Spatial and Temporal Analysis of Urban Traffic Volume

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Abstract

This study explores traffic patterns in the Twin Cities metropolitan area from 1997 to 2006. Traffic flows are analyzed at the annual, monthly, weekly, and daily time scale. The results show that there are significant traffic volume changes among 847 traffic volume count stations in major highways with respect to temporary and spatial aspects. For the ten years, the annual total traffic volume has been increased. However, the increase rate of traffic volume has been decreased since 2004. The study illustrates that the new public transit (LRT) helps decrease the urban traffic volume on the major highways. In terms of the monthly traffic volume pattern, August has the highest traffic volume whereas January has the lowest traffic volume. The difference in monthly fluctuation is mainly due to weather conditions. Among the days of week, Friday has the most traffic volume whereas Sunday has the least. Commuting traffic flows are used to illustrate the hourly traffic pattern.

Key words: transportation, GIS, traffic volume, commute, light-rail train, the drive miles per vehicle

1 Introduction

Based on previous studies regarding urban traffic flow, there are several common findings. First, urban traffic volume is increasing every year. Second, studies show that urban traffic problems occur due to over-supplied traffic on limited roadways. Third, traffic congestion is not incurred randomly. Fourth, traffic volume pattern is different spatially and temporary.

Last, a deep understanding of traffic flow gives benefits to all levels of government and private agencies.

In the U.S., traffic volume has been increasing rapidly especially in the metropolitan areas, likewise a total number of vehicle miles on all roads and streets have been increasing as well. According to the traffic volume trend report from the Federal Highway Administration (FHWA), the number of annual vehicle distance traveled on roads has doubled compared to the value in the year 1981. In addition, FHWA estimated that an individual driver drove 1,036 vehicle miles (35%) in rural areas and 1,960 miles (65%) in urban areas in 2006 (FHWA, Traffic Volume Trend 2007). However, road infrastructure has not increased as much as demand increased. A total distance of lane in the U.S. has increased 2.62 percent: the total distance of lane is 8,158,181 miles in 1995 whereas it is 8,371,718 miles in 2005 (FHWA, Highway Statistics 1995 1995, FHWA, Highway Statistics 2005 2006). These reports imply that overall traffic volume has increased greatly in the U.S., a high percent of the traffic volume is related with urban area, and supplied infrastructure does not meet the traffic demands. As traffic volume increases in an urban area, urban traffic congestion becomes a serious problem. Cervero (2006) addressed that traffic congestion incurs not only waste time, money, and energy but also affects productivity. In terms of monetary loss, in 2002, the traffic congestion wasted 63.2 billion dollars in urbanized areas of North America (Schrank and Lomax. 2004).

Contemporary traffic data collection became the responsibility of State DOTs, cities, counties, metropolitan planning organizations in standard rule (Mergel 1997). For example, the Minnesota Department of Transportation (MN DOT) has been collecting and forecasting traffic volume statewide using the Traffic Monitoring Guide by FHWA. MN DOT uses two different data frameworks; one is for short duration counts, and another is for permanent continuous counts. These frameworks use three detectors, such as the Automated Traffic Recorder, Weigh in Motion, and Tube Counters to count traffic flow. Based on the collected traffic flow information, MN DOT provides various information of traffic flow such as Average Annual Daily Traffic (or “AADT”), Average Daily Traffic (or “ADT”), Average Daily Load (or “ADL”), Average Summer Weekly Traffic (or “ASWDT”), Heavy Commercial Annual Average Daily Traffic (or “HCAADT”), etc. Therefore, transportation practitioners and researchers can articulate their research via the mobility of human and accessibility of location in order to find and solve derivative problems of urbanization. The short duration and continuous traffic count are related with capabilities of transportation infrastructures such as road facilities, parking lots, public transportation systems, etc. These capabilities of transportation infrastructures are related with receptive capability of living environmental capacity such as noise level, air quality, commuting time, traffic congestion, etc.

A travel pattern model consists of home, workplace, day care center, food store, and health club as aspects of daily travel pattern (Hanson 2004). Among these trips, journey to work is the most important factor of urban traffic flow. In 1983, FHWA estimated that 30.7 percent of vehicle-trips are related with work or work related business purposes: 20 percent with shopping, 1.2 percent for health, 14.9 percent for family related, 5.9 percent for school or religion, 22.2 percent for all social and recreation including vacation, visit friends, pleasure driving, etc. (FHWA, America's Challenge for highway transportation in the 21st century 1988). Thus, the research concluded that commuting flow is the highest proportion of overall urban traffic flow. The drive alone percentage is relatively higher than any other modes; also it has increased gradually (Nancy and Nanda 2003). This implies that the number of people driving to work alone is almost as high as the total commuter traffic flow.

2 Background

The Twin Cities metropolitan area consists of seven counties: Anoka, Carver, Dakota, Hennepin, Ramsey, Scott and Washington. When looking at size, economy, employment and education, the Metropolitan Area has a great influence on the Midwestern United States. According to the U.S. Census Bureau, the population of the area is approximately 2.64 million as of 2000. The Twin Cities metro area is ranked 15th in population the 25 major metropolitan areas in the U.S. Regarding the economy, the metro area is considered as one of the economical hotspots in the Midwest. As of 2007, 32 of the Fortune 1000 companies are headquartered in the Twin Cities Metro Area (Tully 2007). In terms of the average median family income ($54,304) and household income ($65,450), the metropolitan area is ranked as the 3rd highest out of the 25 major metro areas in the U.S. The poverty rate is ranked the least as the 25th. As aspect of work force, the rate of labor force participation is high when compared to other metro areas. It is ranked as the highest at 74.3 percent. The unemployment rate is relatively low. In terms of education levels of workforce, more than 90 percent of the residents have at least a high school diploma, and more than 33 percent of the residents have a bachelor’s degree or higher.

In terms of the transportation system, there is air transportation service and two major public transportation services such as light rail and bus. Regarding air transportation service, there is the Minneapolis-Saint Paul International Airport (MSP) which is the busiest airport among the upper Midwest region. It serves as a main hub for Northwest Airlines, Sun Country Airlines, and Champion Airlines. In regards to public transit, there are 198 bus routes and one light rail service. The bus routes mainly cover the downtown area, and the light rail route covers from downtown Minneapolis – Minneapolis – Fort Snelling – MSP - Mall of America. There are three major highway systems around the Twin Cities metropolitan area. Seven interstate highways run throughout the area: I-35, I-35 East, I-35 West, I-94, I-394, I-494 and I-694. The traffic volume data has been continuously collected by MN DOT since 1997 over the 847 stations on the major highways. Each station consists of several detectors which count traffic volume at 30 second intervals. In terms of efficiency of data handling and a common agreement of data aggregation level, the traffic volume is aggregated to 60 minute intervals in this study.

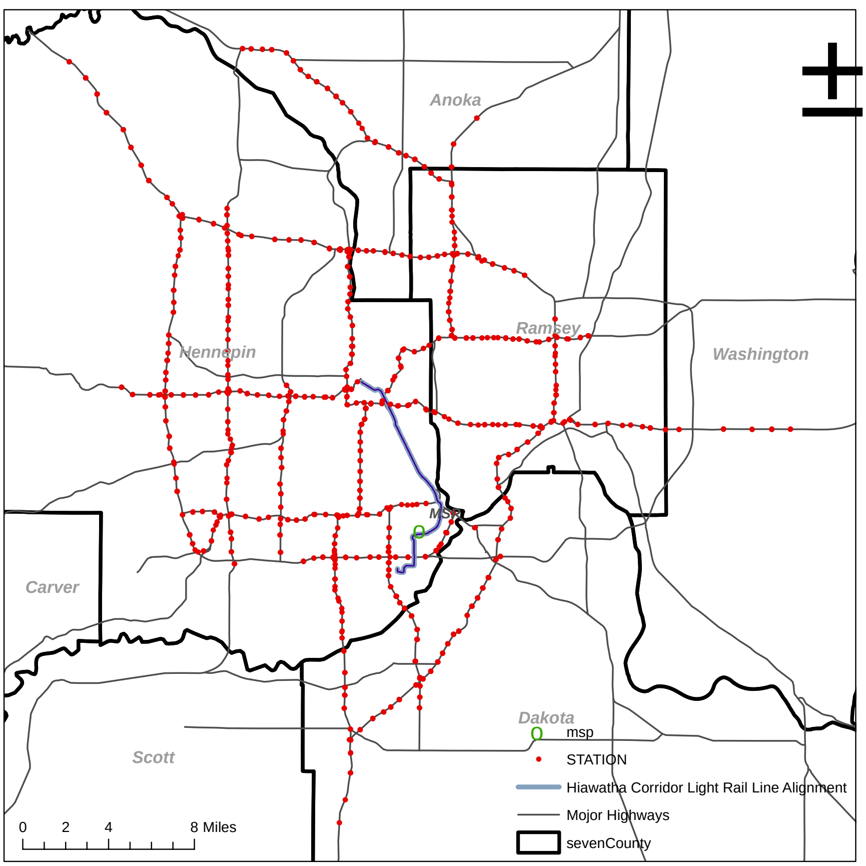

Figure 1. Study Area: The Twin Cities Metropolitan Area

3 Temporal Traffic Patterns

The total traffic volume during the last two decades in the Twin Cities area has increased. Figure 2 and Table 1 show that the Twin Cities' overall traffic volume has been changed from year to year. The total travel in the Twin Cities between 1997 and 2006 grew at the annual rate of 4.65 percent per year. Despite the fact that the annual rate is positive, traffic volume decreased during the periods of 1998-1999, and there is a significant change between years of 1999 and 2000. This is due to a portion of data missing in June and July of 1999, and December of 2000. When considering the limitation of data collection in 1999, the highest increase is during the period of 2000-2001 with an 8.6 percent growth rate. Since 2004, the increasing rate of traffic has declined gradually. Generally, traffic volume is supposed to be increased each year as population, total number of drivers, and economic growth increase. Traffic volume has been increased in most urban areas, but its degree of increasing rate has been decreased in some areas.

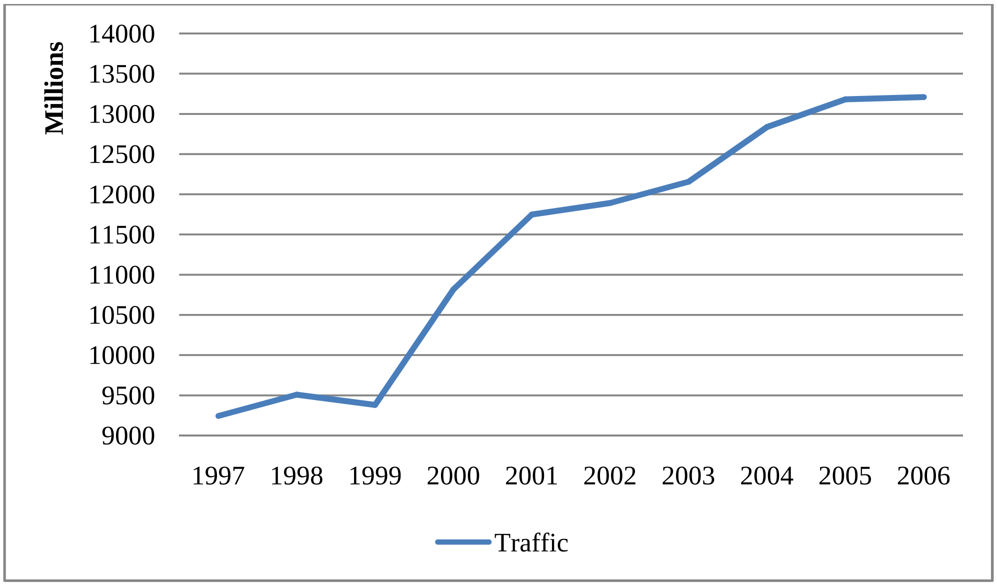

Figure 2. Yearly Traffic Volume Changes (1997-2006)

Among the reasons, various choices of public transit modes and increased public transit services are the most proper reason in the current urban transportation phenomenon. In case of the Twin Cities metropolitan area, the relationship can be explained by the increased alternative choices of transit modes which are bus and the Hiawatha Corridor Light Rail Train (LRT). As can be seen in Figure 3, the ratio of bus service has increased steadily since 2002, and the LRT service started in 2004. Note that all the classes' values are calculated based on each class value in 1997. The traffic rate has slowed down since 2004. Moreover, the traffic increase rate has been decreased in 2005 when it is compared to the previous year. This implies that the ridership of public transit has been increased. According to the Metropolitan Council's report, the ridership of LRT has been increased dramatically: 2,938,778 in the year 2004; 7,901,669 in the year 2005; 9,356,982 in the year 2006. In addition, the total number of vehicles has not been increased since 2000, while the total number of traffic volume has clearly been increased. This means that people drive more miles than they did before. Generally, human activities increase when they are opulent financially. Because of this reason, the drive miles per vehicle (DMPD) has increased considerably.

Table 1. Annual Total Traffic Volume

Year	Traffic Volume	Changes (%)
1997	9,243,900,652	N/A
1998	9,508,481,619	2.86
1999	9,379,414,269	-1.36
2000	10,816,491,935	15.32
2001	11,748,475,428	8.62
2002	11,891,424,589	1.22
2003	12,156,980,009	2.23
2004	12,836,569,939	5.59
2005	13,181,398,117	2.69
2006	13,209,420,149	4.65

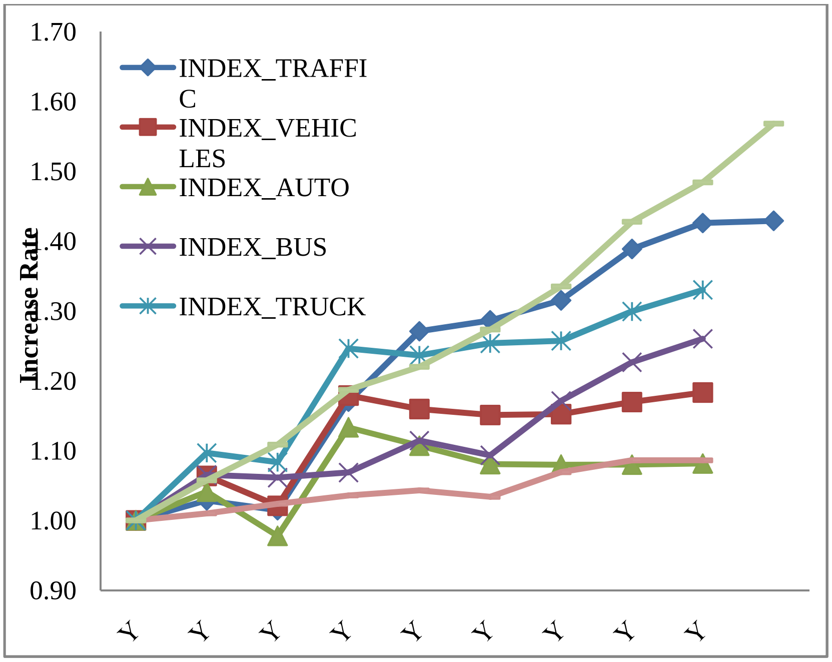

Figure 3. Comparison: Traffic volume, GDP, Number of vehicles and licenses

Figure 4 and Table 2 show the general traffic volume pattern from month-to-month. In order to represent the most recent trend, the average total traffic volume between 2001 and 2006 is shown. The chart and table represent the average daily total traffic volume for each month during the periods from 2001 to 2006. This is calculated by dividing the monthly total amount of traffic volume for each month by the number of days in each month. As can be seen in Figure 4, January has the lowest traffic, whereas August has the highest. The average traffic volume has increased from January to June steadily then it drops off in July. After August it decreases until January. The peak month and low point trend match and coincide with the nation-wide traffic pattern. Festin (1996) previously showed the similar results where the peak month for traffic volume in the U.S. is August, and the lowest level of traffic occurs in January. He also addressed that the traffic pattern is different between rural and urban areas. Traffic in rural areas has more seasonal variation than traffic in urban areas. The reason is that summer traffic in rural areas involves more seasonal vacation or tourism traffic volume. The gap in the Twin Cities metropolitan area is less than 10 percent like traffic in other urban areas. Generally, traffic volume in the winter season appears lower than other seasons.

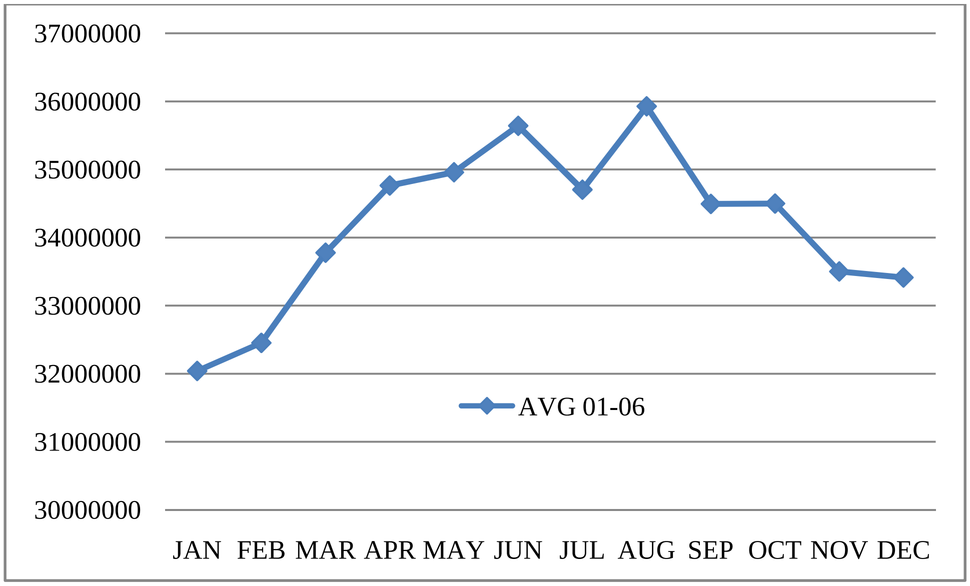

Figure 4. Monthly Traffic Volume Changes (2001-2006)

Table 2. Average Monthly Traffic Volume (2001-2006)

Month	Average	Percent	Rank
JAN	32039603.96	7.81	12
FEB	32452672.89	7.91	11
MAR	33777163.15	8.23	8
APR	34764063.82	8.48	4
MAY	34958900.83	8.52	3
JUN	35642050.13	8.69	2
JUL	34703137.08	8.46	5
AUG	35928484.99	8.76	1
SEP	34494677.11	8.41	7
OCT	34499824.56	8.41	6
NOV	33501453.48	8.17	9
DEC	33412915.90	8.15	10

Traffic patterns in the Twin Cities have a unique pattern in July. The traffic has increased from January to August except in July. In general, urban traffic reflects daily major human activity such as commuting travel, shopping travel, social meeting travel, traveling to school and etc. Since July is the end of the school year, trips which are related with school decrease. In the Twin Cities area, the population of the age group from 5 to 17 is 509,298 which is almost 20 percent of the total population, and the age group from 18 to 21 is 137,670 which is almost 5 percent of the total population respectively. Therefore, in terms of school's summer break, traffic volume may decrease in July.

In the Twin Cities metropolitan area, traffic volume in the winter season (November – February) is relatively lower than traffic in other seasons. The average traffic volume in the winter season is 0.5 percent lower than average of other seasons (Table 2). On average, ground is covered by at least 1 inch of snow for more than 100 days in between November 22nd and the next year of April 2nd (MPX 2006). The snowing and low temperature conditions lead elderly seasonal migration from Minnesota to the Sunbelt States such as Arizona, California, Florida or Texas. Hogan and Steinnes (1994) addressed that over 20 percent of the seasonal migrants from Minnesota start the activity before the age of 60, and the elderly seasonal migration rate in the area is 10.1 percent. In the Twin Cities Metro Area there is of population of 365,837 in the 50 to 64 age range and 255,245 in the 65 and above range. Collectively, these age groups represent 24% of the total Metro Area population (US Census Bureau, 2000). Therefore, during the winter season, roughly, 62,108 people are not residing in the area. The number of seasonal migrants (over 3% out of age group over 18) may affect the winter traffic volume. Monthly fluctuation needs to be examined year by year in order to find annual fluctuation of traffic volume for each month. As shown in Figure 5, traffic volume has been increased except for December in the year 2000. These cases are considered as outliers due to missing data from Dec. 4th to Dec. 14th. In the last 10 years, the highest traffic volume is recorded in August of 2005, whereas the lowest traffic volume is recorded in February of 1998.

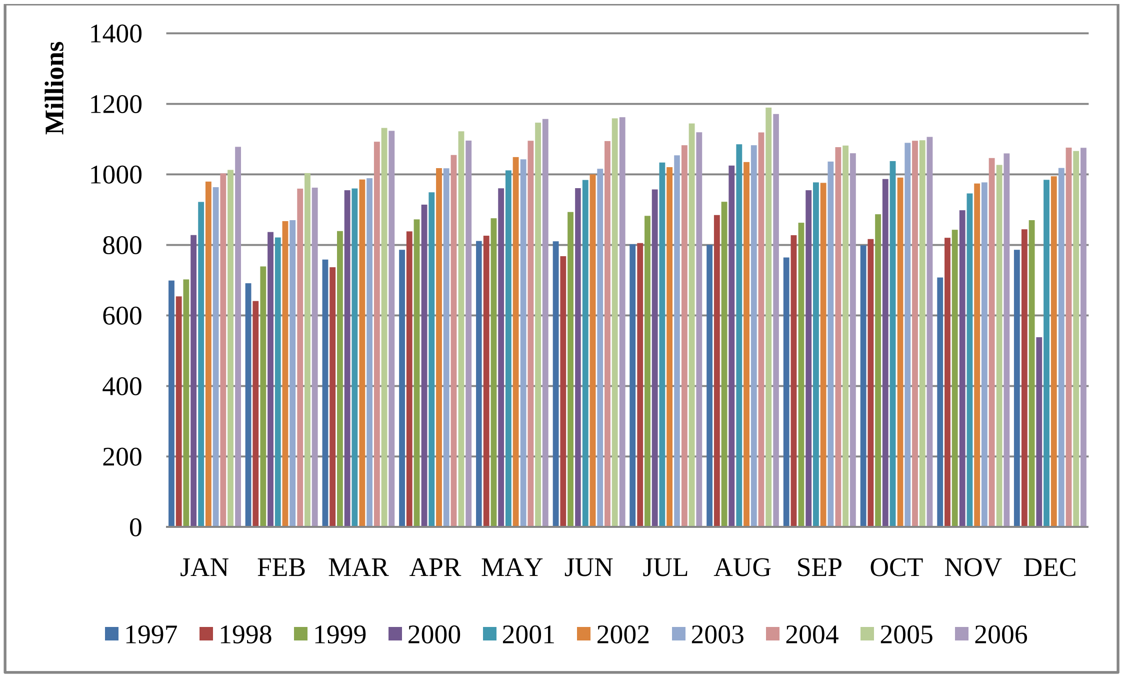

Figure 5. Daily Total Traffic Volume Changes by Month (1997-2006)

Hourly traffic volume data derives more suitable than yearly or monthly traffic volume data for urban transportation research. Many traffic congestion research projects have used traffic volume data as an important variable. Especially, as considering traffic congestions incurred in a certain time and location, the most disaggregated and up-to-date hourly traffic volume data is required. The traffic volume data presented in Figure 6 represents average annual daily traffic volume between 1997 and 2006. Note that T00 represents 12 A.M.-1 A.M. and T23 does 11 P.M.-12 A.M. The lowest point of the day is at 3 A.M., and the highest point of the day is at 4 P.M. 0.47 percent of daily traffic is measured at 3 A.M., and about 7.37 percent of daily traffic is measured at 4 P.M. The morning rush hour is starting at 5 A.M. There is approximately 4 percent increase between 5 A.M. and 7 A.M. After the morning peak hour, traffic volume decreases gradually until 10 A.M. It drops down from 6.05 percent to 4.97percent. From 10 A.M. to 4 P.M., the traffic volume increases steadily, and 4 P.M. is the highest point of daily traffic volume. Results indicate that traffic volume increases up to 7.37 percent during the afternoon peak hour. After the afternoon peak hour, traffic volume sharply decreases until 7 P.M.

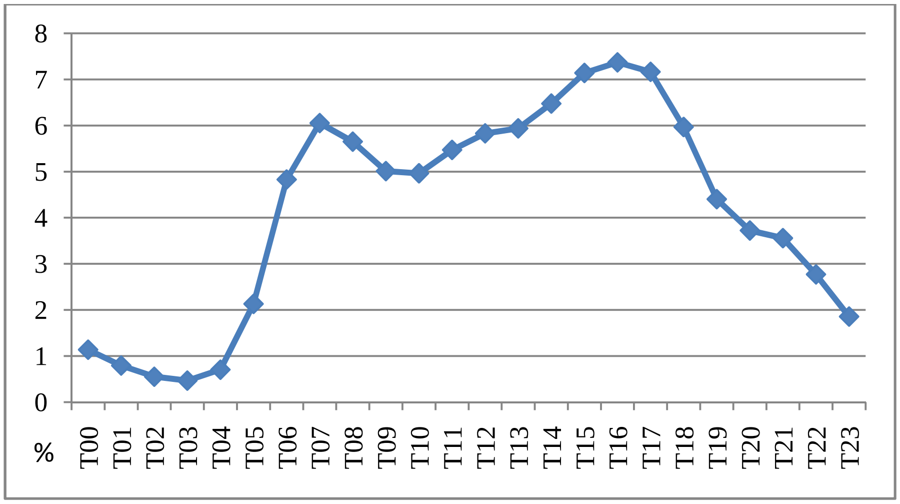

Figure 6. Distribution of Average Annual Daily Traffic (1996-2006)

In order to see the changes of daily traffic volume over the ten years, average annual daily traffic volume data is displayed for each year in Figure 7. All years of daily traffic patterns appear to be similar. However, there are several noticeable points. First, before the morning peak hour between 1 A.M. and 4 A.M., the amount of traffic volume rarely changes. Second, in terms of peak hours, the peak hours do not change (period 5 A.M.-7 A.M. in the morning peak hour and period 3 P.M. 5 P.M. in the afternoon peak hour). However, the amount of traffic volume increased year by year.

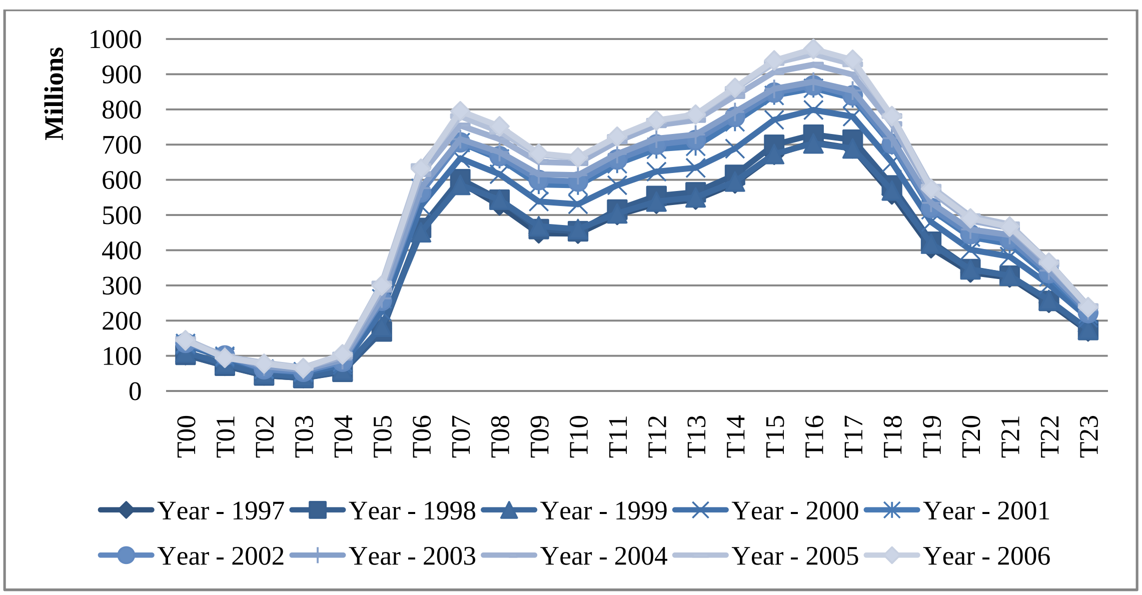

Figure 7. Annual Average Daily Traffic Volume Changes (1997-2006)

Annual average daily traffic volume is examined hour-to-hour to show the morning peak hour and afternoon peak hour trend. However, traffic volume and patterns appear differently every day of week in terms of the total amount of traffic and the patterns. In this section, first, the total traffic volume of each day of week for over ten years is examined in a year scale. Second, average traffic volume of each day of week for over the ten years is examined in a 24 hours scale. Third, distribution of total traffic volume of weekdays and weekends is examined in a 24 hours scale. Last, yearly fluctuation of total traffic volume of weekdays and weekends is examined in a 24 hours scale. In Figure 8, weekly average total volume is calculated by dividing the total traffic volume of each day of the week by the number of years. Friday is ranked as the highest in a week. In terms of total traffic volumes are similar from Monday to Friday, and traffic volumes of Saturday and Sunday are relatively lower than the other five days. On average, 78 percent of traffic occurs during the weekdays and 28 percent of traffic occurs during the weekends.

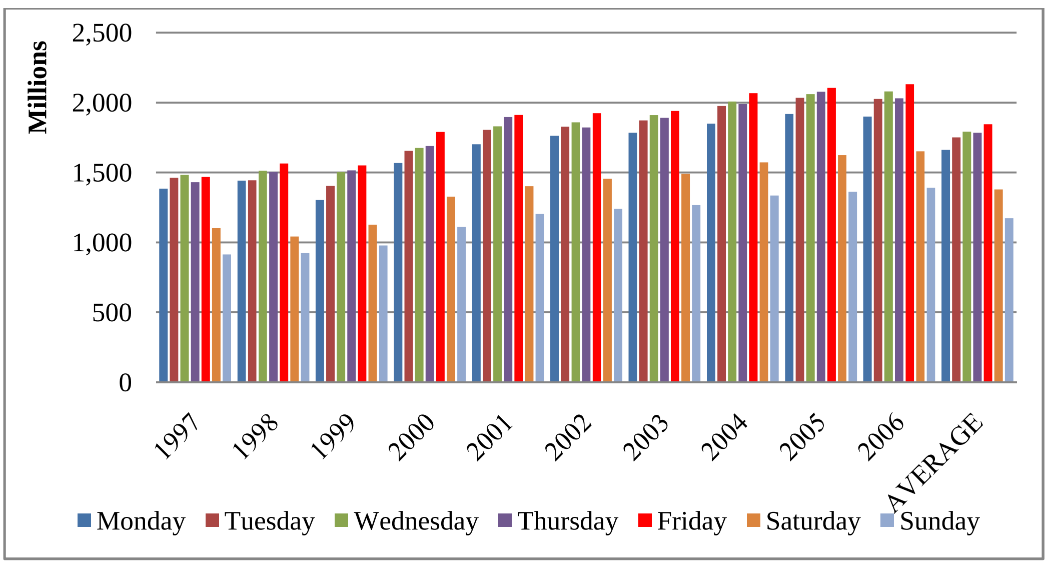

Figure 8. Weekly Average Total Traffic Volume by Days of Week

For more detail of the traffic patterns, traffic volumes for each day of the week are presented in a 24 hours scale in Figure 9. From Monday to Friday, traffic volume patterns are very similar in terms of the peak hours (morning and afternoon) and amount of traffic volume. However, the pattern on Friday is noticeable. As can be seen in Figure 8, although Friday has the highest traffic volume, traffic volumes in the peak times are lower than others. Moreover, there is more traffic during the day on Friday. There is 3.8 percent more traffic between 9 A.M. and 3 P.M. on Friday than other weekdays of traffic volume for the same time period. Saturday and Sunday are relatively distinct from other days of traffic volume in terms of the traffic volume trend and percent of traffic volume in a week. In terms of total traffic volume, there is only 12 percent of the weekly traffic volume on Saturday, and 10 percent on Sunday (Table 3). Traffic volume trends on Saturday and Sunday are bell-curved shape. This means that there is only a period of peak hours between 12 P.M. and 4 P.M. while weekdays have the two noticeable peak points. Also, the morning total traffic on Saturday and Sunday is relatively lower than that of others. The biggest gap of traffic volume is more than 100 million (107,432,127) at 7 A.M. between Wednesday (Highest) and Sunday (Lowest). Traffic volume between 10 A.M. and 12 A.M. is very consistent for 7 days except Friday and Sunday. Figure 10 shows distribution of traffic volume patterns for weekdays and weekends. The patterns of peak hour are different from each other. In the case of the weekdays, the peak hours occur at 7 A.M. and 4 P.M. However, the morning peak hour does not exist for the weekend trend.

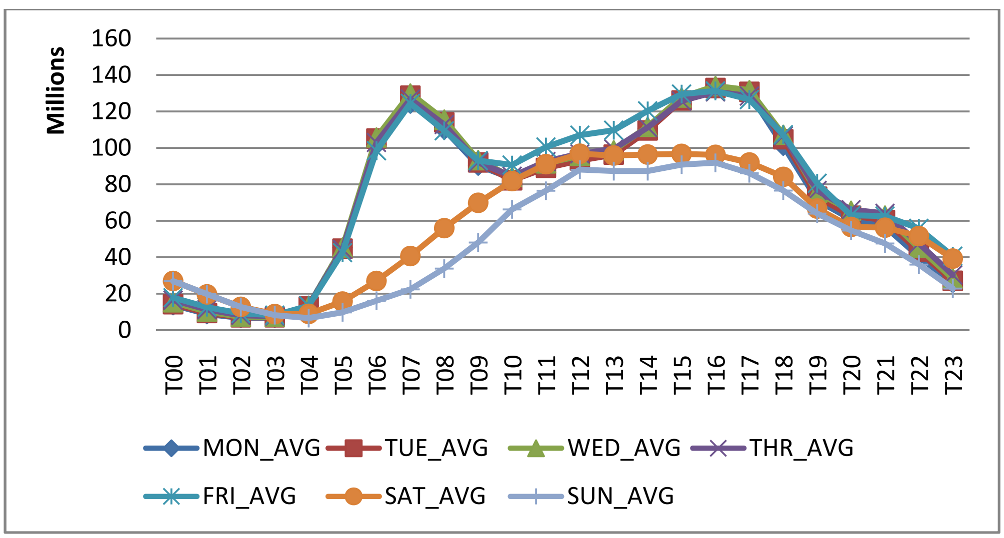

Figure 9. Daily Traffic Volume for Days of Week (1997-2006)

Table 3. Proportion of Traffic volume by days of week

Days of week	MON	TUE	WED	THR	FRI	SAT	SUN
Percent (%)	15.10	15.32	15.63	15.57	16.09	12.04	10.24

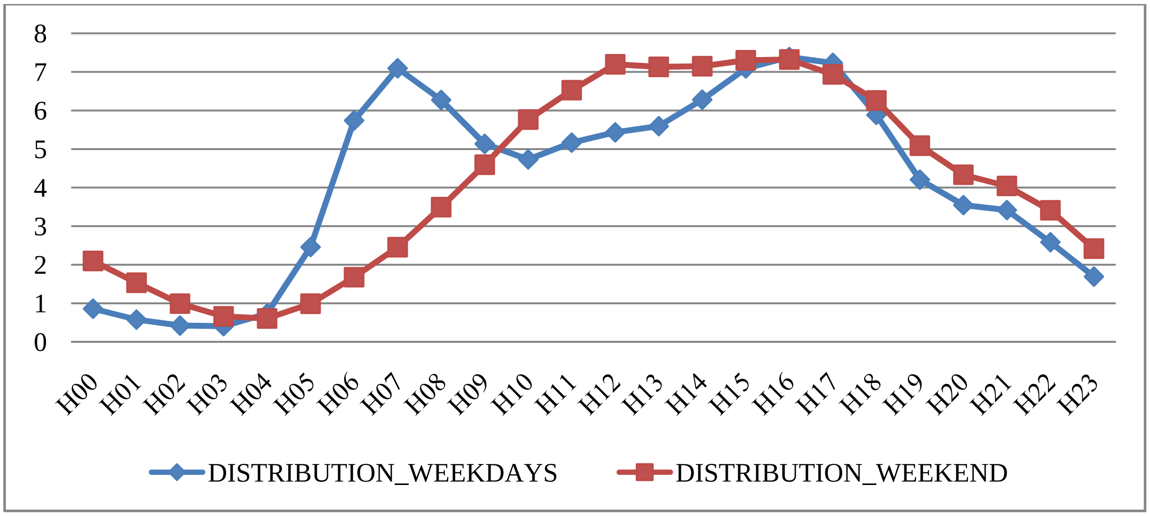

Figure 10. Distribution of Average Total Traffic Volume: Weekdays and weekend

The traffic pattern is summarized at the annual, monthly, weekly, and daily time scale. First, the total traffic volume has been increased year by year. Since 1997, traffic volume has increased 4.64 percent on average yearly. The highest increase was recorded between the year 2000 and 2001 at 8.6 percent. Second, the traffic volume varies with the time of day, the day of week and the month of year. The peak month for traffic volume in the Twin Cities Metropolitan Area is August (8.76 percent out of the total traffic volume in a year). The low point of traffic volume in the study area comes in the winter, January (7.81 percent out of the total traffic volume in a year). This means that there are low seasonal variations in the study area, even though the area has high snow fall precipitation during the winter. The peak day for traffic volume in the study area is Friday, and the low point is Sunday respectively. The peak hour for traffic volume in the study area is 4 P.M. (7.37 percent out of the total traffic volume in a day), and the low point is 3 A.M. (0.47 percent out of the total traffic volume in a day) respectively. Therefore, the highest traffic volume is captured at 4 P.M. on Friday.

4 Impact of Light Rail Service on Urban Traffic Volume

Population in suburban areas has rapidly increased, thus drive miles per driver (DMPD) has been increased. It incurs serious traffic congestions on major feed-lines in the morning or afternoon peak times. The traffic congestion not only wastes each individual driver's time, it also burden city's entire economy with higher cost and lower productivity. There are many strategies to alleviate traffic volume on major highways such as developing public transit, increasing the capacity of highways and controlling incoming traffic from major and minor arterials. Among those strategies, light rail service provides transit service to people continuously and regularly without traffic congestions.

The Metro bus system provides 198 bus routes in the entire metropolitan area, and Hiawatha Light Rail Train (LRT) has provided one route between Minneapolis downtown and the southern suburb of Bloomington, Minnesota since 2004. The Hiawatha Light Rail has provided service since June, 2004 along the Highway 55 corridor. It provides services between 4:00 A.M. and 2:00 A.M. covering the 17 stations along 12 miles of service distance connecting downtown Minneapolis, Minneapolis-St. Paul International Airport (MSP) and Mall of America in Bloomington. In this case study, we investigate how the LRT affects the traffic system in the Twin Cities metropolitan area based on traffic volume changes nearby the service area (Figure 11). The study area comprises with 19 links on major highways nearby the Hiawatha LRT service area. In order to identify the impact, general traffic change pattern for 2000-2003 is obtained using equation (1). Traffic change pattern in pre-event (June 24th, 2003-June 24th, 2004) and post-event (June 25th, 2004-June 24th, 2005) is calculated using equation (2). The difference is compared using equation (3).

$$f(G) = \frac{1}{i}\sum_{N\in i}^{i-1}\left[\frac{\{(Y_i)-(Y_{i-1})\}}{Y_i}\right] \qquad (1)$$

Where:

N = {2003, 2002, 2001}

Y_i = Total traffic volume in year i

$$f(P) = \left[\frac{T_i - T_{i-1}}{T_i}\right] \qquad (2)$$

Where:

T_i = Total traffic volume in the post-service year

T_{i-1} = Total traffic volume in the pre-service year

$$f(N) = f(P) - f(G) \qquad (3)$$

Where:

F_N = Fluctuation of node N

$f(P)$ = Average change of traffic volume

$f(G)$ = Changes between the pre & post LRT service

For the case study, links 5 and 7 are selected. In Figure 11, traffic volume stations on Interstate Highway 94 are selected for link 5. From the East to West interstate highway it connects Canada, Montana, North Dakota, Minnesota, Wisconsin, Illinois, Indiana, and Michigan. In Minnesota, I-94 connects the Southeast side of the Twin Cities metropolitan area to Northwest side of Minnesota and vice versa. The junction where I-94 and I-35W link together is considered to be one of the heaviest links in the Twin Cities metropolitan area in terms of annual average traffic volume (Figure 12).

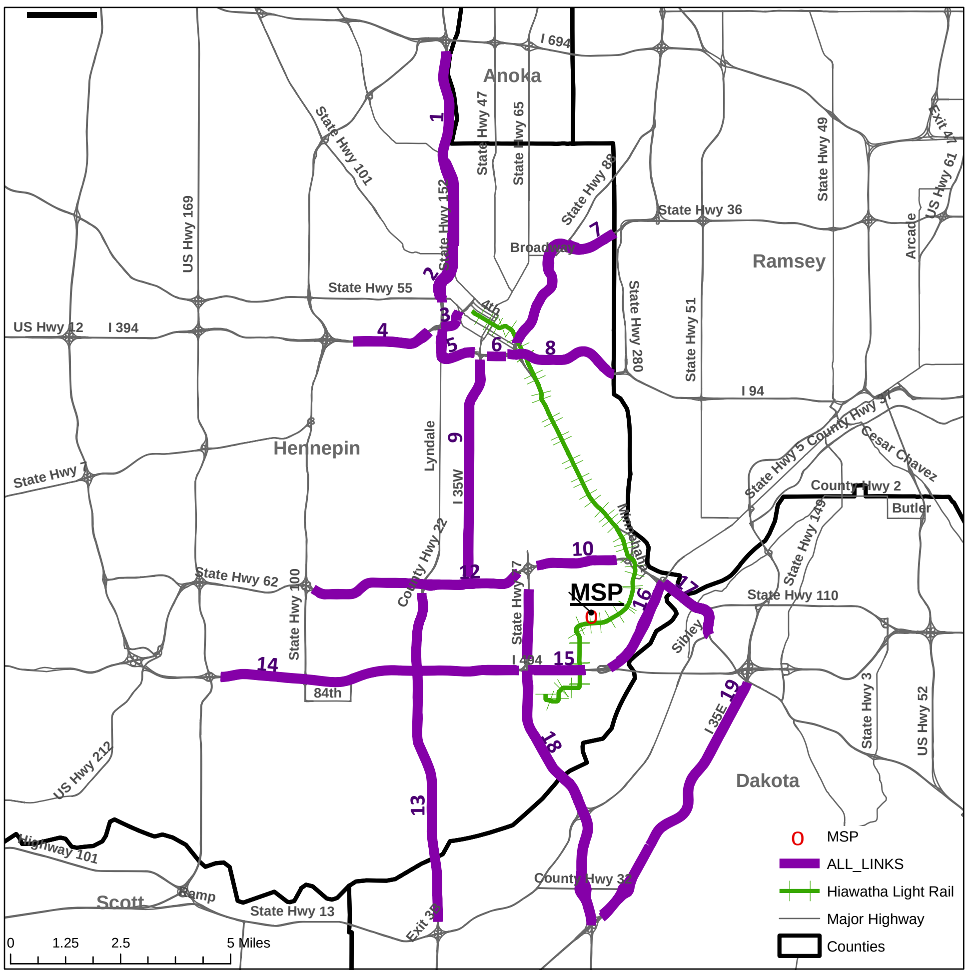

Figure 11. Selected Links around LRT

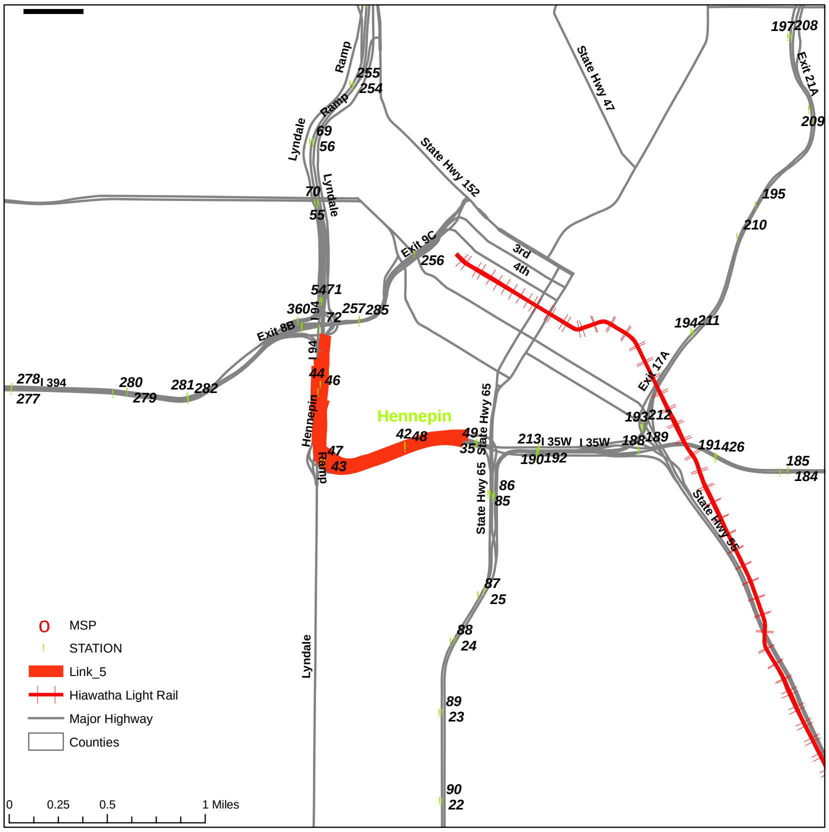

Figure 12. LRT Case #1: Link 5

Figure 13 shows annual average daily traffic volume on link 5 in periods 2000-2006. The traffic volume on the link gradually increased between the years 2000 and 2004. Traffic volume has been decreased by 0.1% in 2003 compared to year 2002. The 2000-2004 traffic patterns on the link 5 correspond to the general traffic pattern. However, there are noticeable patterns in 2005 and 2006. Traffic volume in the period has been decreased. It has been decreased 2.1 percent in 2005 and 4.3 percent in 2006 respectively. The result implies that newly developed Hiawatha LRT service may alleviates the traffic volume on I-94.

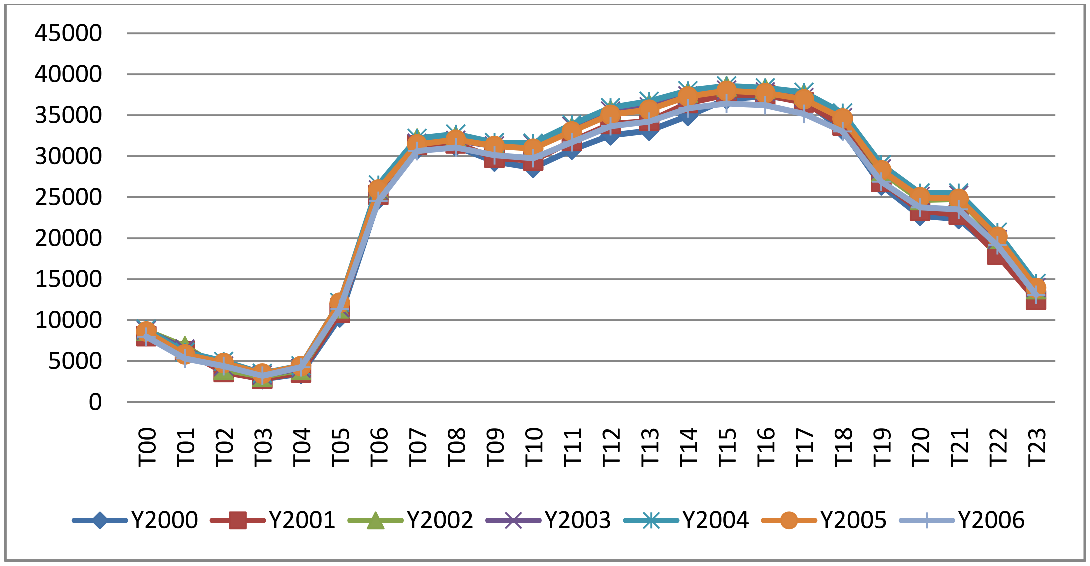

Figure 13. Average Daily Traffic Volume on Link 5

The degree of alleviated traffic volume on I-94 differs depending on the time of day. In Figure 14, "Average" line represents the average fluctuating rate of traffic volume (AFRT) in the period from 2000 to 2003 and the "EVENT_Changes" line represents AFRT between the previous year period (June 24th, 2003-June 24th, 2004) and the post year period (June 25th, 2005-June 25th, 2005). AFRT (EVENT_Changes) between 12:00 A.M. and 2:00 A.M. had notably been decreased. This may be caused by people who started to return home early due to the service time of LRT. However, AFRT (EVENT_Changes) has been increased between 4:00 A.M. and 6:00 A.M., and AFRT (EVENTt-Changes) has dramatically been decreased at 7:00 A.M (the peak time of morning rush hours). It implies that early-morning (4:00 A.M.-6:00 A.M.) commuters are willing to drive their own vehicles instead of LRT whereas general morning (7 A.M.-9 A.M.) commuters desire to take LRT. The AFRT (EVENT-Changes) increased between 3:00 P.M. to 5:00 P.M., and the AFRT has decreased at 9:00 P.M. dramatically. Most traffic flows during these times include a high proportion of returning home traffic flows. The traffic from 3:00 P.M. to 5:00 P.M. may reflect the early-morning commuters whereas after 5:00 P.M. may reflect the late-morning commuters. Overall, the increase rate of traffic volume on the link 5 is decreased due to the LRT service.

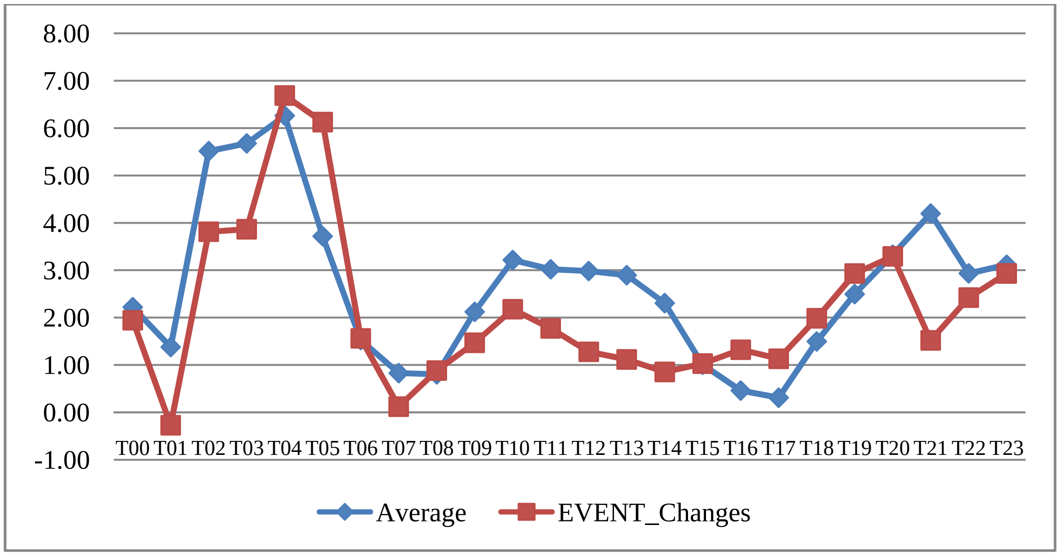

Figure 14. Flow Changes on Link 5

Link 7 is selected from Interstate Highway 35 W (Figure 15). I-35 W connects the two major cities: Minneapolis (Hennepin County) and Saint Paul (Ramsey County). As can be seen in Figure 16, contrary to the pervious example of link 5, average annual traffic volumes decreased from 2000 to 2003. However, it has dramatically increased in the year 2004 on link 7. The average daily traffic volume has increased 10.4 percent in the 2004 and 2005. This may be due to the fact that is willing to take the new LRT mode opportunity in order to travel to the South side of the metropolitan area.

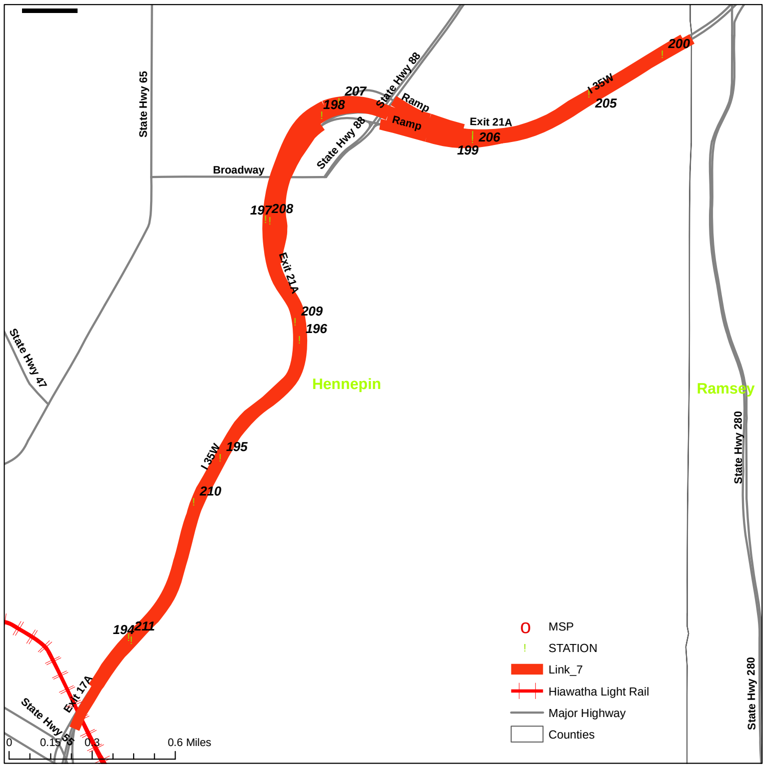

Figure 15. LRT Case #1: Link 7

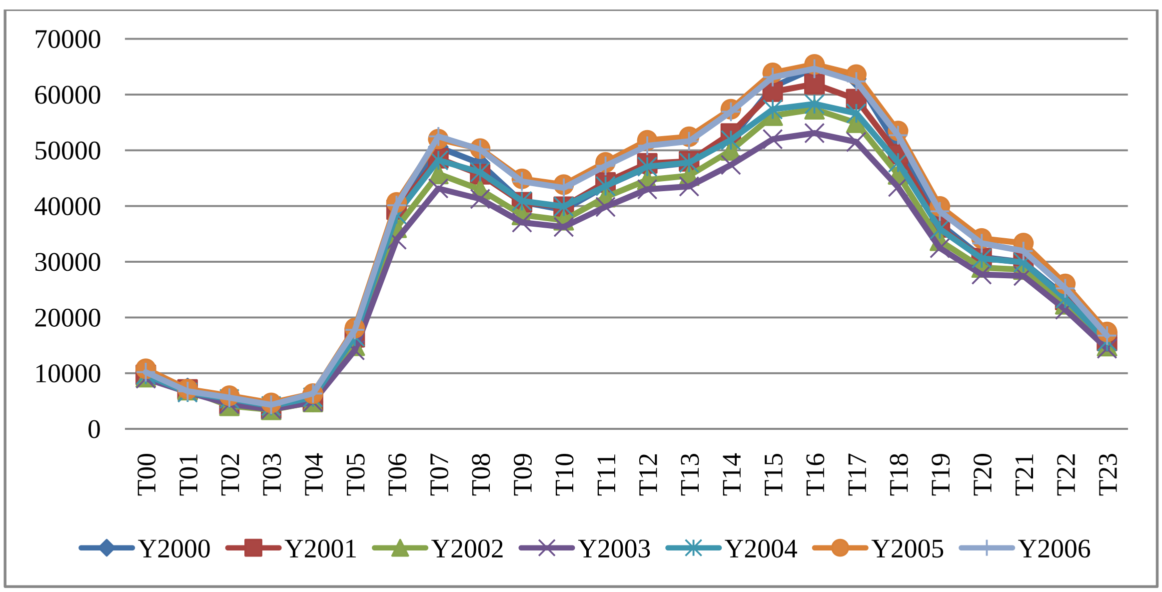

Figure 16. Average Daily Traffic Volume on Link 7

Figure 17 shows the AFRT patterns for the link 7. In the previous example of link 5, the AFRT pattern shows varied fluctuations by time period. However, the AFRT (EVENT_Changes) is always higher than the AFRT (Average) on link 7. The most distinct difference is identified between 3 P.M. and 8 P.M. Exemplified by both examples, traffic pattern has been affected by the Hiawatha LRT. The traffic volume has decreased on the link 5 whereas the Hiawatha LRT brought more traffic on the link on the link 7. The following, Figure 18, shows overall changes for the nine selected links in the study area. The traffic volume in 5 out of 19 links has increased since the first day of the Hiawatha LRT service. It decreased in the rest of links. As can be seen in Table 4, link 4, link 7, link 12, link 14 and link 15 correspond to the increased one (red-color) whereas link 1, link 2, link 3, link 5, link 6, link 8, link 9, link 10, link 11, link 13, link 16, link 17 and link 18 correspond to the decreased one (blue-color).

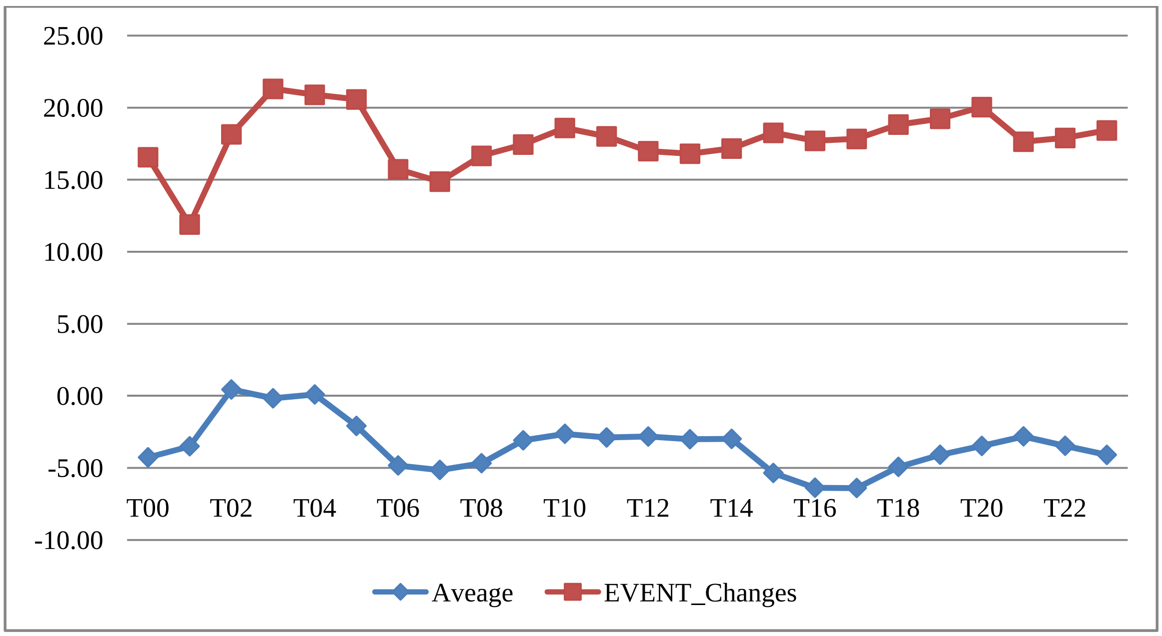

Figure 17. Traffic Changes on Link 7

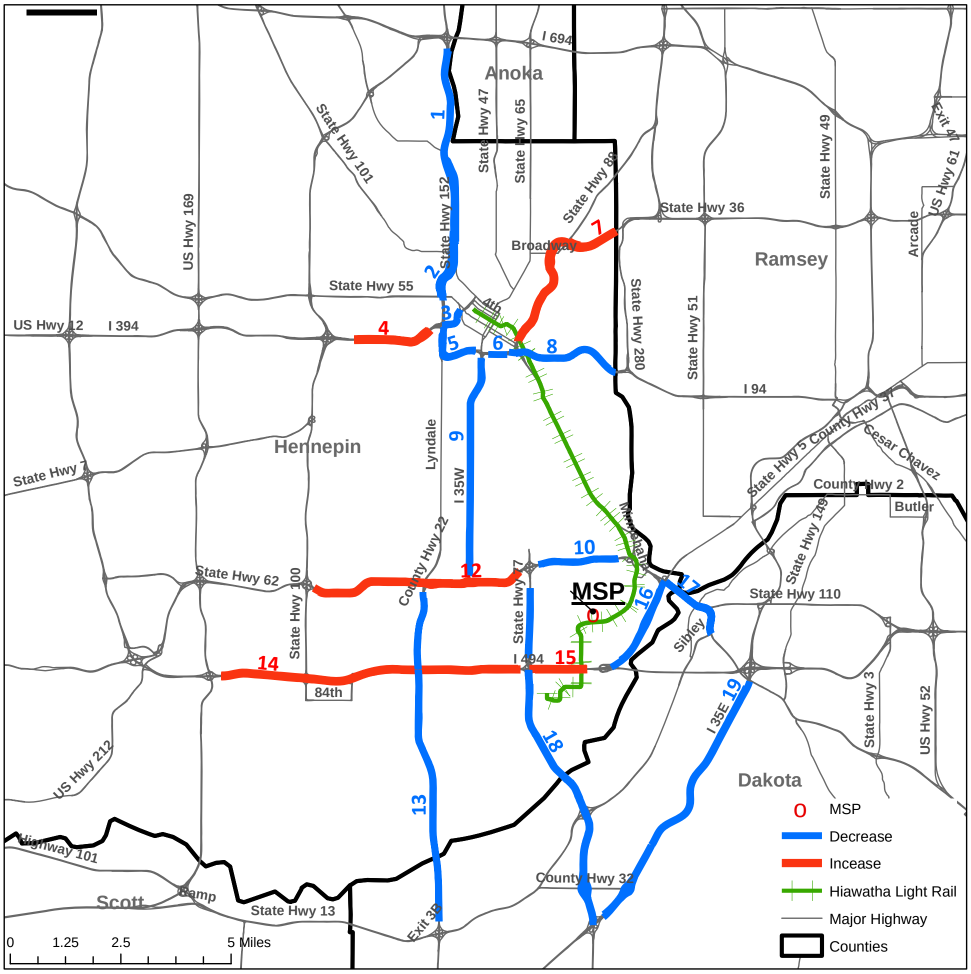

Figure 18. Traffic Volume Changes in Links

Table 4. Traffic Volume Changes in Links

ID	Change	ID	Change
LINK 1	-	LINK 11	-
LINK 2	-	LINK 12	+
LINK 3	-	LINK 13	-
LINK 4	+	LINK 14	+
LINK 5	-	LINK 15	+
LINK 6	-	LINK 16	-
LINK 7	+	LINK 17	-
LINK 8	-	LINK 18	-
LINK 9	-	LINK 19	-
LINK 10	-	N/A	N/A

5 Conclusions

In this research, the characteristics of urban traffic in the Twin Cities metropolitan area are studied. The traffic patterns are summarized at the various time scales. For the ten years, the annual total traffic volume has been increased. However, the increase rate of traffic volume has been decreased since 2004. The study illustrates that the new public transit (LRT) helps decrease the urban traffic volume on the major highways. In terms of the monthly traffic volume pattern, August has the highest traffic volume whereas January has the lowest traffic volume. The difference in monthly fluctuation is mainly due to weather conditions. Among the days of week, Friday has the most traffic volume whereas Sunday has the least. Commuting traffic flows are used to illustrate the hourly traffic pattern.

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