e.g. autonomous vehicles), or some policy that eliminated congestion.

Effectively, there are only 4 land use scenarios for this network. The two mixed centralized/decentralized scenarios have the same geographic distribution of accessibility as the appropriate all centralized/decentralized scenario for this network because congestion is absent. However, the weights for person-weighted accessibility change, so the numbers are different for all six land use scenarios. For all other networks, the location of labor affects access to employment (and vice versa) because it alters congestion patterns.

2.2.2 2010 Highway Network

This scenario represents the existing highway network as of 2010 (N1). The scenario with 2010 Land Use is the existing condition, while all other scenarios with this network show what would happen in 2030 without any network improvements.

2.2.3 2030 Highway Network

This case (N2) includes all network improvements envisioned by the Metropolitan Council in their Comprehensive Plan. Most of the changes are new roads or expansions outside the Beltway, but there are a few freeway expansions planned inside the Beltway: I-494 near Woodbury, I-35E north of downtown Saint Paul, MN-36 in Maplewood, and I-94 near the University of Minnesota campus. The scenario with 2030 Land Use shows the 2030 accessibility if all growth and network improvements occur according to the Comprehensive Plan.

2.2.4 Diamond Lane Network

This scenario (N4) represents the 2030 highway network with the addition of HOT lanes. As of 2010, HOT lanes exist on I-394 and I-35W south of downtown Minneapolis. This network would extend HOT lanes to the rest of the freeway network on or inside the Beltway. As such, this network will be similar to the freeflow network because freeflow travel is possible on most freeway links (assuming the HOT lanes are regulated to maintain freeflow speed). The cost of tolls is not included in the accessibility measure here.

2.2.5 Congestion Pricing

This scenario (N5) represents the 2030 highway network with congestion pricing implemented. This was modeled by assigning users to network paths in order to achieve a system optimal solution. A true system optimal would be difficult to achieve, but this modeled scenario could be implemented by using dynamic pricing to move users away from heavily congested links. The toll that users pay in this scenario was assumed to be in terms of travel time (i.e. the volume delay function (link performance function), which is normally the average cost of travel, was converted to the marginal cost function, so the difference represents the additional congestion cost travelers impose on others. As a consequence the accessibility measured from this scenario is not the simply the time cost travelers pay, but a composite of time cost plus marginal cost (as if the toll were converted to travel time). This follows the methodology developed and applied by [1].
2.3 Transit Networks

2.3.1 2010 Transit Network

This scenario represents the existing transit network as of 2010 (T0). The scenario with 2010 Land Use is the existing condition, while all other scenarios with this network show what would happen in 2030 without any network improvements.

2.3.2 2030 Transit Network

This scenario considers accessibility by public transit (T1). The transit network is the anticipated 2030 network according to the Metropolitan Council. It includes the Bottineau, Rush Line, and Cedar Avenue transitways (as BRT), the Central Corridor and Southwest light rails, and the Red Rock commuter rail east of Saint Paul. In addition to these, there are also a number of planned bus routes that are not part of a transitway or feeders into a rail line. A map of all the transit networks is shown in Figure ??

2.3.3 Minneapolis Streetcars

This scenario (T2) includes the 2030 transit network plus the following lines identified in the Minneapolis Streetcar Plan. This includes lines on West Broadway, Hennepin Avenue, Nicollet Avenue, Chicago Avenue, Central Avenue NE, University Avenue SE, and on the Midtown Greenway. Present-day bus routes that follow the proposed streetcar lines were eliminated to avoid duplication.

2.3.4 Rhodium Network

This case (T3) is a network of rail corridors. These are radial transit lines that are in planning stages but were not included in the Metropolitan Council’s 2030 network. This includes Bottineau (as LRT), Red Rock commuter rail between Minneapolis and Saint Paul to Hastings, the Gateway Corridor, Robert Street, and a line from Saint Paul to Shoreview. This scenario includes all lines from the 2030 Transit Network and Minneapolis Streetcars. Present-day bus routes that follow the proposed lines were eliminated to avoid duplication.

2.3.5 Retro Transit

This scenario (T4) includes the 2030 base transit network plus the Twin City Rapid Transit (TCRT) network at its maximum extent in 1932. Present-day bus routes that follow old streetcar lines were eliminated to avoid duplication.

2.3.6 Platinum Network

This case (T5) is a network of rail corridors. It includes several circular lines, complementing the radial lines of the existing and proposed transit networks. Many of these corridors are on new terrain (meaning in this case, not served by any current transit route). This scenario can be used to evaluate the effectiveness of circular as opposed to radial transit routes, as well as the changes in accessibility that would result from an aggressive expansion of the transit network. This network includes all of the above transit networks as well. Present-day bus routes that follow the proposed lines were eliminated to avoid duplication.
Figure 2.11: Flowchart of Transit Scenarios

2010 Transit Network

2030 Base Network

Minneapolis Streetcars

Rhodium Network

Platinum Network

Figure 2.12: 2030 Highway Network

Number of links: 22,823
Number of nodes: 8,881

Primary Data Sources: Twin Cities Metropolitan Council
2030 Metropolitan Council Planning Network
Links Changed or Added Since 2009
Figure 2.13: Transit Networks

Transit Networks

Primary Data Sources:
Twin Cities Metropolitan Council
Transit Networks

05 1 02.5 Kilometers
036 1.5 Miles
NEXUS Research Group

1932 TCRT
Platinum
Rhodium
Minneapolis Streetcars
Transportation Analysis Zones

2030 Base Network
Chapter 3

Methodology

3.1 Highway Travel Time Calculations

The highway scenarios, with the exceptions of the freeflow and diamond lane networks, were run in the SAND model developed as part of a previous project and employed by MnDOT for several studies (Beyond Business as Usual (as SONG/2), Evaluating the effects of I-35W bridge collapse on road-users in the Twin Cities metropolitan region, Travel Impacts of Bridge Closures 1: Lafayette Bridge, Travel Impacts of Bridge Closures 2: Saint Croix River Bridges). The details of the model are in the Appendix.

For the congestion pricing network, the link function was transformed from an average cost to a marginal cost

\[ MC = \frac{\delta(Q \times AC)}{\delta Q} \] (3.1)

This increases the costs for congested links by the amount of delay a driver is imposing on other vehicles, thereby moving travelers to less congested links (in the short run) and to changing trip destinations in the long run. These long run feedbacks are included in the model, which iterates between trip distribution and route assignment.

The model returns population and employment accessibility (cumulative opportunities) for each TAZ at the six time thresholds (10, 20, 30, 40, 50, 60 minutes). Labor accessibility was computed after the model run by joining labor data to the OD matrix in TransCAD 4.8. The freeflow network was computed by running travel time skims in TransCAD. This procedure uses a version of Dijkstra’s algorithm [5], but it was not necessary to perform multiple iterations because freeflow speeds were assumed. Additionally, the diamond lane network was created from the 2030 network model run by replacing the link speeds on freeway segments with HOT lanes with freeflow speeds. This assumes high occupancy toll facilities are operating at freeflow speeds.

3.2 Transit Travel Time Calculations

The transit scenarios were run using an SQL database following the procedure in [7]. This code took schedules, transfers, and stop data as inputs. The data for the current (2010) network was supplied by Metro Transit in this format.

New routes were first drawn in ArcMap 9.3 from the Metropolitan Council’s 2030 plan. Stops were added in new areas, but only at a frequency of two per TAZ considering the scale of this analysis. Using Network Analyst tools, nearby stops were associated with each route and the distance between stops along the route was measured. Each new route was classified as an urban local, limited stop, suburban local,
express, LRT, or commuter rail and schedule times were calculated based on the average speed (from end to end, which includes stop dwell times) for current routes in the same class. Schedule headways were given by the Metropolitan Council. None of the new routes have timed transfers; for example, if a route has a 15 minute headway then it starts trips at 6:00, 6:15, 6:30 and so on. Transfers between routes were calculated assuming no greater than a 200m walk radius.

Once the schedules, transfers, and stops had been produced for the new routes, this data was loaded into the database. For each stop, the code calculates what census blocks can be reached with a maximum of one transfer and saves the lowest travel time to each block. When the code has finished running, a file of block to block travel times is exported. The block to block files were converted to TAZ to TAZ files and dissolved to obtain the lowest travel time for each TAZ pair. Using ArcMap, another TAZ to TAZ matrix was created of walk times, assuming an average speed of 5 km/h. The walk time matrix takes the shortest path between zones. These two TAZ to TAZ matrices were combined, and the lowest time was taken for each pair. This leads to a low level of accessibility in outlying areas, despite having no transit service, as individuals could walk between zones.

### 3.3 Accessibility Calculation

The cumulative opportunity accessibility measure is traditionally defined as:

\[
A_{i,T} = \sum_{j=1}^{J} O_j D(C_{ij})
\]

where:

- \(A_{i,T}\) = cumulative opportunities from a zone \((i)\) to the considered type of opportunities \((j)\) reachable in time \(T\).
- \(O_j\) = opportunities of the considered type in zone \(j\) (e.g., employment, shopping, etc.)
- \(C_{ij}\) = generalized (or real) time or cost from \(i\) to \(j\)
- \(D(C_{ij}) = 1\) if \(C_{ij} < T\) and 0 otherwise.

The threshold \(T\), indicating the time for which we will compute the number of activities that can be reached, varies from 10 minutes to 60 minutes.

The cumulative opportunity measures are combined to develop a complete time-weighted accessibility measure used in this report uses a different impedance function, defined in [Levinson and Kumar] as:

\[
A_{i, tw} = \sum_{T=10}^{60} (A_{i,T} - A_{i,T-10}) \cdot e^{\beta \ast T}
\]

where:

- \(\beta = -0.08\)
- \(T\) = time threshold for cumulative accessibility

This measure weighs the cumulative accessibility at 10 minute intervals from 10 to 60 minutes. The result, a weighted employment accessibility for each TAZ, is weighed by zone population as described above.

An overall person-weighted accessibility \(A_{pw}\) is calculated for employment by multiplying the cumulative accessibility by zone at the time threshold by a weight \(W_i\) (e.g. the zone population) and dividing the product by the sum of the weights. The same calculation was performed for population and labor, but with zone employment as the weight.
\[ A_{pw,T} = \frac{\sum_{i=1}^{I} A_{i,T} \cdot W_i}{\sum_{i=1}^{I} W_i} \] 

Similarly a composite time-weighted, person-weighted accessibility is

\[ A_{pw, tw} = \frac{\sum_{i=1}^{I} A_i \cdot W_i}{\sum_{i=1}^{I} W_i} \]
Chapter 4

Results

Looking at the accessibility maps for all the different scenarios (contained in Appendix A), the trends are easiest to see at 10 and 20 minutes. By 30 minutes, the differences between the scenarios are starting to subside, but it is still interesting to compare how far the red color (minimum of 1 million jobs reachable) extends into the suburbs. At 40 and 50 minutes, the differences between scenarios are relatively small, and at 60 minutes the entire metro area is red for most scenarios. This does not mean that every job is accessible from every zone in the 7-county metropolitan area, merely that at least 1 million jobs are reachable from every zone. It should also be noted that the accessibilities for zones on the edges of the 7-county metro are underestimated. In reality, people in these zones would be able to reach jobs outside of the metro as well. This is particularly true for western Carver County, which has poor accessibility to the metro area due to the geographical barrier of Lake Minnetonka, but is close to the cities of Hutchinson and Glencoe, which are both outside of the metro area.

Tables A.1 through A.6 show person-weighted accessibility at 20 and 30 minutes for employment, labor, and population, respectively. Looking across the different land use patterns, the highest person-weighted accessibility to jobs and to labor in almost all scenarios comes with centralized employment and population (LCC). The second highest is usually with centralized population and decentralized employment (LCD). However for labor accessibility, and the Met Council anticipated 2030 network (N2), decentralized population and centralized employment (LDC) slightly outperforms LCC and LCD. In all cases LCC has higher accessibility than fully decentralized growth (LDD).

In general centralizing population and decentralizing (LCD) employment produces more access to jobs than decentralizing population and centralizing employment (LDC), consistent with the suggestion of [9]. This scenario will also produce shorter commute times. It also usually produces more access to labor.

Compared to the forecast scenario, LCC produces about 20 to 25 percent more accessibility, depending on the network configuration.

Table C.1 shows the time-weighted accessibility measure. Although the numerical values are different, the overall trends are essentially the same. Centralized population and employment produces the highest accessibility, followed by centralized population and decentralized employment. The decentralized population, centralized employment scenario performs better than the 2030 comprehensive plan on the freeflow, diamond lane, and 2030 transit networks, but falls behind on the 2010, 2030, and congestion pricing networks.

Comparing networks (e.g. Table A.2, person weighted jobs within 30 minutes), the freeflow network (N0) has the highest accessibility, followed by the Diamond Lane network (N4) (which has freeflow times on the freeway system inside the Beltway) (excluding the cost of tolls). The freeflow network (N0) has about 20 percent more accessibility than forecast network (N2). So if some technology could bring about freeflow travel, we would expect accessibility to be about 20 percent higher in peak. It is even greater for shorter time thresholds (i.e. the number of jobs that can be reached in 20 minutes increases more than 20 percent). The Diamond Lane network, which has freeflow times on freeways has about two-thirds as much gain as N0.
compared to N2.

The anticipated 2030 network (N2) generally bests the existing 2010 network (N1) except when there is centralized population and centralized employment (LCC), but the two are very similar. Remember while the trip generation is the same across networks, the trip distribution is not, and depends on congestion levels. So adding to capacity in some areas will re-distribute demand and reroute traffic and thus shift congestion. While there may be a net reduction in congestion (this is not guaranteed), the change in congestion will make some places more accessible and others less. The model nets this out and solves for the equilibrium. It turns out adding capacity in some places reduces accessibility to others. The added capacity in general adds about 2 percent to 20 minute accessibility to jobs and 1 percent to 30 minute regional accessibility to jobs.

The congestion pricing scenario is only slightly better than N2. The reason is the the “tolls” are paid in terms of travel time in this scenario, so the costs are embedded, which differs from the assumption in the Diamond Lane network. That said, it provides about a 1 to 2 percent increase in (generalized time plus money) accessibility over the base, after considering tolls. This model accounts for the spatial benefits of tolling in terms of reallocating traffic to better routes, and some redistribution of traffic to different destinations, but does not fully account for time of day shifts, as the trip generation (by time of day) is fixed.

Transit accessibility is about twice as high in the centralized LCC vs decentralized LDD scenarios, indicating transit works significantly better at connecting people to jobs at higher densities.

Figures 4.1 and 4.2 show the ratio of highway to transit accessibility by zone at 20 and 30 minutes, respectively. The highway network, transit network, and land use in these figures are all from the Metropolitan Council’s 2030 Comprehensive Plan. At 20 minutes, there are some zones with a ratio of less than 1, a consequence of the decision to include walk times in the transit model and to calculate them based on the shortest distance between TAZ polygons. At 20 minutes, this is still a significant assumption, but there are other zones where the ratio has exceeded 100. At 30 minutes, the walking assumption appears to no longer be significant. Transit fares relatively well in this comparison in Minneapolis, Saint Paul, and some of the inner-ring suburbs, but does poorly outside of the I-494/694 Beltway. The highest ratios are found in outer-ring suburbs and exurban areas, which is to be expected. Walking is surprisingly effective in western Carver County (the westernmost part of the Metro area), as this area is poorly served by the existing highway network.
Figure 4.1: Ratio of Highway to Transit Accessibility: 20 Minutes

Figure 4.2: Ratio of Highway to Transit Accessibility: 30 Minutes
Chapter 5

Conclusion

This study uses accessibility measures to compare a set of planning scenarios for the Twin Cities Metropolitan Area. At first glance, it would be easy to pick out the combination of land use and network with the highest accessibility and select that as the planning goal. Although this combination, centralized population and employment on a freeflow network, might be ideal, it is likely not cost-effective or feasible under current technologies. Trying to achieve this combination would mean working against both the trends of increasing congestion (due to population growth) and decentralization of population and employment. Instead, the best use of these tables are the comparisons that can be made.

First, it is clear that a change in land use is more effective than the anticipated changes in the network, though moving to a freeflow network (through technological change or through pricing) would have significant time accessibility improvements (20 percent) though clearly at some monetary cost. [Levinson and Marion] came to the conclusion that network changes have a more local effect while land use changes have a regional effect. That is confirmed here, and one of the strongest arguments in favor of this conclusion is a comparison between the centralized population decentralized employment and the decentralized population centralized employment scenarios. The Twin Cities have highway and transit networks that were designed to serve a decentralized population commuting to centralized employment, and yet reversing this land use trend has higher accessibility, as it can make use of under-utilized capacity in the off-peak direction. This is not so surprising on the highway networks, as they work just as well for reverse commutes, but is interesting to see for the transit network as they are still designed to bring commuters into downtown.

The results of this study show that accessibility measures are a viable tool for comparing planning scenarios. With a selection of possible scenarios as broad as this one, it would be difficult to select one as the best choice to implement without knowing more about the cost and feasibility of each option. If the trend of decentralized development is too difficult to reverse, an investment in congestion pricing or HOT lanes might be best. On the other hand, decentralized development renders the transit system ineffective and reduces the effectiveness of the highway system in connecting people to jobs. A concentrated effort for higher densities and infill development in the central cities would benefit accessibility the most, and this study shows that increasing the centralization of population is more important than centralizing additional employment. A good use for this type of analysis would be to prioritize investments and land use strategies based on "accessibility-effective" they are, or how much accessibility per unit dollar of investment. In determining final investment and planning strategies, the value of accessibility to jobs or labor needs to be traded off against other values.
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References


5.1 Travel Demand Model

The highway travel demand model used in this project (SAND - Simulator and Analyst of Network Design) is based on the SONG 2.0 model which is originally designed to support the MnDOT project “Beyond Business as Usual” ([? ]). This model predicts the travel demand and forecasts the future metropolitan (Seven County) road network with assumptions that network investments are driven by travel demand growth and the factors that have shaped the travel demand in the past will affect future demand in a consistent pattern.
Necessary refinement has been made in this study to account for the changes in network structure (e.g. new freeways and bridges) and demographics. The new 2009 Metropolitan Council planning network that has been conflated to real network geometry is adopted. This network includes 22,477 links, 8,619 nodes, 35 external stations, and 1,236 transportation analysis zones (TAZ) for demand analysis. Links are divided into 15 categories according to their functional classes and link capacities, including AM peak, PM peak and off-peak capacities, are estimated by Metropolitan Council. The travel demand model has been calibrated against the real traffic measured by the loop detectors, and then used to predict the morning peak hour traffic. The model also estimates the morning peak hour factor using the detector data and expands peak hour traffic to AADT. Given that the public transit ridership only accounts for 3% of daily travels in the Twin Cities area, our model drops the mode choice module and directly estimates vehicle trips as a simplification of the traditional four-step process. For the same reason, the freight traffic is not explicitly modeled in this study. Instead, we inflate the passenger car traffic to account for the missing freight traffic. More details about the three major components of our demand model are discussed below.

5.1.1 Calibration

The travel demand model is calibrated against traffic data provided by loop detector stations. MnDOT maintains about a thousand traffic count stations on freeways throughout the Twin Cities Metro area. Volume and speed is measured every 30 seconds and the data are documented at MnDOT traffic data server. We randomly picked 10% of the full set of detector stations, removed malfunctioning detectors, and matched 73 out of the remaining stations with the planning network. As shown in Figure 5.1, this set of detector stations represents a good sample of the entire Twin Cities freeway system, including I-35W, I-35E, I-94, I-494, I-694, I-394, TH 36, TH 52, TH 62, TH 77, TH 100, TH 169, TH 212 and TH 280. The morning peak hour traffic rate is estimated by averaging the traffic volume from 7:00 am to 9:00 am during the weekdays of the first full week, April 2010. The peak hour rate, which is used to expand peak hour cost to daily cost, is estimated by comparing the peak hour rate and daily volume of observed at these stations.

The target of calibration is to minimize the different between the morning peak hour volumes estimated by the model and the actual morning peak hour volume observed on the selected set of links. As trip generation models have been calibrated separately and the peak hour factor has been directly estimated from the traffic data, the only parameter to be adjusted in calibration is the trip distribution friction factor $\theta$. The parameter is calibrated by using a brute force search technique. The friction factor that provides the best fit is $0.151 \cdot min^{-1}$, resulting in an overall 0.25% error between the average volumes that predicted by the model and the average real traffic count given by the detectors. The $R^2$, estimated by regressing forecast peak hour volumes on observed volume for selected stations is 0.94. The root mean square error (RMSE), defined by the formula below, is about 28%.

\[
RMSE = \sqrt{\frac{(V_n^M - V_n^O)^2}{N - 1}} / \bar{V}_n^M
\]

Where:

- $V_n^M$ is the estimated traffic volume on link $n$;
- $V_n^O$ is the observed traffic volume on link $n$; and
- $N$ is the number of detector stations used for calibration.

5.1.2 Trip Generation

Trip generation module estimates the number of personal vehicle trips that originate from (production) or are destined to (attraction) each traffic analysis zone. The traffic production and attraction models are separately estimated by regressing the 2005 composite vehicle trip rates by TAZ, which is provided by Metropolitan Council, on a set of zonal characteristics variables. The model that provided the best goodness-of-fit is
Figure 5.1: Selected 73 stations for model calibration
adopted. The following explanatory variables turn out to be significantly correlated with the dependent variable:

- Population
- Retail Employment
- Non-retail employment
- Residential density
- Shortest distance from centroid zone to either downtown Minneapolis or St. Paul (estimated within ArcGIS)
- Shortest previous distance squared

5.1.3 Trip Distribution

Trip distribution allocates trips generated in one zone to destination zones in the study area. In our study all trips are treated equally and one aggregate Origin-Destination matrix is generated through this process since we do not distinguish trips by purpose. The gravity model is chosen here because of its simplicity, accuracy, and wide application in many US urban areas. This study adopts a doubly constrained gravity-based trip distribution model. The number of trips $T_{i,j}$ between zone $i$ and zone $j$ is determined by:

$$T_{i,j} = K_i K_j T_i T_j e^{-\theta C_{i,j}}$$

Where:
- $K_i$ and $K_j$ are balancing coefficients;
- $T_i$ is the traffic production of zone $i$;
- $T_j$ is the traffic attraction of zone $j$;
- and $C_{i,j}$ is the travel cost between zone $i$ and $j$.

The gravity model assumes that the interaction (here travel demand) between two locations is positively associated with the amount of activity at each location but declines with increasing impedance between them, which is modeled by a the negative exponential function of the travel cost here. The friction factor $\theta$ is a parameter to be calibrated in the model. It is an inverse function of travel time, which captures where people prefer longer or shorter trips. The balancing coefficients $K_i$ and $K_j$ ensure that the aggregate trips match both the number of traffic generation at the origins and the number of traffic attraction at the destinations. These coefficients are solved iteratively in the model by following:

$$K_i = \frac{1}{\sum_j K_j T_j f(C_{i,j})} \quad \text{and} \quad K_j = \frac{1}{\sum_i K_i T_i f(C_{i,j})}$$

5.1.4 Assignment

Traffic assignment determines the actual route that will be used by travelers between each Origin-Destination pair and the number of vehicle trips can be expected on each network link. The predicted network traffic pattern depends on the assumption about route choice preferences among travelers. For example, User Equilibrium (UE) models assume each traveler chooses the route minimizing their own travel time. In this study, we adopt the Stochastic User Equilibrium (SUE) model which is originally introduced by Daganzo and Sheffi [3], and assumes that travelers choose the route with minimum perceived travel time. Dial's algorithm [4] is used to perform network loading and the Method of Successive Average (MSA) is used to
find the SUE link flow. The Bureau of Public Road (BPR) link performance function is adopted to derive the congested link travel time as a function of link flow rate and capacity. Following Leurent [8], a scaling coefficient of 0.2 is used in the discrete choice module. The convergence for MSA is defined by a maximal allowable link flow change below a threshold of 100 vehicles.