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Research

Sample-Based Estimation of Bicycle Miles of Travel (BMT)

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16. Abstract (Limit: 200 words)

This project provides a statistically defensible estimate of bicycle-miles of travel (BMT) for at a least substantial portion of the Twin Cities region and assesses the feasibility of monitoring bicycle volumes using sampling methods similar to those used to monitor motor vehicle traffic.

Researchers used an ArcView database of the Twin Cities street system for the initial sampling frame and extended the database by manually adding information about average annual daily traffic volumes and about on- and off-road bicycle facilities. A stratified random sample of roadways links in Hennepin, Ramsey, and Dakota counties was drawn, and during the months of May through June and August through October 1998, the daytime bicycle volume for one day at each sampled site was obtained using time-lapse video. Researchers then used Cochrane's "combined" estimator to compute an estimate of average daytime BMT for the study area.

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Sample Based Estimation of Bicycle Miles of Travel (BMT)

Final Report

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The authors express appreciation to all whose cooperation made it possible for us to collect the bicycle count data including: all communities, counties and regional park systems who gave their permission to videotape in their jurisdiction; Northern States Power Company; ATD Northwest; and the Real Estate Office and the Human Subjects Committee at the University of Minnesota.

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EXECUTIVE SUMMARY

This project was undertaken to (1) provide a statistically defensible estimate of bicycle-miles of travel for at least a substantial portion of the Twin Cities region, and (2) to assess the feasibility of monitoring bicycle volumes using sampling methods similar to those employed to monitor vehicle traffic volumes. An ArcView database of the Twin Cities street system developed by The Lawrence Group provided the initial sampling frame, and this was extended by manually adding information on average annual daily traffic volumes, and about on- and off-road bicycle facilities. Because of time and resource constraints, the extended data base could be developed only for Hennepin, Ramsey and Dakota counties, so these three counties comprised the project's study area. A stratified random sample of roadway links was then developed for the study area, where each combination of four roadway link types, and four geographical subareas, made up the sample strata. During the months of May-June, and August-October 1998, the daytime (7 AM to 7 PM) bicycle volume for one day at each sampled site was obtained by first recording the traffic activity on videotape and then manually counting bicycles. Cochrane's "combined" ratio estimator was then used to compute an estimate of average daytime BMT in the study area (383754 bicycle-miles/day) and the estimate's standard error (69994 bicycle-miles/day). Estimates of future sample sizes needed to achieve given levels of precision were also computed, as well as estimates of annual BMT for the study area, and the entire metro area.

Chapter 1 INTRODUCTION

In 1976, Orhn estimated that purposeful trip making by bicycle in the Twin Cities could potentially draw more users per day than the bus system.[1] And for at least 20 years, it has been argued that an increased use of bicycles for purposeful trip making could help lessen urban traffic congestion and have a positive effect on congestion-produced air pollution and energy consumption. However, estimates of actual bicycle usage, expressed either as trips or as bicycle miles of travel (BMT), have never been available.

More recently, the Minnesota Comprehensive State Bicycle Plan calls for "…bicycle miles traveled to reach a growth rate of 10% per year"[2] by 1999. This goal leads to the problem of developing objective methods for estimating total use, so that growth rate can be measured or more objectively estimated. In fact, program recommendations in the State Bicycle Plan also state, "that statistics on bicycle use and accident rates per mile traveled be maintained in such a way that they are comparable with those for motor vehicles, and are integral parts of transportation information systems."[3]

The problem of developing an estimate for Bicycle Miles of Travel (BMT) has never been addressed. However, an analogous problem is the development of estimations of Vehicle Miles of Travel (VMT) using a limited number of vehicle counts. The Federal Highway Administration (FHWA) has published several documents describing how such estimations for VMT can be accomplished.[4] This project used these methods, particularly those described in *Guide to Urban Traffic Volume Counting* (1975), along with bicycle count data gathered by the project. Regarding the use of estimation procedures, the guide comments:

The most desirable method for determining urban VMT … would be to make representative traffic counts on every section of urban street. This of course, would result in extremely expensive counting programs and would be practical only in cities which make extensive counts for traffic engineering purposes. Accordingly, probability sampling procedures were developed to provide a cost-effective basis for estimating VMT on urban streets and highways.[5]

The primary objective of this project was to compute a sample-based estimate of BMT on a network of bikeways and roadways in the Twin Cities region. This involved the mapping and development of a (GIS) database describing the bikeway and roadway network and obtaining single-day bicycle volume counts on a sample of network links using videotape traffic counting technology. The program sample organized bikeways and roadways into four distinct facility types and divided the Twin Cities area into four subareas having "homogenous bicycle use" (as described in Chapter 2).

A secondary objective, implicit in a project that addresses a new topic of inquiry, is the objective of learning more about the methodology employed. This study developed or uncovered methodological details regarding sample program design, data collection and sample sizes needed to guarantee BMT estimates with a specified level of precision.

The report is organized as follows:

- Chapter 2 gives a context for the study and a context for the methodology employed by the project by reviewing the literature on the subject;
- Chapter 2 describes the project's sample program design, along with data collection and BMT estimation methodologies;
- Chapter 4 provides the estimate for BMT;
- Chapter 5 provides recommendations and commentary.

The appendices provide the following information:

- Appendix A describes the metadata this project developed for bicycle facilities and added to the Metropolitan Council's street centerline database for Dakota, Hennepin, and Ramsey counties;
- Appendix B provides the forms developed for managing the bicycle count;
- Appendix C describes the local power company's installation requirements placing the video equipment on power company poles;
- Appendix D briefly discusses the policy of the University of Minnesota and the policy of the federal government regarding the observation of public behavior and gives websites for more detailed information;
- Appendix E contains tables providing the bicycle counts taken at the randomly selected locations in the study area, along with characteristics of the locations such as bicycle facility type and the Average Daily Traffic (ADT) for motor vehicles on the selected roadways.

Chapter 2 LITERATURE REVIEW

Although the project's literature search failed to turn up papers or reports in which region-wide BMT had been estimated, there are two related lines of work: one addressing the estimation of vehicle miles of travel (VMT), and the other dealing with patterns of variation in bicycle traffic volumes.

In a report prepared for the Federal Highway Administration (FHWA), Ferlis, Bowman and Cima [6] presented a formula for estimating regionwide VMT from traffic counts collected on a sample of roadway locations along with detailed instructions on how to develop the sample program. Although the sample development procedures described in this report are sound, the VMT estimation formula suffers from technical inadequacies. The report was to be an update and extension of an earlier report prepared by FHWA, *The Preliminary Guide to Urban Traffic Volume Counting* (hereafter, referred to as the GUTVC)[7].

The GUTVC describes two procedures, a basic approach and an alternate approach, for estimating region-wide VMT from a sample of traffic counts, where the estimation formulas were taken from well-known texts on sampling. [8, 9] The GUTVC also recommends basic sample program design and describes how to estimate the minimum sample size that will give VMT estimates with some desired precision.

For the basic approach, coefficients of variation describing the temporal and spatial variability of vehicle volumes, together with the average length of the roadway segments making up the population, must be known beforehand. A ratio estimator of average VMT per mile is then multiplied by the total mileage of population in order to estimate total VMT. This method also is implicitly recommended in the *Traffic Monitoring Guide*[10]. For the alternate approach, the average and the standard deviation of the lengths of the roadway segments making up the population must be known. Average VMT per segment is multiplied by the total number of segments in the population to estimate total VMT. The authors of the GUTVC recommend using the alternate approach when the required link length statistics are available and Hoang and Poteat[11] describe using the alternate method to estimate statewide VMT in Florida.

Using Geographic Information System (GIS) software such as Arc View from ESRI Corp., segment length statistics are easily obtained once a network of roadways and bicycle facilities has been mapped and represented in a database. The other inputs required for estimating the sample size, mean daily volume and the variance in daily volumes across time and across segments, can only be determined by counting bicycles.

The research dealing with patterns of variation in bicycle traffic volumes is scant. Buckley[12] described a bicycle counting program conducted in Boston and reported that bicycle traffic volumes 1) appeared to grow over a six-year period, and 2) showed significant seasonal and weather-related variation patterns. Estimates of BMT were not reported, and the data reported in this paper were not sufficient to compute estimates of either temporal or spatial variation in bicycle volume. Hunter and Huang[13] reviewed bicycle counts on trails and paths reported by a number of different cities in the U.S., and showed examples of peak-hour counts of 100 bicycles/hour and daily volumes of 400-1200 bicycles/day. Once again, estimates of BMT were not reported and the information this paper provided was not sufficient to estimate temporal or spatial coefficients of variation. Niemeier[14] described morning and afternoon peak period counts conducted in Seattle across an entire year. The data in Niemeier's Table 2 show temporal coefficients of variation ranging between 37% and 72% for the morning peak volume at four sites in Seattle. Using this data, it is possible to compute a spatial coefficient of variation equal to 68%. Estimates of BMT were not reported.

If temporal and spatial coefficients of variation equal to 60% are taken as being typical of daily bicycle traffic, then it is possible to use formula #5 in the GUTVC[15] to estimate a bicycle count sample size for planning purposes. In particular, if we want to estimate region-wide BMT with a 10% accuracy and 68% confidence, we would need to count about 72 miles of segments. Assuming each segment is ½ mile long, then about 144 segments should be included in the sample. (The project actually measured 160 segments.)

Chapter 3 SAMPLING METHODS

Since there has been little to no rigorous collection and modeling of data related to bicycle use, the project could not rely on previous research to provide it with any kind of methodology, especially with respect to understanding various parameters of bicycle use. For most of this century, transportation research has developed fundamental knowledge regarding travel behavior for motor vehicle transportation and transportation modeling relies today on this primary material. This wealth of understanding and background does not exist for bicycle transportation. Basic questions regarding vehicle use that can be answered in the world of the motor vehicle remain unanswered in any research or modeling procedures involving bicycle transportation.

With this situation, it was necessary for project personnel to use available information and their collective knowledge and understanding of the study area and bicycling as transportation planners, long-time area residents and cyclists. This was particularly true when characteristics of the sample were developed as discussed in sections 3.3 and 3.4.

The project used video technology to count cyclists in three counties in the Twin Cities metropolitan area (Figure 1). Though video technology has been used before in transportation, to our knowledge it was never used on a project of this type and scope. In addition, the project discovered a number of unexpected aspects of the data collection process that needed to be addressed in order for any data to be collected at all. All of these aspects of the BMT research are discussed in this chapter as follows:

- The overview in section 3.1 provides a quick description of the sampling program used in this research;
- Section 3.2 describes the sample program recommendations given in the *Guide to Urban Traffic Volume Counting,*[16] published by the USDOT and FHWA, for developing estimates for (motor) vehicle miles of travel (VMT) using a limited number of vehicle counts;
- Sections 3.3 and 3.4 define and discuss in detail the bicycle facility types and the geographic subareas developed for the BMT sample program;
- Section 3.5 provides an assortment of study characteristics including when the counts were taken, weather, topography and a table of the total number of segments of each facility type in each subarea and county;

- Section 3.6 opens with an overview in checklist format of the more detailed subsections that follow it, all describing various necessary or recommended steps to be taken during the data collection phase.

3 County Study Area

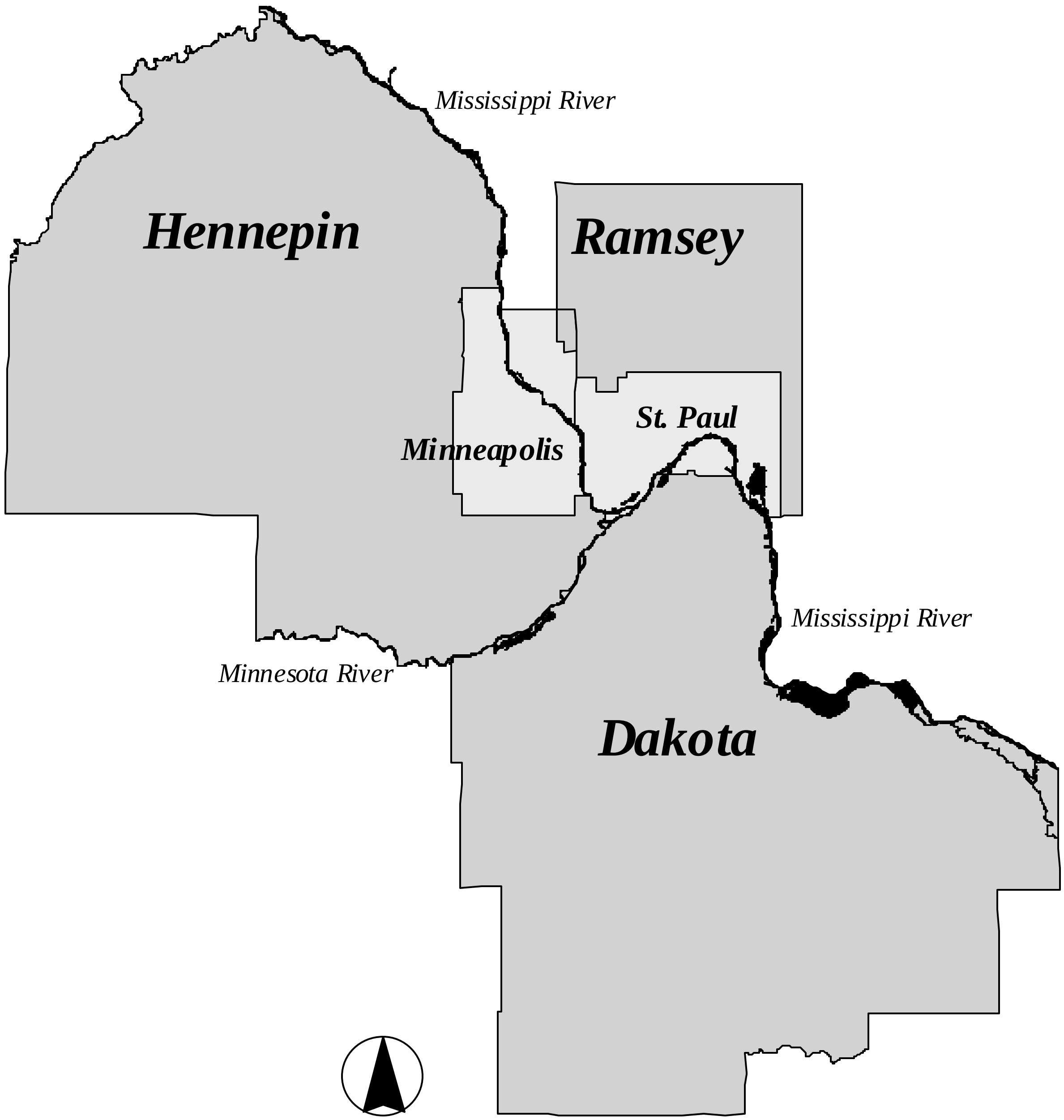


Figure 1. Three County Study Area

3.1. *Overview*

This section provides a quick overview of the sampling program's bicycle facility types and geographic subareas for easy reference. More detail and discussion on the information included here is found in sections 3.3 and 3.4.

Bicycle Facility Types

The BMT project established four basic facility types for measuring bicycle use:

- ***Off-road bicycle facilities***
  Off-road bicycle facilities are physically separated from roadway space for motor vehicles and include bicycle facilities in parks and alongside roadways.

- ***On-road bicycle facilities***
  On-road bicycle facilities are physically marked within a street or roadway that is used by motor vehicles and includes all striped bicycle facilities.

- ***Roadways with motor vehicle ADT <5000***
  And with no bicycle facilities
  This category defines smaller and quieter streets and consists mostly of local or residential streets.

- ***Roadways with motor vehicle ADT ^{3}5000 (Average Annual Daily Traffic, AADT)***
  And with no bicycle facilities
  This category defines larger and busier streets and consists mostly of arterials and collectors.

Geographic Subareas

The project established the following four subareas with the following characteristics:

- ***Urban***
  Highest density of roadways
  Grid street system
  High connectivity of existing streets and roadways
  Overall, medium to sparse density of bicycle facilities

- ***Suburban***
  Medium density of roadways
  Non-grid, street patterns; many culs-de-sac and eyebrow street types
  Lower connectivity of existing streets and roadways, many dead-ends
  Dense bicycle system

- ***Rural***
  Low density of roadways
  Grid roadways follow section lines, small towns
  High connectivity of existing streets and roadways
  Very sparse bicycle system

- ***University of Minnesota***

  (The area is described by a radius approximately 1 mile from the University of Minnesota's East Bank and West Bank campuses in Minneapolis)

  Has characteristics of the urban subarea

  Medium density of bicycle facilities

  Observations, together with previous counts and surveys show a high bicycle mode share around this U of M campus and therefore, a separately identifiable homogenous zone of bicycle use.[17]

3.2. *Sampling Procedures*

The *Guide to Urban Traffic Volume Counting* (GUTVC) describes statistical procedures for urban traffic counting programs and sets forth sampling guidelines to be used in developing estimates for traffic volumes and vehicle miles of travel. In general, their guidelines note:

- A street link is assumed to be a designated section of street with relatively homogeneous volumes …
- A "link-day" is a 24-hour [count] period for a given link. This procedure will allow sampling links and days separately. [18]

Any measurement of vehicle miles of travel requires counting vehicles on a "segment" (also called a "link") of roadway. A segment is defined to be a length of roadway with similar traffic characteristics (i.e., with "homogenous" volumes). In motor vehicle networks, the boundaries of a segment are typically street intersections, exit/entrance ramps, or entries to parking lots of major destinations. However, the definition of the segments in any bicycle network is at a finer granularity than in the motor vehicle network. This is because the bicycle is smaller, more maneuverable and flexible than the motor vehicle, making it possible for bicyclists to enter a segment in the system at locations in addition to those that are typically recognized as 'formal' entries to a segment by motor vehicles. Determining all entries for bicyclists to all of the segments in a system is impossible at present and will probably remain so because of the bicycle's extreme maneuverability and flexibility.

Therefore, for the BMT project, entry to segments in the system used by cyclists is defined:

- On streets and roadways, as that which is defined for motor vehicles and
- On off-road bicycle facilities, as intersections that can be seen on maps or aerial photos of the off-road bicycle facilities.

The GUTVC continues by recommending that the following steps be used in developing a sampling program (for modeling motor vehicle use).

1. Establish Geographic Sub-Areas – The urban area should be subdivided into the analysis units for which specific information is desired. A small urban area (population under 250,000) would probably be subdivided into 2 or 3 divisions which distinguish between central city and suburbs…. Larger urban areas (population over 1,000,000) could be subdivided into 5 to 7 sub-areas…. The location of rings and sectors should be judiciously selected to correlate with common growth areas. It should be noted that total number of samples required increases significantly as stratifications increase.

2. Functionally Classify Streets – The streets in each sub-area should be functionally classified. In order to keep the required sample at a manageable size, the number of functional classes should be limited. The following scheme is recommended:

   a) Local streets;

   b) Arterial streets (including collectors); and

   c) Freeways (including all controlled-access facilities).

   Stratification by type of facility is essential since each basic group represents a distinctive population.

3. Further Stratify locations in Each Class to the Extent that Prior Information is Available – This stratification should be done on the basis of the best information available – for example, previous volume information and traffic flow maps.

   a) Where previous information is available on volumes, additional stratification is desirable to reduce sample size requirements. In these cases stratified random sampling should be used…. [19]

Thus, the GUTVC recommends that each segment in the transportation system be classified with a subarea and with a functional classification of the transportation facility. This means that if five subareas and 3 facility types were defined, then there are 15 different categories of segment classification. Each category must have the same sample size (number of sites counted). Therefore, if 10 sites were counted in each category, then in the example above, a total number of 150 sites would be counted.

Regarding sample size, the GUTVC comments:

4. General Guidelines – Sample size should be adequate to meet specified precision levels. Once the sample is selected, it should be used to estimate the characteristics of the population being sampled to provide reliable estimates of population parameters.

a) Unduly small sample sizes should be avoided. A sample size of at least 30 observations should be obtained for each functional street type. These will estimate the standard error of the sample to within ± 15 per cent at 68 per cent confidence.[20]

b) There should be at least 6 to 10 observations in each volume stratum where stratification is used. A stratum sample of about 10 units will give almost as good a variance estimate as a much larger sample; with less than 6 units per stratum, the individual stratum variances will be unreliable.[21]

c) Where an urban area is subdivided geographically, and stratified by volume, a minimum strata sample size of 10 is suggested for the total, with at least 3 observations per geographic area in any given strata. For local streets, at least 30 observations should be obtained.[22]

With the recommendations for the establishment of geographic subareas and the categorization of (bicycle) facility types in mind, along with the requirements for minimum sample size, this project divided the study area into 4 subareas and 4 bicycle facility types for a total of 16 different categories. The 4 bicycle facility types are described by a combination of basic facility type and by volume stratification. With a goal of a minimum of 10 counts in each category, the following would be satisfied regarding minimum sample size:

- There would be 40 observations obtained for each facility type (at least 30 were recommended by the GUTVC, item #4,a above),
- There would be 40 observations obtained for each volume stratum (10 observations for each volume stratum were recommended; item #4,b above),
- There would be 10 observations obtained per facility type per geographic subarea (at least 3 observations per geographic area in any given strata [facility type] were recommended; item # 4,c above),
- There would be 40 observations on local streets (at least 30 were recommended; item #4,c above).

The following sections describe the rationale used in defining the bicycle facility types and the geographic subareas used in the study. The metadata for the information added to the GIS database for each bicycle segment in the system is described in Appendix A.

3.3. *Bicycle Facility Types*

This section is divided into two subsections. The first provides the definition established by the project for bicycle facility types and the second provides a discussion on how and why the definitions were established.

Definition

The GUTVC recommended the classification of transportation facilities according to function and if possible, on other stratifications, such as volume. The BMT project established four basic facility types for measuring bicycle use:

- ***Off-road bicycle facilities***
  Off-road bicycle facilities are physically separated from roadway space for motor vehicles and include bicycle facilities in parks and alongside roadways.

  Note this category can include sidewalks if the jurisdiction responsible for the bicycle system identifies sidewalks for bicycle use. The project found that many communities specifically consider the use of sidewalks as part of their bicycle system. Many have chosen to designate some of their sidewalks as part of their bicycle system and have mapped them as such. This is usually seen in suburbs. The project decided that if a community designated sidewalks as part of their bicycle system, then sidewalks mapped for bicycle use by the community would be entered into the project database as off-road bicycle facilities.

- ***On-road bicycle facilities***
  On-road bicycle facilities are physically marked within a street or roadway that is used by motor vehicles and includes all striped bicycle facilities. The physical demarcation must consist of a visual or spatial definition of bicycle space within the larger roadway space. Note this category does not include streets marked only with a bicycle route sign.

  This category usually consists of on-road, striped facilities and paved shoulders that are designated and mapped by the community as a bicycle route. Bicycle facilities within the roadway which are raised (e.g., raised facilities within the street) are considered on-road bicycle facilities.

- ***Roadways with motor vehicle Average Annual Daily Traffic, or ADT <5000***
  And with no bicycle facilities
  This category defines smaller and quieter streets and consists mostly of local or residential streets.

- ***Roadways with motor vehicle ADT ^{3}5000)***
  And with no bicycle facilities
  This category defines larger and busier streets and consists mostly of arterials and collectors.

Bicycle Facilities by Type
in the 3-County Twin Cities Metro Area

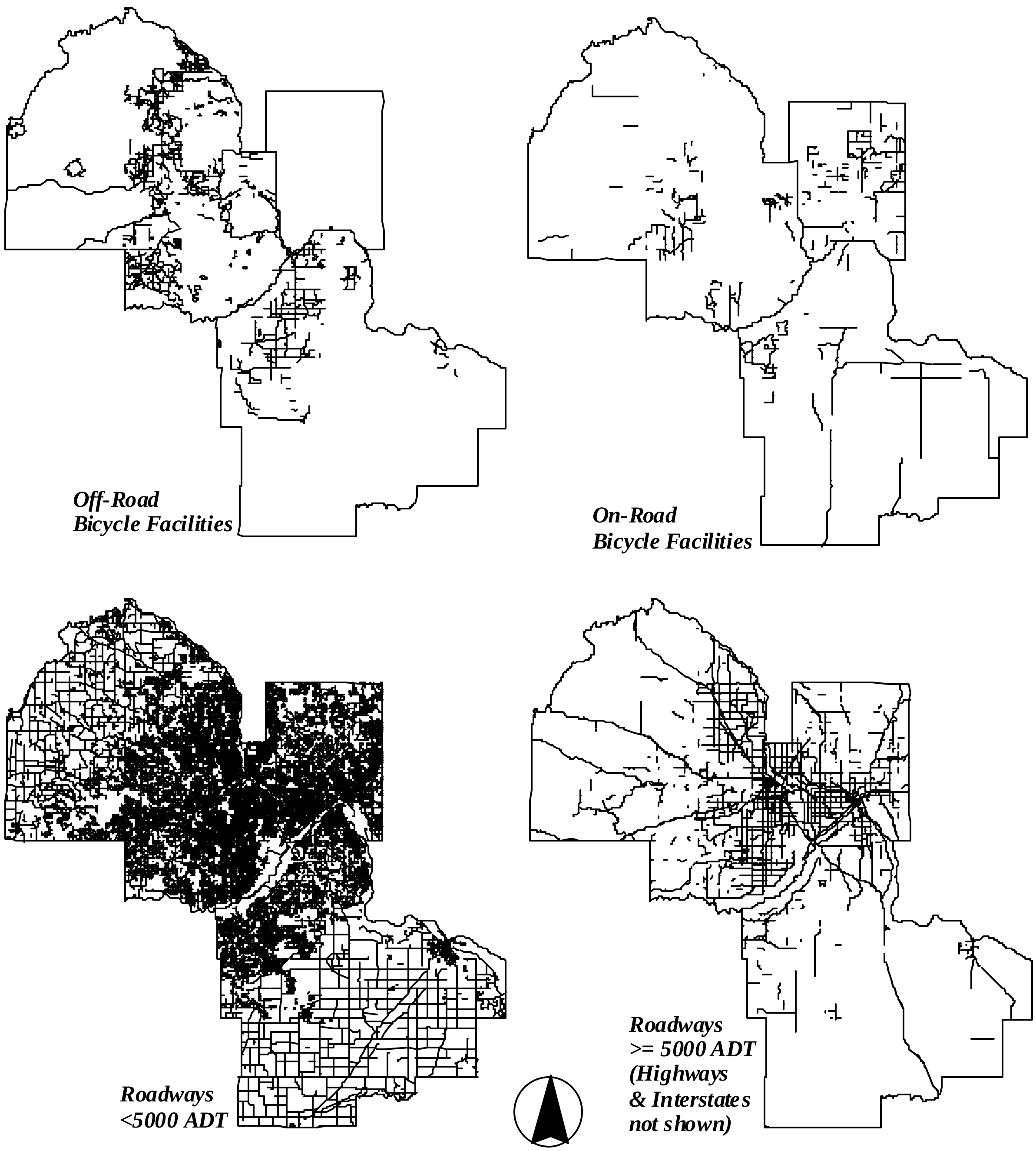


Figure 2. Bicycle Facilities by Type in the 3-County Metro Area

Note, interstate highways and some trunk highways were excluded from the study and from the GIS database (i.e., their mileage is not included in the BMT estimate). In Minnesota, it is illegal to cycle on an interstate highway. However, other highways are equally busy and dangerous to cyclists and in most cases, bicycle riding is specifically prohibited on Minnesota trunk highways.

The project could not find a list or a map that specifically identifies those roads that prohibit bicycle riding. Therefore, the Minnesota Department of Transportation (Mn/DOT) map identifying "Metro Freeways/Expressways" was used to identify large highways that should be excluded from the transportation network for bicycles. In addition, a few highways that were not identified as a Metro Freeway/Expressway were excluded by the project because of their high ADTs and their physical and functional similarity to interstates and trunk highways. (These latter exclusions include Highway 280, the Washington Ave. Bridge/3rd Ave. connector by the University of Minnesota and freeway-style roads leading to the Minneapolis/St. Paul international airport.)

The project identified and recorded the ADT for all roadway segments with ADT > 2000 in its GIS database. A boundary of 5000 ADT was selected as the demarcation between "larger" (collector and arterial) and "smaller" (local) roadway types.

Once ADT had been entered for all segments, the project looked at roadway maps of the three counties using different ADT values assigned as the delimiters for the two categories. Since local streets are usually defined with ADT between 2000 and 5000, ADTs in this range were examined as potential boundaries.

When smaller ADTs (e.g., 4000, 3000, 2000) were selected as the boundary between the larger-street and smaller-street categories, the system for the larger arterial and collector streets became very dense (similar to the map labeled, Roadways < 5000 ADT, in Figure 2). If larger ADTs were selected as the boundary (e.g., 6000, 7000, 8000 etc.), the map for the larger arterial and collector streets did not show a system of roadways, but many fragments of roads. At a boundary of 5000 ADT, a full system of larger (arterial and collector) roadways was evident on the maps, rather than varying degrees of unconnected roadway segments. It was decided that including a *system* of facilities, be they roadway or bicycle, was probably desirable for each of the categories, so an ADT value of 5000 was selected for the boundary between the larger and smaller streets.

Discussion

Regarding the categorization of bicycle facilities, design standards have been set for building bicycle facilities[23] and a functional classification of bicycle facilities has been offered.[24] Regarding the former, these categorizations strictly address how facilities should be designed and do not speak to how facilities might be used by bicyclists as part of a functional transportation system. The latter addresses functional bicycle facility use, but has not been formally adopted.

Therefore, with the sampling requirements set forth by the GUTVC in mind, study personnel reached the classification described in the preceding section by first considering the fundamental milieu cyclists find themselves in. Cyclists find themselves on two basic types of facilities. They travel a) on facilities that are visually and spatially designed for them and b) on streets and roadways with no visual or spatial definition for bicycle use.

Within these two basic categorizations, there are further fundamental classifications of a cycling environment. There are two basic sub-classifications of bicycle facilities with spaces defined for cyclists: on-road and off-road bicycle facilities. And, there are two basic sub-classifications of streets and roadways with no space described for bicycles: "larger, busier" streets with a higher traffic volume (ADT) and "smaller, quieter" streets with a lower traffic volume (ADT). Thus, four categories were established which describe fundamental environments (and differences in those environments) for cyclists:

1. Off-road bicycle facilities,
2. On-road bicycle facilities,
3. Roadways with no cycling facilities and ADT <5000 (smaller, quieter streets), and
4. Roadways with no cycling facilities and ADT ≥ 5000 (larger, busier streets).

Aside from this typological analysis of fundamental cycling environments, previous explorations in 1996 by the Sustainable Transportation Initiatives Unit at the Minnesota Department of Transportation (Mn/DOT) [25] indicated that some assumptions regarding cycling on urban streets might not be true. The assumption sometimes made in bicycle planning and research circles which the Mn/DOT inquiry seems to question holds that cyclists like to stay away from busy, high volume streets, preferring quieter local streets. The four categories developed for this project might further illuminate the Mn/DOT findings, which are reported as follows.

The Mn/DOT study did not use a random sample, but selected intersections (and the streets leading to them) in and around Minneapolis and St. Paul to investigate. (Note the

Mn/DOT study defines on-road bicycle facilities as “bike lanes” and off-road bicycle facilities as “bike paths.”)

Manual counts were taken on weekdays for a total of six hours at each site. The 1996 Mn/DOT study reports:

> According to bicyclist volume usage graphs:
>
> - High traffic volume (especially greater than 10,000 average daily traffic,) urban streets during weekdays had nearly as much bicyclist volume per mile as multi-use recreational paths.
> - Combining bicyclist volume of bike lanes, bike paths and high traffic volume, urban streets create more than 75% of bicyclist volume per mile studied. All other (ten) street categories combined, create less than 25% of bicyclist volume per mile studied.
> - Bicycle lanes, on average, received more than twice the bicyclist volume as multi-use (…) bicycle paths.
> - Bicycle lanes received more than 5 times the transportation bicyclist volume as multi-use paths on separate travel corridors from streets
> - Bicycle lanes received nearly half of all ”on-street” bicyclist volume per mile studied. When bicycle lanes are combined with high traffic volume, urban street, this “on street” bicyclist volume jumps up to slightly less than 75%.
> - On average, streets studied had more than 60% of bicyclists riding on the street itself as opposed to riding on sidewalks. This average appeared to remain, even when there was an adjacent recreational path.
>
> This study seems to suggest that adjacent recreational paths do not accommodate most of the (…) bicyclists in the street corridor. It also appears from this study [that] the best way to encourage bicycle use is to provide bicycle lanes on higher traffic volume, urban streets.[26]

Though not conclusive, the data from this small study suggests a different reality of bicycle use from current assumptions. The study suggests that bicycle use might be more prevalent on larger and busier streets than it is on off-road facilities and perhaps, on local streets. On-street allocation of bicycle space (bike lanes) appears to increase bicycle use even more on the larger streets.

Though the Mn/DOT study did not directly address local streets, it shows a category of streets labeled “2000-10000 ADT with a poor bicycle comfort rating formula” as the least used of their study’s types (6-10% usage). Conversations with Mn/DOT personnel involved in the study confirmed that they considered these the traditional “local streets,” and that contrary to the assumption of many, -- that cyclists prefer local streets to collectors and arterials, -- the study appeared to show the opposite.

The four types of bicycle facilities defined by the BMT project categorize bicycle use in a fundamental, logical, and typological manner. The definition of bicycle facilities in this way has a number of benefits. A primary benefit is that the categorization is a simple one and understandable. The categorization allows the collected data to address fundamental issues of bicycle use. The categorization provides an equal number of counts on bicycle facilities and regular roadways. It allows the categories to be combined in different ways to raise and address questions other than BMT, yet address them in a straightforward manner (e.g., bicycle facilities vs. roadways with no facilities, or off-road bicycle use vs. any on-road bicycle use.

Geographic Subareas Showing Roadways
in the 3-County Twin Cities Metro Area

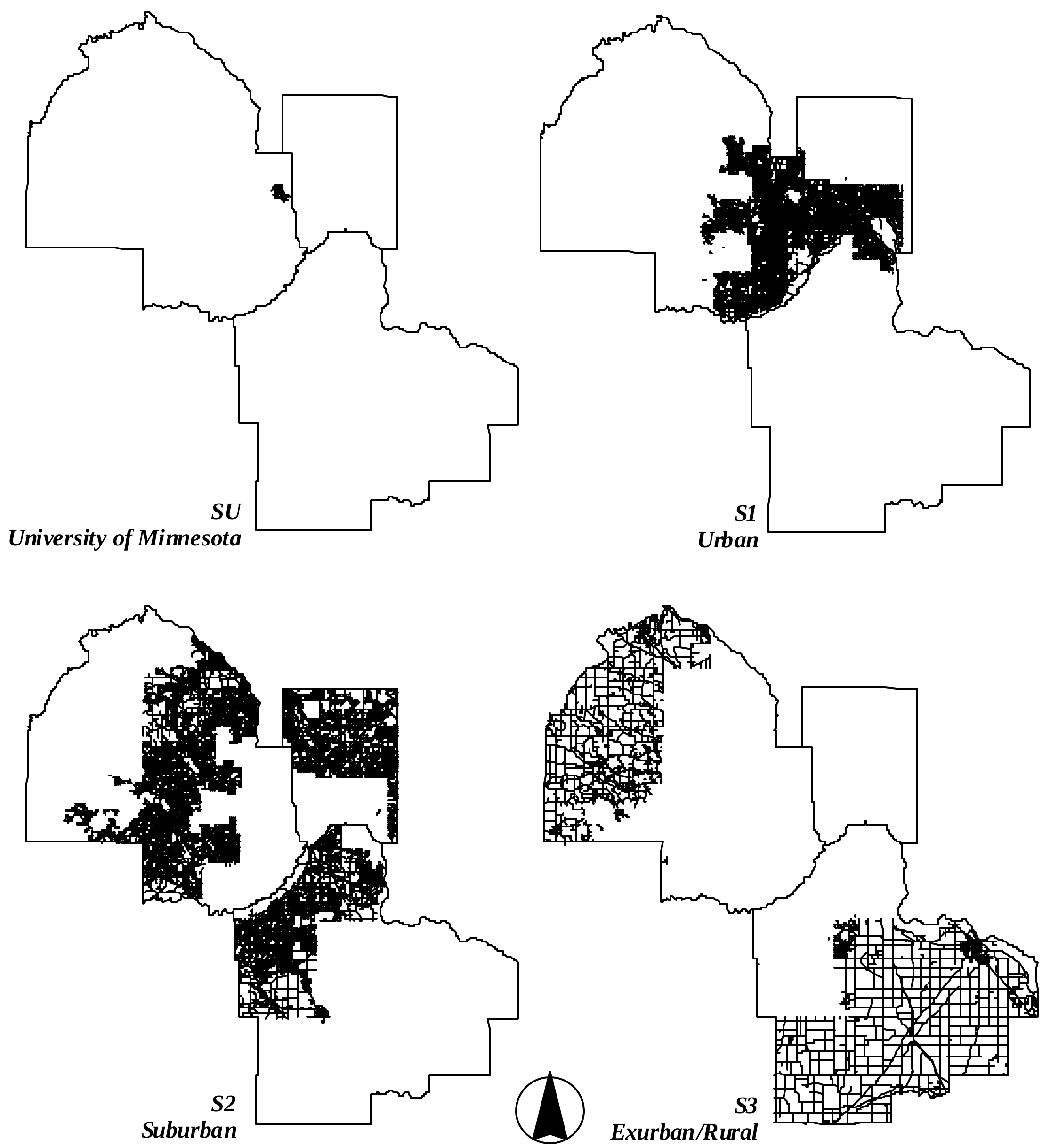


Figure 3. Geographic Subareas

3.4. *Geographic Subareas*

This section is divided into two subsections. The first describes the geographic subareas established by the project. The second subsection discusses how the subareas were established and provides commentary on the defined subareas.

Definition

In addition to recommending the definition of transportation facility types, the GUTVC recommended that geographic subareas be established within the study area. The project established the following four subareas with the following characteristics (see Figures 3 and 5):

- ***Urban***
  Highest density of roadways
  Grid street system
  High connectivity of existing streets and roadways
  Overall, medium to sparse density of bicycle facilities

- ***Suburban***
  Medium density of roadways
  Non-grid, street patterns; many culs-de-sac and eyebrow street types
  Lower connectivity of existing streets and roadways, many dead-ends
  Dense bicycle system

- ***Rural***
  Low density of roadways
  Grid roadways follow section lines, small towns
  High connectivity of existing streets and roadways
  Very sparse bicycle system

- ***University of Minnesota***
  (The area is described by a radius approximately 1 mile from the University of Minnesota's East Bank and West Bank campuses in Minneapolis)
  Has characteristics of the urban subarea
  Medium density of bicycle facilities
  Observations, together with previous counts and surveys show a high bicycle mode share around this U of M campus and therefore, a separately identifiable homogenous zone of bicycle use.[17]

Discussion

Project personnel studied the roadway and bicycle network maps produced in the previous tasks and used their collective knowledge of bicycle use in the area to develop guidelines for the division of the area into subareas of homogenous bicycle use.

- First, it was assumed that there would be a difference between bicycle use in rural areas as compared to urbanized areas.
- Second, it was assumed that there would be a difference in bicycle use in the urban core vs. the suburbs.
- And, finally, previous counts (specifically in October 1994) and general observation around the Minneapolis Campus of the University of Minnesota showed extremely dense bicycle traffic compared to other urbanized areas. (The 1994 counts showed that 10% - 21% of all vehicles on the road in the U of M area were bicycles.)

In addition, once all of the bicycle facilities and the ADTs for all of the roadways were entered into the GIS database, patterns of transportation system density and roadway configurations could be seen on GIS-generated maps, as seen in Figure 4, Figure 5 and Figure 6. (Note the patterns for the roadway system in Figure 5 are more readily apparent on maps larger than the page size of this report.) It was noted that the bicycle network was the densest in a ring encircling the inner core of the Twin Cities area (Figure 4). The bicycle networks in the inner core and in the rural area, outside of the dense ring, were sparse compared to the bicycle networks in the suburban ring. The roadway network, however, was most dense in the inner core and less dense in the suburban ring (Figure 5). And, as expected, the sparsest system of roads was in the rural area.

Thus, concentric rings of roadway and bikeway density were apparent on both the bicycle facility maps and on the roadway maps. Within the urbanized area, there was a sort of inverse relationship between the two different target-like configurations where roadway and bicycle network densities were concerned. The inner core had the densest roadways compared to the suburban ring. However, the bicycle facilities in the inner core were significantly less dense than those in the suburban ring.

Patterns & Densities
On-Road & Off-Road Bicycle Facilities

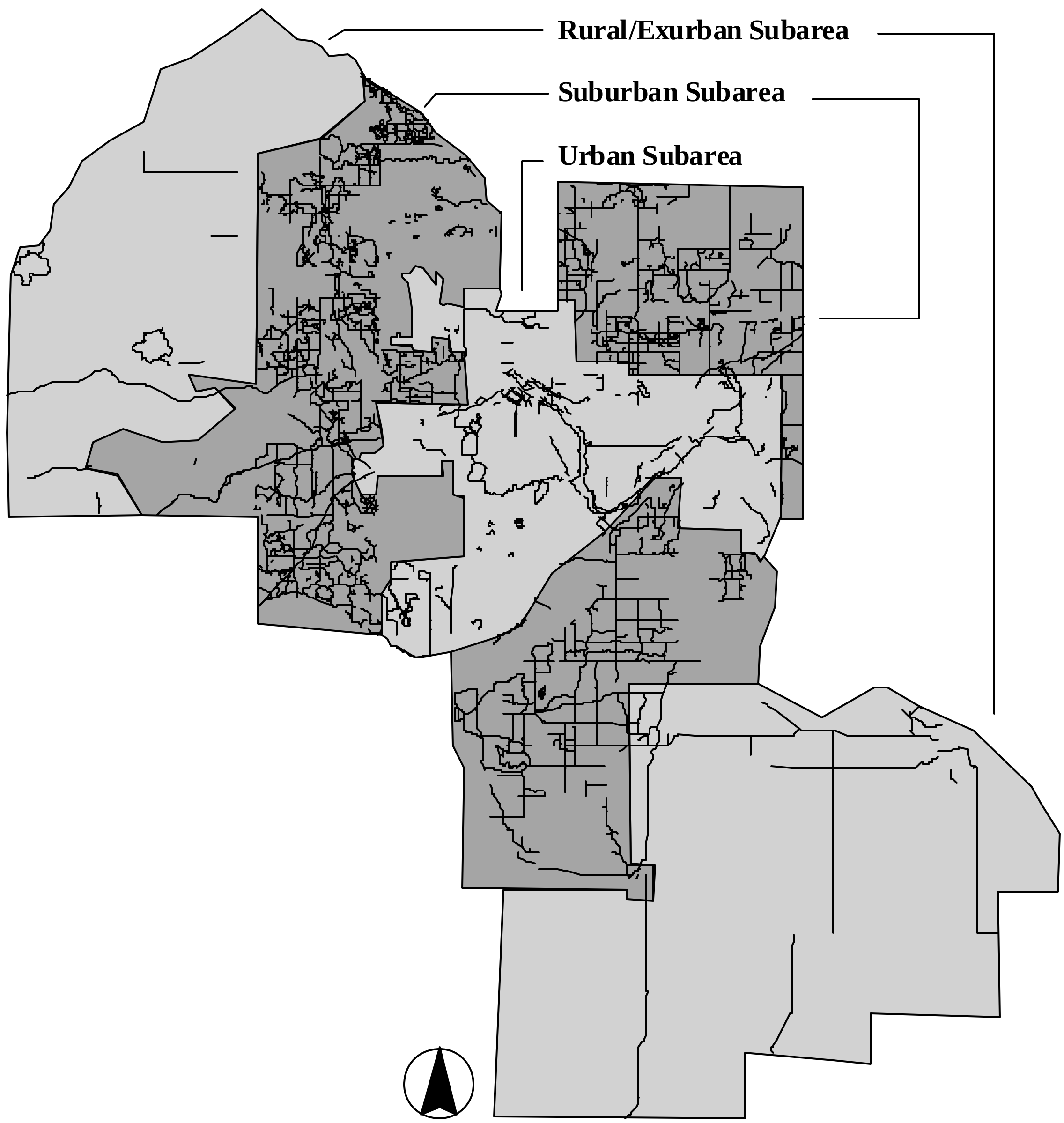


Figure 4. Patterns and Densities – On-Road & Off-Road Bicycle Facilities

Patterns & Densities
Roadways

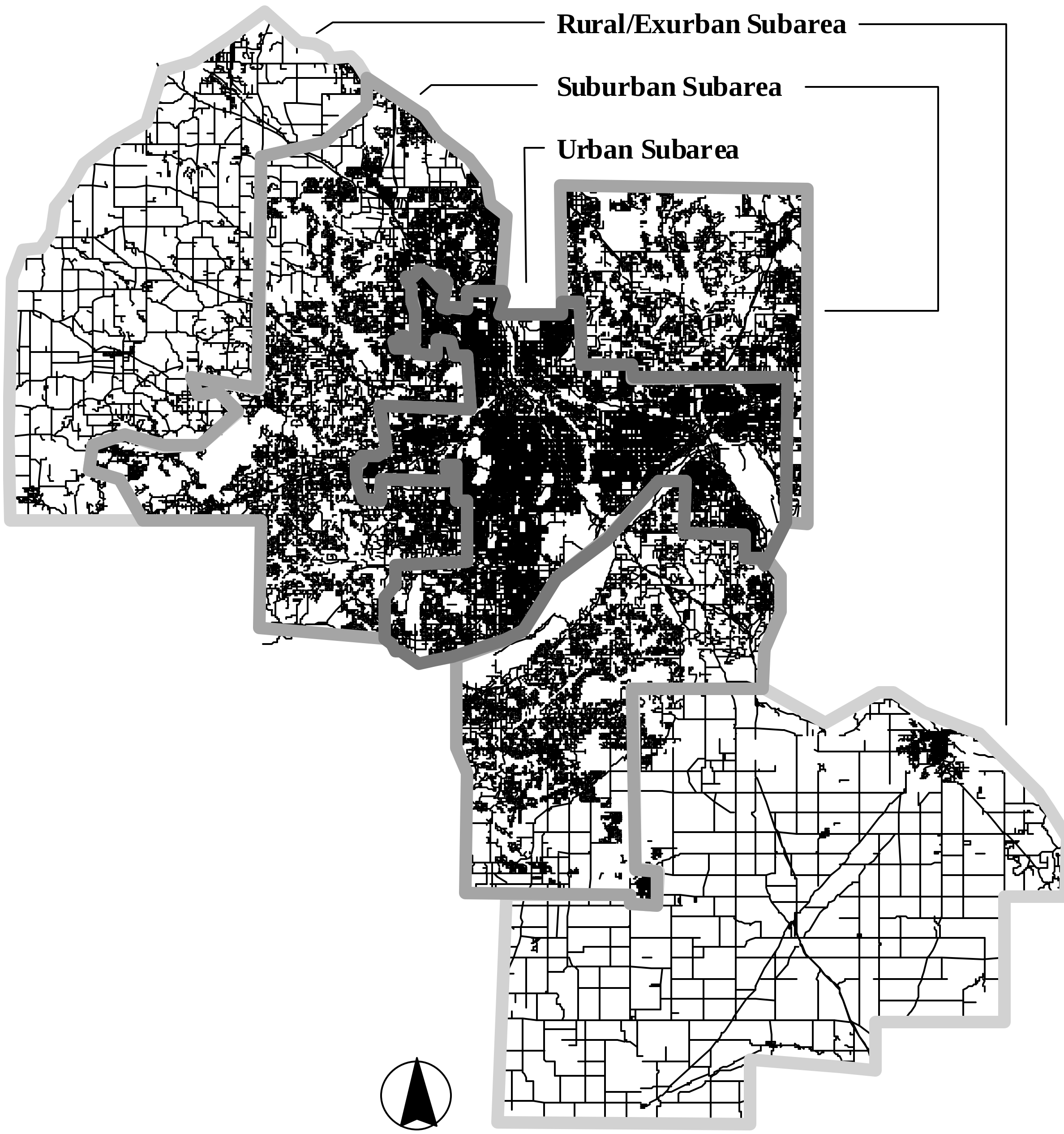
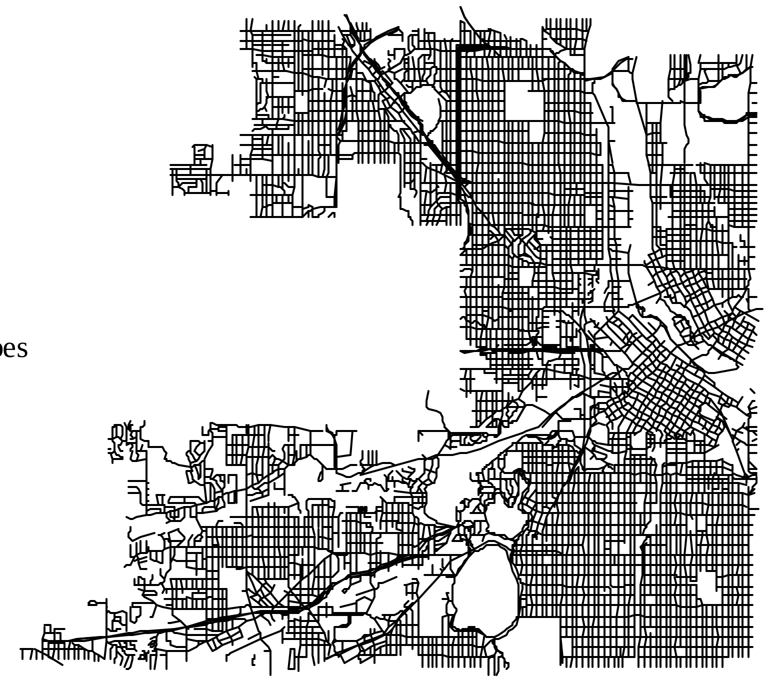


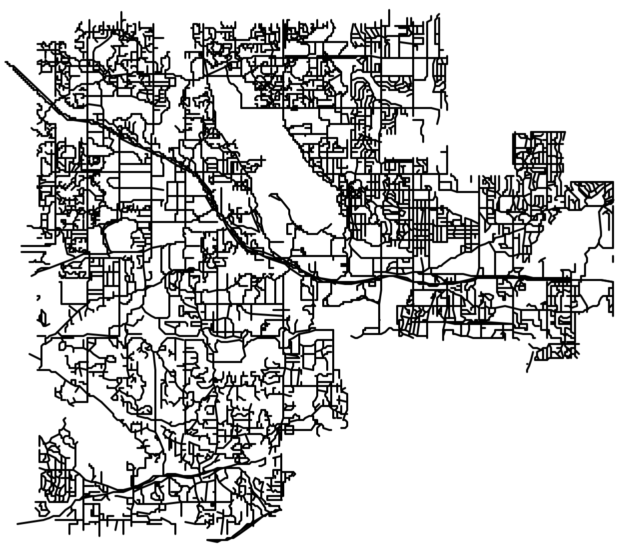
Figure 5. Patterns and Densities - Roadways

There was also a relationship between roadway and bikeway density and system connectivity. The roadway maps clearly showed distinctions in roadway patterns that roughly followed the distinctions in roadway and bicycle system density (Figure 6). The street pattern of the inner core consistently showed a grid system of straight streets, with high connectivity in general and high connectivity of different street types (e.g., in addition to arterial/collector intersections, there are many intersections of arterial streets and local streets). The street patterns in the suburban ring consisted almost entirely of curvilinear roads, culs-de-sac and eyebrow street types. The suburban cul-de-sac and eyebrow street types are the local streets of the implementation of the functional hierarchy of streets in the suburbs. The strict implementation of the functional hierarchy of streets (arterial, collector and local) results in a system of more controlled access and less overall connectivity.

Pattern & Density Samples
Urban & Suburban Roadways



Urban Subarea (S1)
Highest density of roadways
Grid street pattern
High connectivity in general
High connectivity of street types



Suburban Subarea (S2)
Medium density of roadways
Non-grid street pattern
Many culs-de-sac & eyebrow street types
Lower connectivy, many dead ends

Figure 6. Pattern and Density Samples – Urban and Suburban Roadways

Aside from economic, political and any other issues regarding the implementation of bicycle facilities, the connectivity of the motor vehicle street patterns might help explain the difference in the density of bicycle systems in the suburbs and the inner core. That is, the grid system by its nature gives any street user, including bicyclists, a high degree of connectivity to all destinations. The strict implementation of the functional hierarchy of streets always ends with the local street. The local streets often do not reconnect to the system, because culs-de-sac dead end and eyebrow streets only connect to one street, thus coming to a dead-end in function.

Suburban Connectivity
Bicycle & Roadway Systems

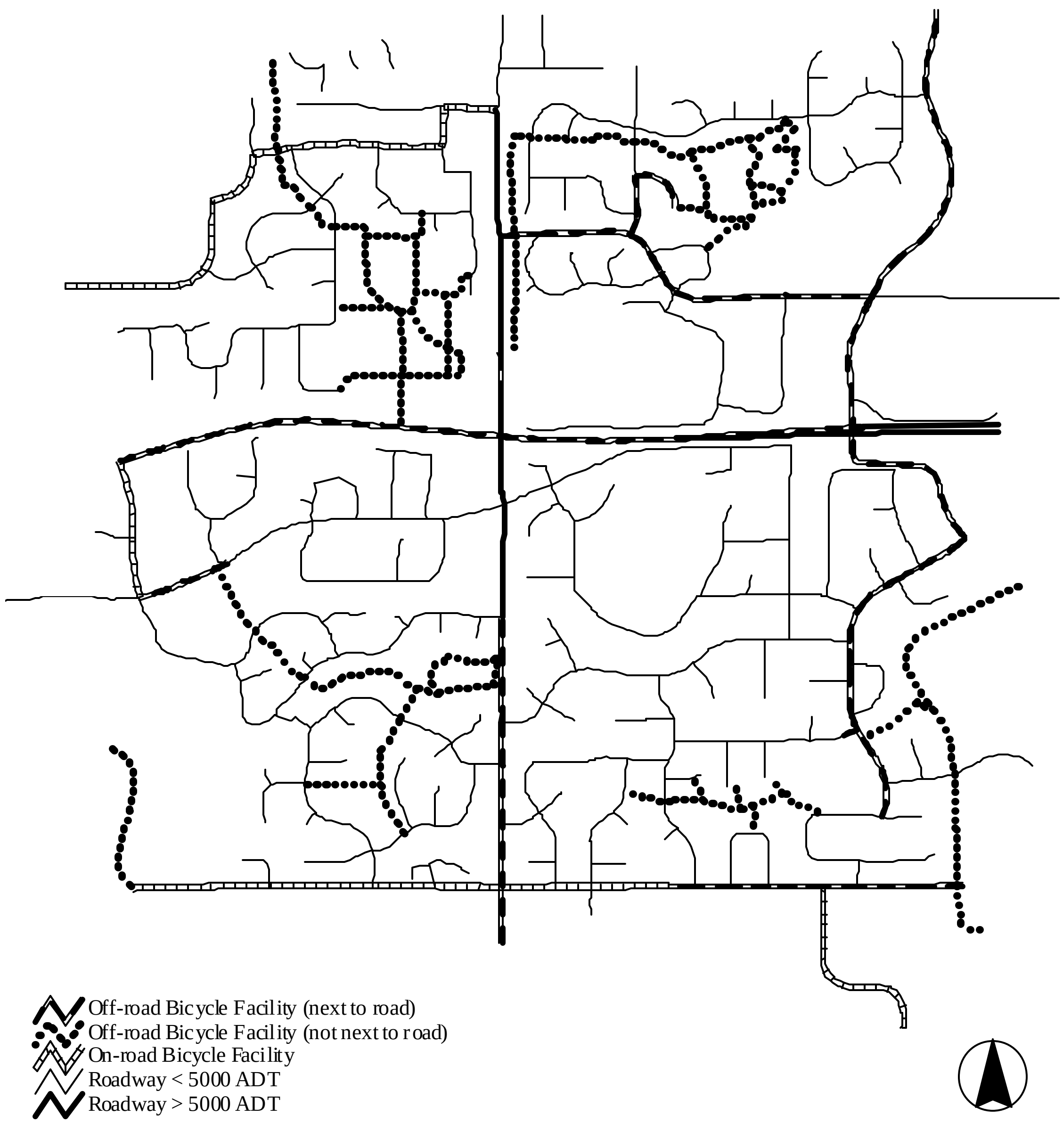


Figure 7. Suburban Connectivity – Bicycle and Roadway Systems

Roadway connectivity (as allowed by the different types of street patterns) could be indicative of the need for bicycle facilities. With low connectivity, bicycle facilities are more necessary so that cyclists can connect to their destinations conveniently and in a time efficient manner. The suburban ring in the three counties clearly shows the existence of more bicycle facilities and bicycle facilities designed to enhance connectivity in conjunction with the roadway system. Figure 7, taken from the GIS maps of a Minneapolis suburb, has many examples of this.

Analysis of the GIS-generated maps showing metro area roadway and bicycle systems confirmed the initial analysis of the types of subareas that project personnel formulated. Whether connectivity and density play a role or not, there were clearly four different subareas visible on the GIS maps that indicated there could be homogeneity of bicycle use. The four subareas represent fundamental differences in transportation system design, and roadway and bicycle system density. Like the four bicycle facility types, the definitions of the four different subareas are straightforward and easy to understand.

3.5. *Study Characteristics*

The table below shows the number of segments of each facility type in each subarea and county. Additional characteristics of the study area include a relatively flat terrain with slopes occasionally exceeding 10%. Only one of the randomly selected count sites was not on flat terrain. This site was located on a segment of a regional park trail. Neighboring segments of the selected count sites were also on flat terrain. Thus, topography probably played no role in use of either roadways or bicycle facilities by cyclists.

Counts were taken from mid-May through the first week in July and between the end of August and the middle of October. The weather during the count period was seasonably pleasant. The autumn time period, from the end of August to the middle of October was unseasonably warm and sunny. Thus, a variety of warm season counts were taken during the study.

Table 1. Numbers of Segments by Facility Type, Subarea and County

	Bicycle Facilities		*Roadways with no Bicycle Facilities*		
	On-road	**Off-Road**	**<5000 ADT**	**≥5000 ADT[a]**	***TOTAL***
University subarea (SU)					
Dakota[b]	None	None	None	None	None
Hennepin	48	28	178	76	330
Ramsey[b]	None	None	None	None	None
SU Total	**48**	**28**	**178**	**76**	***330***
Urban subarea (S1)					
Dakota	2	24	1426	223	1675
Hennepin	280	469	17869	3767	22385
Ramsey	216	249	8591	2102	11158
S1 Total	***498***	***742***	***27886***	***6092***	***35218***
Suburban subarea (S2)					
Dakota	388	1081	9908	740	12117
Hennepin	529	3257	17947	1821	23554
Ramsey	610	1224	7261	660	9755
S2 Total	***1527***	***5562***	***35116***	***3221***	***45426***
Rural/exurban subarea (S3)					
Dakota	149	113	2791	231	3284
Hennepin	37	57	2497	211	2802
Ramsey[b]	None	None	None	None	None
S3 Total	***186***	***170***	***5288***	***442***	***6086***
Dakota	*539*	1218	14125	1194	17076
Hennepin	*894*	3811	38491	5875	49071
Ramsey	*826*	1473	15852	2762	20913
TOTAL	***2259***	***6502***	***68468***	***9831***	***87060***

[a] Does not include interstates and trunk highways. See section 3.3.
[b] County does not contain this subarea or facility type.

3.6. *Data Collection*

3.6.1. *Overview and Checklist*

For those who might wish to conduct a similar BMT project, the contents of the introduction to this chapter are listed in checklist format. Details and commentary are found in the subsections that follow.

The checklist of tasks for collecting and processing BMT data include:

1. GIS Database
   a) Obtain accurate database of all streets and roadways in study area; must show all street and roadway segments, provide the length of each segment and have each segment digitized for the display of GIS-produced maps.
   b) If not already provided, insert all ADTs for all streets and roadways; preferably for all ADTs $\geq$ 2000, but minimally, for all ADTs $\geq$ 5000.
   c) If not already provided, map bicycle facilities as follows:
      1) Indicate if street or roadway has on-road facilities and enter all data for all on-road bicycle facilities.
      2) Map in and enter all data for all off-road bicycle facilities in the study area.
2. Sample Selection
   a) Create unique identifiers for each segment.
   b) Randomly select equal numbers of segments in each of the categories (each facility type in each subarea) as data collection sites. (In this study, there were 4 facility types and 4 subareas for a total of 16 categories.)

      Select a large number because once counting has begun, some sites might be rejected (section 3.6.3).
   c) Create a master list of selected sites identified by facility type and subarea for record keeping (see Master Site Selection Sheet in Appendix B, Project Management Forms).
3. Count Program using Video Technology
   a) Obtain permission from all jurisdictions and all power companies in study area.
   b) Obtain exemption from federal guidelines regarding observation of public behavior.
   c) Prepare initial count schedule.
   d) Familiarize field personnel with video equipment installation and record keeping routines.

4. Scheduling and Management

   a) Prepare site lists and site maps, installation sheets and count sheets (see Appendix B, Project Management Forms.)

   b) Monitor installations and supervise installation scheduling

5. Bicycle Counting (for BMT estimation)

   a) Count each individual cyclist as he/she passes on the selected segment.

   b) Count only cyclists on the selected corridor segment (i.e., not on adjacent segments or in neighboring intersections).

   c) Count all cyclists in the corridor, whether on the bicycle facility, in the street or on sidewalks.

   d) For convenience and additional information, record at 15-minute intervals and record weather.

   e) Count tandem cyclists as one count (vehicle miles of travel are measured in bicycle miles of travel, not person miles of travel).

3.6.2. *GIS Database*

Any project measuring BMT or other volumes of bicycle traffic on a large scale requires a database to minimally provide basic data such as total length of the system. A Geographic Information System (GIS) product is recommended to manage the data and to provide maps of the study area and facility types. GIS products correlate data with maps. That is, a database accompanies each roadway map and each defined roadway segment in the map has a data entry. Serious errors could occur without the GIS ability to produce maps from the data, particularly when the study area and therefore, the data are of any size.

The project used the Arc View GIS product from ESRI Corporation. The base data for the streets and roadways in the Twin Cities area was the street centerline database that Mn/DOT and the Metropolitan Council jointly developed with an outside vendor in 1996-97. The street centerline database was developed to provide common base data for researchers, planners and mapmakers of roadways in the Twin Cities area and to provide base data that was more accurate than that which was used in the past. This project was one of the first users of the new database.

The project added ADT and bicycle information to the base data for each roadway in three metropolitan area counties: Hennepin, Ramsey and Dakota. *Seven County Street Series Traffic Volume Maps* (1996) produced by Mn/DOT and USDOT were examined to identify all roadways in the three county area with an ADT >2000. If ADT was ≥ 2000, the segment data was amended to include the segment's ADT. For segments <2000ADT, the ADT was set to zero. The ADT was given a value of 1 for anomalies (e.g., usually a small segment indicating an arterial crossing in the original base data, see Figure 8). (See section 3.3 for a discussion on why ADT=5000 was selected as the boundary between the larger street category and the smaller one.)

The next task in the development of the project database was the entering of data for on-road bicycle facilities and the mapping and entering of data for off-road facilities. This task sometimes required contacting appropriate personnel in each jurisdiction. It was often necessary to resolve differences between the maps produced by the different jurisdictions (e.g., county maps vs. community maps). Also, since each jurisdiction categorized their facilities in the manner they saw fit, it was sometimes necessary to determine how their classification of bicycle facilities fit within the classification system of this study or with classifications used by other communities. Finally, since bicycle maps are not produced every year, it was necessary to determine if facilities marked as scheduled for construction were indeed built on schedule.

The project used Digital Orthographic Quadrangle aerial photographs (DOQs)[27] as a tracing base for mapping the off-road bicycle facilities. At the time of the study, it was not practical or possible to digitize the off-road facilities (i.e., manually transfer the bicycle facilities from accurately measured maps, which are precisely registered with the maps in the database). One reason digitization was not possible was that exact locations and lengths of off-road bicycle facilities are not as precisely surveyed or mapped as are motor vehicle roadways. Off-road bicycle facilities, for example, are not found on USGS maps, which have the necessary precision for digitization. It was, therefore, not possible to digitize off-road bicycle facilities for the BMT project from available maps. And thus, the off-road bicycle facilities were traced from DOQs onto the Metropolitan Council's Street Centerline Map as a base.

Roadway Anomalies Omitted from Study

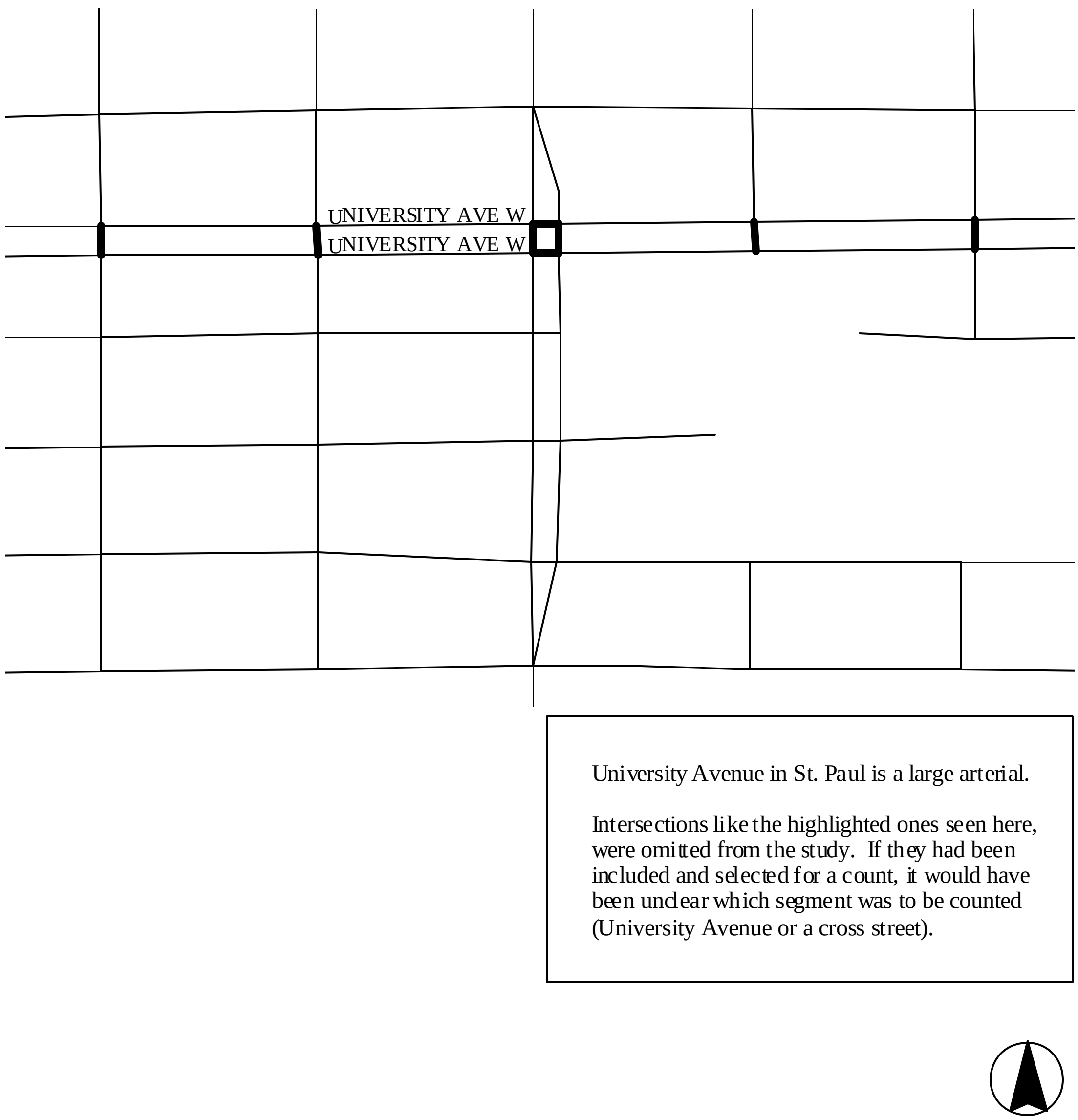


Figure 8. Roadway Anomalies not included in the Study

Next, the project used the GIS mapmaking flexibility to produce maps to analyze how the subareas for the study were to be defined and where the boundaries were to be set. Section 3.4 discusses the analysis used to define the four subareas that are used in this study. Project resources did not permit individually assigning each roadway segment and each bicycle segment in the database to a specific subarea. The project therefore looked at subarea demarcation according to community boundary (the subarea designation could be marked in the database as a group of roadways segments located within a specific community because community name was a field in each segment's data record). Visual examination of the characteristics of the roadway and bicycle systems in the four subareas showed a close correlation between community boundaries and the subarea characteristics (also described in 3.4).

As a final note, the street centerline database is organized by county. ADTs, and on-road and off-road bicycle data were added as new fields in the database accompanying the street centerline map. In the case of off-road facilities, new records were added to the street centerline base data and new segments were added to the map, making one large database per county that shows all roadway and bicycle information in the county. Since GIS product capabilities allow users to make subsets of this information or to merge or join databases, the user has significant flexibility in subdividing and analyzing the data.

Counted Sites

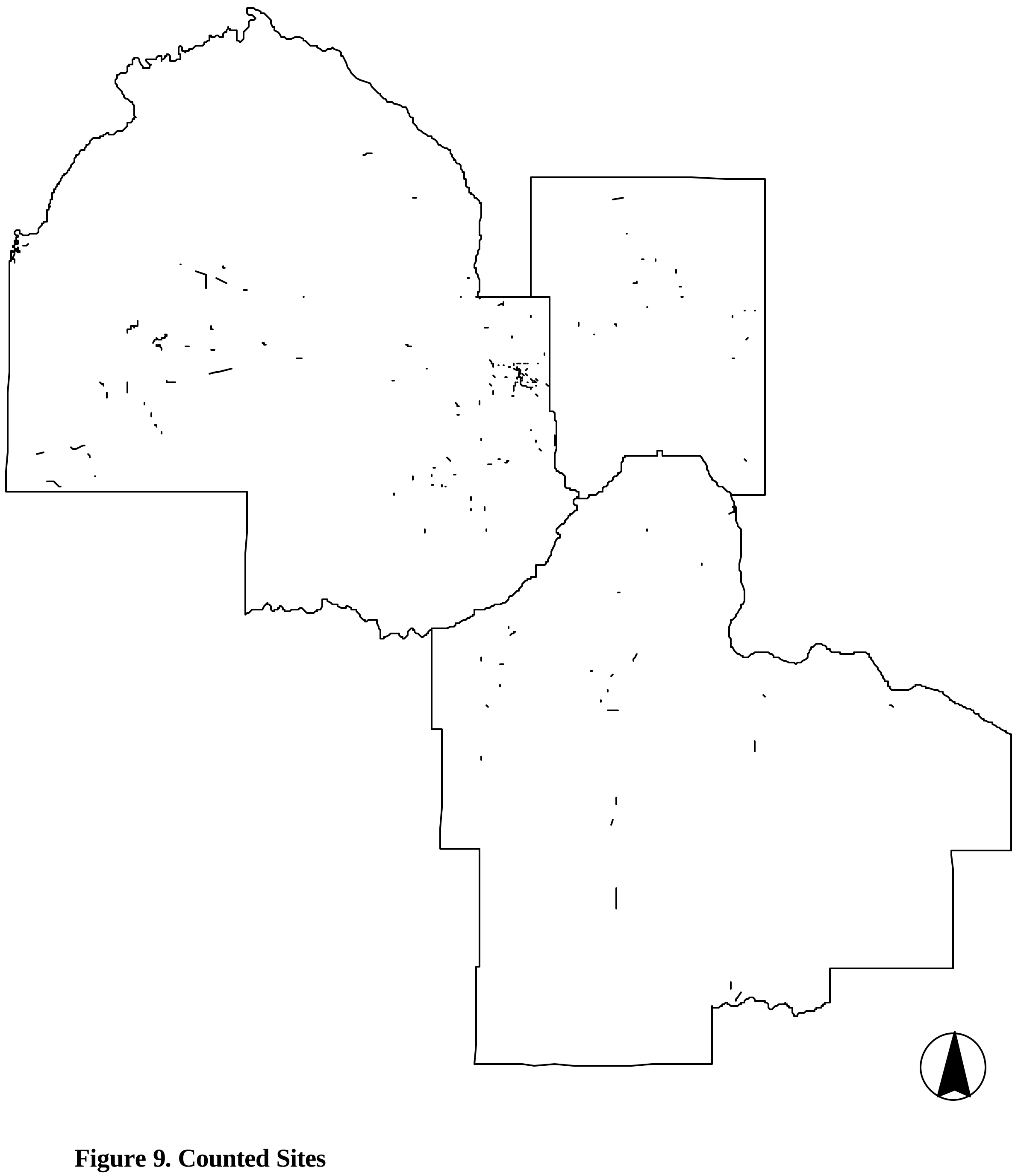


Figure 9. Counted Sites

3.6.3. *Sample Selection*

As discussed in section 3.2, the *Guide to Urban Traffic Volume Counting* recommends that each facility segment be classified with a subarea and a facility type. The BMT project defined four facility types and four subareas. Therefore, there were a total of 16 unique classifications in the BMT study.

Each classification must have an equal number of counts and the count sites must be randomly selected. Therefore, each segment in the database must be uniquely identified. Since the street centerline database was organized according to county, the intra-county identifier supplied with the original data was not unique on an inter-county basis (i.e., county-id #1, #2, … etc. was assigned in each of the three counties.) Inter-county (unique) identifiers assigned in the street centerline base data were not adequate because of their inconvenience to project researchers. That is, the sequential nature of the assignment of the inter-county identifier did not allow off-road bicycle facilities to be added and numbered in a logical, easily understood fashion. The inter-county identifiers proceeded sequentially through all nine counties of the Twin Cities metro area. The addition of identifiers for off-road bicycle facilities would necessarily have had to begin at the end of the last number in the last county. While this would have worked, it would have become quite confusing to understand segment identifiers for purposes of the study.)

Thus, the project assigned each of the 16 classifications its own series of identifiers, beginning with 1 in Dakota County and ending in Ramsey County. Appendix B-3 shows the assignment of bicycle identifiers for purposes of this study. Note, since numbers are duplicated across the 16 classifications, every bicycle identifier is qualified by its subarea and bicycle facility type (i.e., subarea, facility type, ID).

If more studies of this kind are conducted and as new segments are added to the database, it may be necessary to reassign new bicycle identifiers (and erase old ones) for purposes of selecting a random sample and managing the count project. This would be done to simply make it easier for researchers to understand which range of identifiers belongs with which type of facility/subarea. Doing this would not affect any record keeping since all data and geocoding information is carried with the segment's record in the database. The renumbering of identifiers in the future would not affect any previous or subsequent bicycle studies using the database first established by the BMT project.

After identifiers were assigned in each of the sixteen classifications, the random number generator provided with Microsoft Excel 97 was used to randomly select the count sites. Figure 9 shows all of the sites that were counted in the study; i.e., 10 sites in each of the 16 classifications, or 160 sites.

Technically speaking, the days on which bicycle count data were recorded should also have been randomly selected. However, if this had been done, the cost of travel to sites that were also randomly selected according to day of the week would have been prohibitive since travel time to the count sites was the most consumptive of project time during the data collection phase. For example, three count sites for a particular day; if also randomly selected by day of week could require over 150 miles of travel time per day. Even when sites were "clustered," as described next, 60 miles per day was the average travel distance. This average included 25% of the sites, which were located around the University of Minnesota, the "home base" of the project.

Mn/DOT and project personnel decided that the "clustering" of sites was necessary. In other words, sites that were near each other or "on-the-way" to each other were counted on the same day. However, two or more sites where the same cyclist could potentially be counted within a short period of time were not selected for counting on the same day or, even on sequential days. Though not calculated, it appears that this method of counting was fairly random because distances between the randomly selected sites were usually significant. (For example, three sites in south Minneapolis, while appearing fairly close together on an 8½ x 11 map Figure 9, were in reality located in three different neighborhoods, all of which were not located next to each other.)

3.6.4. *Count Program*

The project used traffic video recording technology from ATD Northwest in Redmond, WA to videotape the count sites. Research assistants then counted cyclists from the videotape. Two people were required for equipment installation because the box housing the VCR and marine battery was too heavy and bulky to install by one person. Also, it was more efficient to have a driver and a navigator whose job it was to locate sites and direct the driver to them.

Videotaping cyclists is more time- and cost-effective than using human counters on-site for a number of reasons. First, human counters should usually not be scheduled for more than 4-6 hours per day because of the nature of the work. Since the manual counting of bicyclists for even this amount of time is fairly boring, especially if the human counter works on a regular basis, manual bicycle counts are usually less reliable for collecting count data than an automatic means of collecting the data. Using human counters to collect data also requires significantly more scheduling management; on-site, employee supervision; and travel time to replace personnel during the count day. These requirements significantly increase data collection costs.

Previous tests of other bicycle count technologies (e.g., tube counters and laser counters) showed both were not satisfactory methods for counting bicyclists. Tube counters tested by the City of Minneapolis and Mn/DOT's Sustainable Transportation Initiatives Unit showed that they are probably not a reliable method of counting cyclists for a number of reasons. For example, a tube counter placed on an off-road, multi-use facility in Minneapolis was carefully wound up and placed off of the bicycle facility by a facility user. (Since the counter was carefully wound up and not vandalized, it was presumed that perhaps the tube counter tripped roller blade users, or even interfered with cyclists.) In addition, tube counters do not effectively count cyclists on city streets, where despite even the presence of a striped facility, bicyclists can be found in any place within the street corridor, including the sidewalk. (Note: as discussed in section 3.6.5, all cyclists within the right-of-way corridor space were counted as users despite the location or kind of bicycle facility found in the corridor) The use of laser counters could be very problematic in urban areas and in non-urban areas, the Minnesota Department of Natural Resources found that deer and hikers were counted by a laser counter.

The collection and counting of bicycle data is the most time-efficient when traffic video recording technology is used. The ATD Northwest recording technology is pole-mounted and is usually installed in 5-10 minutes and removed in less than 5 minutes. The technology permits the recording of data at selected time intervals. This, therefore, uses less videotape and requires less time to count bicyclists from the tape. The project found that with a setting of one frame per 5 seconds, one two-hour tape could record more than 24 hours of on-site counts. The project actually counted from 5 AM to 10:30 PM, or 17.5 hours each day; i.e., the longest time of daylight and twilight in a Minnesota summer. Preliminary tests by Mn/DOT and project personnel showed almost no cycling after dark. In addition, unless the camera was positioned near a streetlight and cyclists traveled in the light thrown by the streetlight, nighttime cyclists could not be seen on the videotape. (Since counts were taken into the shorter days of October and exact time periods for all counts are required for the BMT estimate, the project used 12 hours of count time, from 7 AM to 7 PM to formulate the BMT estimate.)

Bicyclists recorded for a 17.5 hour period on a video tape using 5 second timed intervals could be counted in approximately 1½ - 6 hours by project research assistants, depending on the number of automobiles, bicycles and pedestrians found in the corridor. The busier the corridor, the more time it takes to accurately discern and count individual cyclists. Nevertheless, the count time from videotape is significantly more time-efficient than stationing human counters on-site for seventeen hours.

As noted in section 3.6.5, even though the nature of the corridor facility type (e.g., on-street facilities) might have precluded cyclists from some areas of the corridor, (e.g., motor vehicle traffic lanes or sidewalks), bicycles within any part of the corridor were counted. This was done because the purpose of the study was to determine bicycle miles of travel and not the nature of facility use.

Hidden and potential barriers to obtaining bicycle counts from videotape are permissions required from:

1. Communities in which the selected sites are located,
2. Electrical power companies on whose poles the equipment is installed, and
3. Agencies authorized to apply federal guidelines regarding the observation of public behavior.

Failure to obtain permission to videotape from any of the above can terminate a count program or research using videotape.

To obtain permission from communities, the project issued a mailing containing:

1. A brief, one-page explanation of the project,
2. Photos and a description of the video recording technology,
3. A list of selected count sites showing address range and street name of the selected sites within the community (an example site sheet is shown in Appendix B-5), and
4. A simple permission form for return to the project (Appendix B-1).

Communities had a variety of questions and concerns and sometimes altered the permission form to suit their concerns and needs. Different communities placed responsibility for bicycle facilities in different types of city offices including planning, parks and recreation, traffic engineering, and law enforcement. Rather than call each community, the project found that the most efficient way of steering the information and the permission form to the appropriate place within any community government was to initially address the permission packet to Traffic Operations. The project found that if this was done, the information quickly reached the appropriate party.

In the Twin Cities area, the video recording technology usually needed to be installed on power poles owned by the area's electrical utility. Since electrical utilities own these poles, permission is also needed from them to install equipment on their property.

One obstacle the project encountered, particularly in the case of power companies (and somewhat with communities), was that the company had never received or processed a request for mounting equipment on their poles for one day only. The closest type of request the Power Company had experienced was from businesses using microwave communications technology. These companies rented power poles for years at a time. For whatever the reason, because a request to videotape the roadway corridor is an entirely new one, personnel from any bicycle count project and representatives from a power company must initially devote considerable time to find who is responsible for granting permission and how it will be granted. However, once done the first time, permission to obtain future counts should be accomplished fairly quickly.

Rather than issue a lease for each pole, as is usually the case, the power company in the Twin Cities area decided to amend (shorten) their master lease agreement to include a general description of where and how the equipment was to be installed on any pole (see Appendix C). Regarding the latter, was the Power Company's concern regarding the installation of video recording equipment on painted aluminum poles and on fiberglass poles. Some communities also shared these concerns regarding the use of light poles that they owned. The Power Company that was involved in the BMT project decided that the use of painted poles (i.e., aluminum) was permitted if padding was placed around the equipment. Project personnel found this to be more than adequate for protecting the pole. Future projects should investigate whether the equipment is too heavy for fiberglass poles. This was not pursued by the BMT project because count delays due to all of the needs for obtaining permission to videotape had significantly increased. In addition, all of the selected sites proved to have poles made of other materials.

The issuance of a master lease agreement from the Power Company initiated another involved process at the University of Minnesota to process such a request. It should be noted by any other projects measuring bicycle use in this way, that the Power Company required liability insurance in the amount of several million dollars. This was not a problem for the University of Minnesota because it maintains insurance of this nature for all sorts of different uses. It should also be noted that for its part, the University found it necessary to negotiate a few details of the agreement with the power company and that ultimately the master lease agreement required five signatures at the University, including representatives from University leasing and asset management offices, department heads, deans, and vice presidents.

Some communities and the power company initially requested that project personnel and community/power company personnel visit all of the selected counts sites, select a pole on which the video equipment was to be installed and note the location on the pole where the equipment would be installed. Some communities and the Power Company requested payment for this process (a significant amount compared to project resources). In the case of communities, poles had in the past been individually selected for the installation of loudspeakers at picnics and gatherings (less than a handful of sites). In the case of the Power Company, pole rental sites were to be used for years by a commercial concern, so the cost could be absorbed. Since this process was cost prohibitive to the project, the difference in the nature of use, the amount of pole rental time and the nature of the equipment were discussed. Regarding the latter, it was pointed out that the equipment had a self-contained power source; that once installed, it would not physically interfere with other equipment on the utility pole and would not easily be noticed. The Power Company and some communities agreed that the site inspection process was not necessary for this type of project.

In some cases, communities did not respond to the project's permission request or they placed such time-consumptive requests on the project for equipment demonstrations or explanation of the nature of the data collection process, that the project had to forego the inclusion of the community in the count process. However, enough communities comprising a representative sample of all of the subarea types did respond and so count sites in those communities were included in the project sample.

The final issue that any video counting project must address is permission to observe (videotape) public behavior. The observation of public behavior is regulated by federal policy as stated in the Code of Federal Regulations, Title 45, Part 46 (45 CFR 46). This federal policy requires permission from an appropriate regulating agency (e.g., the University of Minnesota's Institutional Review Board, IRB) to record public behavior for purposes of research.

The BMT project obtained an expedited review to videotape public behavior for purposes of counting cyclists. The expedited review took significantly less time than full committee review. Conditions that the project was requested to satisfy included assurance that individuals could not be identified, storage of the tapes in controlled conditions, counting of the tapes by selected personnel only and erasure of the tapes when the project concluded.

Appendix D, Protection of Human Subjects, contains a list of federal and University of Minnesota websites where further information can be obtained on federal policy for the protection of human subjects.

In summary, all of the agencies and jurisdictions requiring review and permission to use traffic video technology for collecting the bicycle count data should be contacted prior to the initiation of any research or bicycle count project of this type. When the BMT project initiated its proposal and its work plan for the project, none of the requirements described above were known. The additional needs for obtaining all of permissions described above placed significant stress on project resources, specifically those designated for project management.

It should be noted, however, that once the processes for obtaining permission for this type of effort are completed the first time, it should be considerably shorter and easier on subsequent count projects. For subsequent efforts, a "permission infrastructure" would be in place and appropriate personnel in various agencies, jurisdictions and companies would be identified and knowledgeable of the purposes of similar projects and the processes required to gain permission for collecting data.

3.6.5. *Counting Guidelines*

The BMT project adhered to the following when counting cyclists from the videotape.

- Only cyclists who rode on the selected segment were counted. Often, adjacent segments and intersections could be seen on the videotape. Counts were not made of cyclists who were on adjacent segments but did not enter the selected segment. In these cases, the cyclist either crossed through the adjacent intersection on the cross street, or turned off the corridor or parked prior to entering the selected segment.
- For BMT estimations, all cyclists within the selected corridor segment were counted, despite the type of bicycle facility found in the corridor (on- or off-road) or existing laws regarding bicycle use in the corridor (e.g., no cycling on sidewalks). The purpose of a BMT calculation is to determine bicycle miles of travel and not the nature of facility use. Therefore, sidewalk cyclists and cyclists traveling outside of an on-road or off-road bicycle facility (e.g., in the roadway) were counted.

- Tandem cyclists were counted as one count (vehicle miles of travel are measured in Bicycle Miles of Travel, not Person Miles of Travel).
- For convenience and additional information, counts and weather conditions were recorded at 15-minute intervals.

3.6.6. *Scheduling and Management*

When this project was being conceived in its proposal phase, it was thought that a schedule for a few weeks or more could be set and that field personnel could simply install the video equipment according to a list of sites. This proved not to be the case. In fact, significant time was necessary to manage and schedule equipment installation. On the BMT project, the project manager performed this, though a field supervisor could be trained to do it.

The reasons for scheduling management are several; including clustering count sites for more efficient travel to and from sites and the rejection of a count site by field personnel. In addition, to use the equipment in the most time-efficient manner, the installation of the equipment rotated in time on a day-to-day basis. These are discussed below.

Project personnel considered different scenarios or schedules of equipment installation during the day. Since the video equipment had on/off times, which controlled the times of data recording, the equipment could be installed at any time during the day and at different times on each day. In other words, time of day, day of week and the continuous recording of data on one day alone were not factors in collecting the data.

The project determined that the most time-efficient use of (rented) equipment was to continually advance the schedule, rather than install the equipment at fixed times. In the worst case when different types of fixed schedules are used, an entire day would have to elapse between field installations of a particular camera. For example, if a camera were scheduled for an 8:00 installation throughout the project, it would be necessary to install the camera every other day. The installation and travel times involved in the installation process would make it necessary to wait an entire day for the camera to be installed again at 8:00 AM.

Continually advancing the schedule allowed for the most time-efficient use of the equipment. With a continually advancing schedule, if camera #1 was installed at 8:00 AM Monday and removed at 8:00 AM Tuesday, it would be installed at the next site at some time later than 8:00 AM Tuesday, say 9:00 AM, because of the travel time involved from site to site.

So, a continually advancing schedule advances in time until the camera or cameras are brought "home." (For safety reasons, research assistants did not install equipment after dark.)

A continually advancing schedule, though most efficient in the use of equipment requires considerable scheduling management, because equipment installation and travel time cannot be accurately determined beforehand. Equipment problems, obscure site locations, traffic jams and so forth contribute to later installations than could be predicted beforehand. Moreover, with four cameras in the field and a study area that was more than 30 X 30 miles wide, it was sometimes found that it was the most efficient to bring a camera "home" and install it first thing on the way to the other sites. Or, it was found that it was more efficient to de-install two cameras and then install both of them before taking down the third camera.

Scheduling equipment installation in this way required regular review of the status of the camera installations (when and where they were set up, and when and where they were to go). The project found that it was usually not possible to schedule for more than four days in advance and this only when the installation routes and so forth were straightforward and fairly well known. More complicated sequences of installations required more scheduling management. In addition, scheduling of equipment installation in this way required regular and frequent production of map sheets and site sheets (Appendix B-5).

It should also be noted that this kind of scheduling, while providing the most counts in the least amount of time, requires field personnel than can and are willing to continually change their schedules on a daily basis (including weekends). This was relatively easy for the BMT project because undergraduate research assistants were used in the summer months. Summer session classes and the beginning of fall quarter classes made it considerably more difficult for any of three research assistants to be available (two at a time) at once. Therefore, it was also necessary for project management to be available to install cameras in the field.

Accurate record keeping and organization are critical on projects like this. Appendix B, Project Management Forms, provides all of the record keeping sheets used by the BMT project, described as follows:

- The master key shows the range of identifiers for each of the sixteen facility type/subarea categories.
- The explanatory label to be taped to the video equipment helped identify the equipment to curious passers-by or neighbors. Local police are sometimes informed by the jurisdiction responsible for the roadway or bicycle facility. However,

sometimes notification is not thorough. Such a label can save time and unnecessary interruptions. Wording like that shown in Appendix B is recommended since gathering bicycle count data is largely supported by the public.

- The master site selection sheet shows the order in which each site was randomly selected. This sheet can be marked up and used as a quick reference for project management regarding sites that have been counted or need to be counted. If the record identifiers are put into a table format, the sheet is automatically created by the random number generator.

  Note, in addition to clustering installation sites, project management or field personnel had the option of rejecting sites. The most common reasons for this included: danger either to project personnel or to equipment in the field; no pole on which the equipment could be installed; roadway or bicycle facility closed due to construction; and improper identification of the facility in the database (a few times, the original base data recorded information regarding the roadway incorrectly; e.g., driveways to businesses were designated as local streets or maps provided by communities indicated the existence of a bicycle facility where none existed). Therefore, because of cluster-type scheduling and the option for site rejection, the master site selection sheet is critical for keeping and reviewing records regarding what has, has not, or should be counted.
- Site sheets contain the information that equipment installers require in the field for finding sites and recording information about the camera installation.
- Site maps give detailed instructions in map form on how to reach the site. Sometimes more than one map is needed to pinpoint the location of the site and to direct field personnel to the site from home base or from a previous site.

  The project found that automatic map production facilities provided on the Internet produced information that was too detailed and not formatted for quick understanding in the field. In addition, sometimes the Internet did not produce maps with the most direct or the quickest route. Production of maps by project management took about the same amount of time as producing, amending and reviewing internet-produced maps. GIS mapmaking capabilities using the project's database allowed project management to quickly produce maps for use in the field.

- Installation sheets are used to record data in the field and provide a record of where and when counts were actually taken. Of particular importance is the numbering of video cameras and recording the camera number used at each count site. This is necessary to more efficiently track malfunctioning equipment which is usually detected when the tape is viewed and counted (fast forward will often not catch equipment malfunction or other installation problems).
- Count sheets are used to record bicycle counts taken from the videotape. Project personnel used hand-held counters and counted for fifteen minutes (as determined by the video tape time-stamp, easily seen on the screen). Research assistants found that a 15-minute interval was the most convenient and accurate interval for recording the 12 hours of counts. After 15 minutes, the researcher recorded the count data and made note of the weather, which is also easily seen on the tape. Thus, the project was able to gather extra information regarding bicycle use than specified by the project proposal without using any extra count time. Providing information regarding recreation vs. transportation use and bicycle contra-flow counts takes more time because of the need for closer review and decision-making on the part of the counter.

Note the project found that recording the site identifier, subarea and facility type on all records, including tape labels, was necessary to efficiently keep project records.

The BMT project required more project management than originally planned. An unanticipated and lengthy permission process, as well as unanticipated scheduling and installation management needs contributed to a significant increase in management time over that which was planned at the project's inception. However, management requirements of future projects will decrease because of the "permission infrastructure" put in place by the first counting effort. In addition, if future projects have the luxury of using cameras purchased by a DOT or other local jurisdictions or agencies (rather than rented by the project), as well as gathering counts for extended periods of time (or included in regular work routines), scheduling and project management requirements might also decrease.

Project management time on the BMT project reached unanticipated levels of time requirements because the project was the first of its type and scale, exploring new grounds in this type of data collection. Despite this, the gathering of bicycle count data is an effort worthy of continuation. The number of cyclists counted shows that there are more individuals cycling than one might perceive in a casual manner. Since cycling is proving to be a space- and time-efficient mode of transportation, especially in urban areas, it is worthwhile to measure and understand it as much as motor vehicle transportation is understood. Once the management needs for conducting bicycle counts are better understood and included as regular parts of transportation data collection and planning routines, the entire process of measuring bicycle use will become easier and more efficient.

Chapter 4 COMPUTING ESTIMATES OF BMT

4.1. *Estimating Average Daytime BMT*

The data collection and processing phase of this study produced a total of 160 12-hour bicycle volume counts, ten in each combination of the four subareas and four facility types. Appendix E of this report lists these counts along with other characteristics of the count sites. In essence this constitutes a stratified random sample of bicycle volumes, where each combination of subarea and facility type constitutes one of the sampling strata. To estimate total BMT from a simple (not stratified) random sample of traffic counts, the GUTVC recommends using a ratio estimator of the form

$$BMT = \left(\frac{\sum_{k=1}^{n} v_k x_k}{\sum_{k=1}^{n} x_k} \right) X \qquad (4.1)$$

where

v_k = counted volume on sample site k,

x_k = length of sample site k,

X = total miles of roadway in the area of interest.

The ratio estimator requires information beyond what is included in the sample (in this case the total roadway mileage) but when the numerator and denominator measurements are correlated, the ratio estimator will usually be more precise than simply multiplying the average BMT computed in the sample by the number of roadway links in the population[28]. When the sample size n is larger than about 30, the standard error of the ratio estimator can also be estimated and inferences concerning the BMT can be based on standard normal distribution theory.

Table 2 - Table 4 display the total mileage in the study area, sample BMT and sample mileage, in each case broken down by subarea and facility type. Table 5 then gives the ratio estimate of BMT for each subarea and facility combination. Because only 10 counts are available for each stratum, the large sample theory should not be applied to these individual estimates.

Table 2. Total BMT on Sampled Links, in each Sample Stratum

	Facility Type			
Subarea	**Off-Road** Bicycle Facilities	**On-Road** Bicycle Facilities	**< 5000 ADT** Roadways	**> 5000 ADT** Roadways
S1	683.97	106.98	25.23	163.63
S2	112.68	12.53	12.32	32.10
S3	742.43	27.93	7.10	52.38
SU	414.32	393.26	143.94	256.84

Table 3. Total Mileage of Sampled Links in each Sample Stratum

	Facility Type			
Subarea	**Off-Road** Bicycle Facilities	**On-Road** Bicycle Facilities	**< 5000 ADT** Roadways	**> 5000 ADT** Roadways
S1	2.05	0.82	0.80	0.92
S2	1.96	0.77	0.91	1.41
S3	5.43	3.50	2.36	3.41
SU	1.01	0.69	0.94	0.71

Table 4. Total Mileage in Study Area in each Sample Stratum

	Facility Type			
Subarea	**Off-Road** Bicycle Facilities	**On-Road** Bicycle Facilities	**< 5000 ADT** Roadways	**> 5000 ADT** Roadways
S1	121.03	55.39	2472.24	580.93
S2	713.08	175.77	3488.37	507.57
S3	43.15	83.91	1369.83	117.62
SU	4.8	4.23	13.42	6.37

Table 5. Estimated Daytime Daily BMT in Each Sample Stratum

	Facility Type			
Subarea	**Off-Road** Bicycle Facilities	**On-Road** Bicycle Facilities	**< 5000 ADT** Roadways	**> 5000 ADT** Roadways
S1	40472.2	7190.6	77999.4	103039.6
S2	41076.3	2848.0	47084.9	11590.5
S3	5895.0	668.6	4110.0	1807.0
SU	1969.4	2393.7	2054.5	2306.8

For stratified samples, the GUTVC recommends summing the BMT estimates across the strata to produce what Cochrane calls the “separate” ratio estimate. This would involve simply summing the entries in Table 5 to produce an estimated total BMT for the study area. Estimates of the standard error for BMT in each roadway type would then computed by pooling across the various subareas. For example, the standard error of estimate for BMT on on-road facilities would be computed using the count from on-road facilities in all four of the subareas. However, inspection of Table 2 and Table 3 reveals that within each facility type both average BMT and average link length show marked variation across the subareas, suggesting that the homogeneity assumptions underlying the use of pooled data to estimate standard errors are not justified. Thus it was felt that the assumptions supporting the use of the “separate” estimator, as recommended in the GUTVC, were not warranted, and it was decided to estimate total BMT using Cochrane’s “combined” estimator, which is more appropriate for stratified samples with small sample sizes in each stratum. This estimator takes the form:

$$B\hat{M}T = \left(\frac{\sum_i \sum_j (N_{i,j}) \bar{y}_{i,j}}{\sum_i \sum_j (N_{i,j}) \bar{x}_{i,j}} \right) X \qquad (4.2)$$

where

$N_{i,j}$ = number of links in subarea i of facility type j,

$y_{i,j}$ = sample average of BMT for subarea i and facility type j,

$x_{i,j}$ = sample average segment length for subarea i and facility type j,

X = total mileage of all facilities in the region.

The link totals needed for this estimate are given in Table 1, the average sample BMTs and average sample link lengths can be computed from Table 2 and Table 3 while the total study area mileage is the simply the sum across rows and columns of Table 4. Applying formula (4.2) to the sample produced the following value for the average 12-hour bicycle-miles of travel in Hennepin, Ramsey and Dakota counties:

Daytime BMT = 383,754 bicycle-miles/day

To estimate the standard error of the daily BMT estimate, formula (6.45) of Cochrane[29] was used, with sample estimates replacing the population quantities. This gave:

S_{BMT} = 69,994 bicycle-miles/day

Because we are using the "combined" estimator, the sample size (n=160) is large enough to justify inference based on large sample properties of the estimator. Thus a 68% confidence interval for the total daily BMT would be:

$(BMT-(1.0)S_{BMT}, BMT+(1.0)S_{BMT}) = (313760, 453748)$

while a 95% confidence interval would be:

$(BMT-(1.96)S_{BMT}, BMT+(1.96)S_{BMT}) = (246566, 520942)$

4.2. *Sample Size Selection*

Using the sample data, the estimated coefficient of variation for the daily BMT total can be computed as:

$C.V. = S_{BMT}/BMT = 69994/383754 = 0.182$

which can be interpreted as stating that with 68% confidence the estimated BMT is within 18.2% of the true BMT, and with 95% confidence the estimated BMT is within about 36% of the true BMT.

In Chapter 1 a rough estimate of the sample size needed to guarantee a precision of 10% with 68% confidence was given, but as no information on the variability of bicycle traffic in the Twin Cities was available prior to this study, this estimate was based on bicycle count data from several bicycle trails in the State of Washington. Using Cochrane's formula (6.45), this sample size estimate can now be refined if it is assumed that the sample sizes for each of the strata will remain equal, and that the stratum sample sizes are small compared to the total number of links in each stratum. In particular, to give a guarantee that the estimated daily BMT is within 10% of the true BMT with 68% confidence, the stratum sample size, n, would have to satisfy

$$n \geq \left(\frac{(1.0(.577)}{.1} \right)^2 \approx 33$$

while to guarantee that the estimated daily BMT is within 10% of the true BMT with 95% confidence, the stratum sample size would have to satisfy

$$n \geq \left(\frac{(1.96)(.577)}{.1} \right)^2 \approx 128$$

Thus the sample sizes needed to detect a 10% change in average daily BMT would be noticeably larger than those employed in this study, and are also at variance with the original sample size estimates presented in Chapter 1. Recall however that the original sample size computations actually recommended that 72 miles of roadway be sampled, and the estimate of 144 links was based on an assumed average link length of 0.5 miles. Using the link lengths in the sample however gives an estimated average link length of 0.172 miles, and dividing this into 72 miles gives an estimated total sample size of about 419 links. This is a bit closer to the 33x16=528 links needed to give 10% precision with 68% confidence, and the additional difference is possibly due to the fact that the original sample size estimate was based on variability measures from a fairly homogeneous set of facility types, dedicated bicycle trails.

4.3. *Annual Expansion of BMT Estimates*

The estimate of 383754 can be interpreted as the total 12-hour BMT in Hennepin, Ramsey and Dakota counties on a typical day during the months of May-June and August-October, when the sample counts were collected. It may be of interest to use this daily estimate to produce an estimate of annual BMT, but this requires knowledge of how bicycle volumes vary throughout the seasons of the year. Such information has been lacking for the Twin Cities region until quite recently, when the City of Minneapolis began collected automatic “vehicle” counts at three locations on the Cedar Lake Trail. A graduate student of the University of Minnesota, Ping-Jui Hsieh, has used these data to estimate monthly and day-of-week factors for 1998, and the estimated factors for Parkway detector are displayed in Table 6 and Table 7. The entries in these two tables are interpreted as multipliers which when applied to the "typical" mean daily traffic give the mean daily traffic for a particular month and day-of-week. For example, the mean daily traffic on a Tuesday in August would be (0.99)(2.49) times greater than the annual mean daily traffic. Estimates for March and April could not be made since no detector data were stored during those months. Interestingly, the day-of-week factors in Table 6 all tend to be very close to 1.0, indicating that the bicycle volumes are not subject to marked day-of-week fluctuations, which supports the decision made in this study to sample bicycle volumes on weekends as well as weekdays. Looking at the monthly factors in Table 7, these can be interpreted as showing that, for instance the daily bicycle traffic in May is 2.75 times greater than what would be typical for the entire year, and supports the view that the estimate of 383754 bicycle-miles per day is greater than what would be typical for the entire year. As a rough correction the average factor for May-June and August-October can be computed as 2.16, and this can then be divided into the daily BMT estimate to give 177664 bicycle-miles of travel on a typical day. Multiplying this by the number of days in the year (365) this gives:

Annual Daytime BMT = 64,847,319 bicycle-miles

for Hennepin, Ramsey and Dakota counties. The standard error can be estimated as

S_{ABMT} = (365/2.16)(69994) = 11,827,690 bicycle-miles

Table 6. Estimated Day-of-Week Factors from Parkway Bicycle Detector

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1.13	0.99	0.99	0.98	0.96	0.92	1.03

Table 7. Estimated Monthly Factors from Parkway Bicycle Detector

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
.15	0.37	NA*	NA*	2.75	2.43	3.28	2.49	2.16	0.98	0.56	0.27

NA – Not Available

Finally, if we assume that the total bicycle travel in Hennepin, Dakota, and Ramsey counties as a fraction of the total travel in the seven-county Metro area is equal to the fraction of the Metro area's total population in these three counties, we can expand the above annual estimate to an estimate for the seven-country area. In particular, the 1990 Census indicates that approximately 80% of the seven-county area's households lives in Hennepin, Ramsey, and Dakota counties. This gives an expansion factor of 1/.8=1.25, and applying this to the annual daytime estimates given above we have

7-county Annual Daytime BMT = (1.25)(64,847,319)=81,059,149 bicycle -miles

with a standard error of

s7BMT=(1.25)(11,827,690)=14,786,613 bicycle -miles.

Chapter 5 SUMMARY AND CONCLUSIONS

The chief objective of this project was to provide a statistically defensible estimate of bicycle-miles of travel for at least a substantial portion of the Twin Cities region, using sample-based procedures similar to those used in estimating vehicle-miles of travel. An ArcView database of the Twin Cities street system developed by The Lawrence Group for the Metropolitan Council provided the initial sampling frame, and this was extended by manually adding information on average annual daily traffic volumes, and on bicycle facilities. Because of time and resource limitations, the extended database could be developed only for Hennepin, Ramsey and Dakota counties, so these three counties comprised the project's study area. A stratified random sample of roadway links was then developed for the study area, where each combination of four roadway link types, and four geographical subareas, made up the sample strata. During the months of May-June, and August-October 1998, the daytime (7 AM to 7 PM) bicycle volume for one day at each sampled site was obtained by first recording the traffic activity on videotape and then manually counting bicycles. Cochrane's "combined" ratio estimator was then used to compute an estimate of average daytime BMT in the study area (383754 bicycle-miles/day) and the estimate's standard error (69994 bicycle-miles/day). Estimates of future sample sizes needed to achieve given levels of precision were then computed, as well as an estimate of annual BMT.

The main conclusion of this work is that, at least in the Twin Cities region, monitoring bicycle-miles of travel using methods similar to those employed for vehicle-miles of travel is now technically feasible. This is especially so since the permanent counters on the Cedar Lake Trail will soon be supplemented by permanent counters on the Midtown Greenway, providing a rudimentary continuous count element.

As was illustrated in Chapter Four, the data from these counters can be used to estimate seasonal and day-of-week adjustment factors, which can in turn be used to adjust short bicycle counts so as to estimate annual volumes and total distance traveled. The chief technical difficulty in implementing a bicycle monitoring program lies in obtaining short counts in a convenient and cost-effective manner. At present it appears that video recording at sample sites provides the best combination of efficient use of personnel and count accuracy, and the video units used in this project can be installed and removed in about the same time as that needed to install or remove a traditional road-tube counter. However, the video units required two people to remove or install them quickly and safely, while a road-tube counter can be installed by one person. In addition, at present manual counting is necessary to extract bicycle volumes from the video tapes and although this counting can generally be done at faster than real-time, it still leads to a substantial inefficiency when compared to the ease at which tube counts can be processed. Current research on using computerized image processing to extract bicycle counts automatically from video may eliminate this bottleneck.

A second conclusion of this work is that a surprising number of procedural and legal obstacles had to be overcome in order to make the sample counts. Unlike the case for standard vehicle traffic monitoring, where generally the roads are owned by the same entity conducting the traffic counts, conducting a video-based bicycle count sample required cooperation and permission from a number of local governments. In addition, permission from a local power company to place the video units on their poles was required as well as clearance from the University's Human Subject's Committee. Admittedly, much of the delay encountered was due to the novelty of the project's requirements, and now that all procedural requirements have been identified, obtaining future permissions and clearances should be much easier. It should be stated also that once the nature of the project's needs was made clear, almost all parties were cooperative and supportive.

The final conclusion concerns the nature of any future bicycle monitoring program. Although in principle it would be possible to compute statewide estimates of bicycle-miles of travel using the methods documented in this report, in practice such an effort is likely to be expensive. Thus rather than using estimates of statewide BMT to monitor progress toward the State Plan's objectives, it is recommended that a small number of representative "indicator areas" be identified, and sampled periodically to estimate their BMT. For example, the study area for this project consisted of Hennepin, Ramsey and Dakota counties, and this area could provide one indicator area. Other areas might be other urbanized areas in the state, along with one or two selected rural counties. Over the course of a three-year counting cycle one or two of the indicator areas might be selected for sampling each year, permitting monitoring the rise (or fall) in bicycle use over time by a small group of personnel assigned exclusively to this task. This would also streamline the procedural requirements, in that once the necessary permissions had been obtained for an indicator area, permissions for subsequent years should be reasonably automatic.

In sum, monitoring bicycle traffic using methods similar to those employed for vehicle traffic is technically feasible, especially for the Twin Cities region where several permanent counters on bicycle trails provide a rudimentary continuous count element. At present accurate short counts of bicycle volume cannot be obtained as easily as vehicle traffic volumes, but a video-based approach appears to be both more accurate and less demanding of personnel than is on-site manual counting. The degree to which bicycle monitoring is continued thus depends on the priority given to obtaining bicycle data.

Appendix A METADATA FOR BICYCLE FACILITIES

Metadata

Bicycle Data for BMT Project

1997

University of Minnesota

Department of Civil Engineering

The following additional fields were added to the street centerline database of the Twin Cities Metropolitan Council for the University of Minnesota research project entitled, *Sample-Based Estimation of Bicycle Miles of Travel.*

Field	Table Name	Field Size	ArcView Field Type	Required for BMT Project	Description/Notes
Name of Street	Street-nam	6	Char	Yes	From the Metropolitan Council's street centerline database. If this field contains "BICYCLE FACILITY," then a new record for the bicycle facility was created in the database (primarily for off-road bicycle facilities). Some on-road facilities were added for roads not found in the street centerline base data (e.g., roads on the U of M campus)
ADT	ADT	6	Num	Yes	Average Annual Daily Traffic • 0 – Roadways < 2000 AADT • 1 – Indicates unmeasurable segment, e.g., intersections (University Ave., for example). Records with ADT=1 on streets and roadways were not used in the BMT sample. • # – ADT for the segment
Bicycle Facility Name	Bk_Name	36	Char	Yes	Name of the bicycle facility, if any (e.g., Cedar Lake Trail). Many facilities are not officially named. For these cases, bicycle facilities were named after surrounding neighborhoods, parks or nearby schools (all or some of which are usually found on community maps). If none of these were found on community maps, a nearby street name was used.
Jurisdiction Name	Bk_Jurisdn	6	Char	Yes	Jurisdiction with the primary responsibility for the facility. • City • CityPk – City Park System • U of M – University of Minnesota • County – County • State – State • Cnty Pks – County Regional Park System. 2 character county identifier appended w/ " Pks" (e.g., Hn Pks, Rm Pks) • Agency – Names of other agencies (e.g., DNR) • Private – Name of privately owned facilities (usually corporate-owned)

Field	Table Name	Field Size	ArcView Field Type	Required for BMT Project	Description/Notes
Subarea Type	Bk_Subarea	3	Str	Yes	Areas judged to be of homogenous use with respect to bicycle use. For the BMT project, reflects roadway network typology, connectivity, and density of roadways and bicycle facilities. • S1 – Urban • S2 – Suburban • S3 – Rural/exurban • S-U – University of Minnesota, Minneapolis campus
General Placement of Facility	Bk_FacLoc	4	Str	Yes	• Blank – Roadway has no bicycle facilities • On – On–road bicycle facility where the facility space is visually or spatially marked. Does not include streets marked only with bicycle route sign. • Off – Off–road bicycle facility where the facility is either horizontally or vertically separate from the roadway. Includes sidewalks if the jurisdiction has specified the sidewalk for bicycle use. • Note – See Bk_#Fac for segments that contain both on-road and off-road bicycle facilities (e.g., City of Champlin). For these cases, Bk_FacLoc = OFF and Bk-#Fac = 4
Number of Facilities in Corridor	Bk_#Fac	1	Num	No	• 0 – Unknown • 1 – Bicycle facility is on one side of the street • 2 – Bicycle facilities are on both sides of the street • 3 – Bicycle facility is in the middle of the street • 4 – Roadway segment has on-road and off-road bicycle facilities. See BK-FacLoc (must be marked OFF for these cases).
Number of Lanes on Facility	Bk_#Lanes	1	Num	No	Indicates number of lanes in the corridor space. Number of lanes on the facility = • 0 – Unknown • # – Number of lanes • Note – Includes both sides of street; e.g., if Bk_#Fac=2 and each are 1 lane wide, then Bk_#Lanes=2.
Direction of Traffic	Bk_Oneway	1	Num	No	Indicates types of permitted directional traffic flow in the corridor space. Facility is designed to accommodate: • 1 – One–way traffic only • 2 – Two–way traffic • Note – If Bk_#Fac=2 and both lanes go in opposite directions, then Bk_Oneway=2
Facility Width	Bk_Width	3	Num precision: 1	No	Width of facility. • 0 – Unknown • # – Width

Field	Table Name	Field Size	ArcView Field Type	Required for BMT Project	Description/Notes
Segment Length	Bk_Length	13	Num precision: 6	No	Length of segment in feet. For all on–road facilities and for off–road facilities that parallel a roadway, Bk_Length=Length. Length is provided in street centerline base data. Must convert to miles for BMT estimate.
Type of Use	Bk_FacUse	8		No	This field describes the traffic environment on the bicycle facility • Blank – Unknown • PavShld – Paved shoulder. Cyclists usually have sole use of the facility, except for occasional stalled vehicles, buses, etc. • Bk Only – Bicycle only. The facility is designated bicycle–only and functions as bicycle only (i.e., in reality, there is little other use such a pedestrian, rollerblade, etc.) • On Str – On–street bicycle facility. Indicates the cyclist may at times share the facility space with motor vehicles and even pedestrians. • Sidewalk – Sidewalk is designated as bicycle facility. Indicates the cyclist may share the facility space with pedestrians. • Bike/Ped – Facility is designated or used primarily as bicycle/pedestrian • Incl Rec – Includes recreational use. This kind of space is used by cyclists and other non–motorized modes (e.g., Pedestrians (adults and children) rollerbladers, skateboarders, and recreational or racing bicycle use.)
Surface	Bk_Surface	4	Str	No	Surface of facility • Conc – Concrete • Asph – Asphalt • Grav – Gravel
BMT Identifier	Bk_sub_id	16	Num	Yes	These identifiers are assigned (starting with 1), in each of the 16 subarea/type categories used in the BMT project (e.g., S1 on, S1 off, S1 <5000, S1 ≥ 5000, S2 on, S2 off, etc.). For future research, identifiers can be extended per category or created anew.

Because of the size of the database, a separate file (database) was created to hold the records for the count sites. These fields in this file are the same as those found in the larger database with the following fields added.

Field	Table Name	Field Size	ArcView Field Type	Required for BMT Project	Description/Notes
12 Hour Counts	98_12hr_co	4	Num	Yes	Bicycle count for a 12-hour period from 7 AM to 7PM.
Day Counts	98_Day co	4	Num	No	Bicycle count from sunrise to sunset. (Length of count period depends on time of year.)
Pick Number	Pick_#	4	Num	Yes	The order in which the count site was selected using a random number generator.

Appendix B PROJECT MANAGEMENT FORMS

Note:
It is recommended that section 3.6.6, Scheduling and Management be reviewed to better understand the use of these forms.

B-1. General Permission Form

The following is the general permission form sent to jurisdictions for permission to install traffic video equipment in their jurisdiction. A few amended this general agreement to meet additional needs or concerns. Also included with this form were a one page description of the project, a two page description of the equipment (along with photos and diagrams), the list of randomly selected sites and a cover letter.

Statement of Permission

For the U of M research project

Sample-Based Estimation of Bicycle Miles of Travel

The University of Minnesota and its designated representatives have permission from

______________________________ ***Name of Jurisdiction*** to install video taping equipment within our jurisdiction in the summer and fall of 1998 for purposes of counting bicycles for the Mn/DOT research project, *Sample Based Estimation of Bicycle Miles of Travel*, with the following stipulated conditions:

1. Our jurisdiction reserves the right to reject any location found on the site lists, labeled "Primary Sites" and "Alternate Sites," and forwarded to us by the University;
2. Our jurisdiction assumes no responsibility for loss or damage to project equipment attached to our poles;
3. No equipment will be mounted on traffic signals without permission from the Traffic Operations Engineer;
4. Any damage to our facilities caused by the research project's equipment installation will be repaired and billed to the responsible party.

______________________________ *Signature*

______________________________ *Print Name*

______________________________ *Title*

______________________________ *Department*

B-2. Explanatory Label

It is highly recommended that a label similar to the following be taped to the video recording equipment. Passersby and neighbors can be curious as to the use of the equipment. A label such as this can forego inquiries to either the police or the researchers regarding the use of the equipment.

University of Minnesota

And

Mn/DOT

Bicycling Research Project

For the Twin Cities Metropolitan Area

Sample-Based Estimation of Bicycle Miles of Travel

B-3. Master Key

Since the street centerline database was structured according to county, it was necessary to keep all three counties in separate database files throughout the project. The following is a master key showing how unique identifiers were assigned for each of the 16 categories (16 subarea/facility type pairs) in each of the three counties (see section 3.6.3, Sample Selection).

Summer 1998
Master Key
(of identifiers)
Sample-Based Estimation of Bicycle Miles of Travel

		Dakota	Hennepin	Ramsey
S1	**On**	*1-2**	*3-282*	*283-498*
	Off	*1-24*	*25-493*	*494-742*
	<5000 ADT	*1-1404*	*1405-19109*	*19110-27389*
	^{3}5000 ADT	*1-231*	*232-4014*	*4015-6141*
S2	**On**	*1-386*	*387-916*	*917-1526*
	Off	*1-1081*	*1082-4355*	*4356-5579*
	<5000 ADT	*1-9793*	*9794-27569*	*27570-34790*
	^{3}5000 ADT	*1-1039*	*1040-2860*	*2861-3525*
S3	**On**	*1-149*	*150-186*	
	Off	*1-113*	*114-170*	
	<5000 ADT	*1-2741*	*2742-5229*	
	^{3}5000 ADT	*1-250*	*251-461*	
SU	**On**	*1-48*		
	Off	*1-28*		
	<5000 ADT	*1-172*		
	^{3}5000 ADT	*1-79*		

* Numbers in italics are the identifiers assigned by the BMT project

B-4. Master Site Selection Sheet

The following is the list of randomly selected sites for each of the 16 categories in the BMT project. This list was marked up and used by the project manager to keep track of sites that needed to be counted. It was also used to delete sites that were rejected and then to select the next random choice for counting. (Only the first page of randomly selected sites is shown here.)

If set up as a table, the random number generator in Excel 97 will create the randomly selected sites as a table like the following. The number of picks in each category (e.g., S1 on, S1 off) will equal the total number of ids assigned for that category (e.g., S1 On = 498 picks; S1 Off = 742 picks).

Also see Appendix B-3, Master key.

Summer 1998

(Example of)

Randomly Selected Count Sites

Sample-Based Estimation of Bicycle Miles of Travel

Pick#	***Urban Subarea & Facility Type***				***Suburban Subarea & Facility Type***				***Rural Subarea & Facility Type***				***University Subarea & Facility Type***			
	S1-On	S1-Off	S1<5000	S1-5000+	S2-On	S2-Off	S2<5000	S2-5000+	S3-On	S3-Off	S3<5000	S3-5000+	SU-On	SU-Off	SU<5000	SU5000+
1	348	190	10629	1505	484	4844	3386	712	98	142	1372	335	12	25	4	43
2	481	143	6465	2203	45	1698	9734	2423	104	21	1211	318	43	11	148	25
3	262	495	5959	5302	329	5507	5946	326	2	146	1873	223	21	4	19	49
4	14	205	1046	5410	301	3108	7646	3013	100	23	1039	217	28	16	145	51
5	104	220	12793	635	248	3749	31676	2230	103	76	3238	264	20	5	1	3
6	198	654	2839	1676	57	3175	26346	2016	95	147	2436	141	46	5	131	76
7	333	328	5311	3204	1471	3088	13170	1040	122	118	3900	347	29	25	148	33
8	423	18	18677	3315	725	5126	32314	2428	181	89	3518	333	28	6	58	2
9	135	104	21106	5547	1271	2732	28137	553	58	37	806	92	37	9	169	41
10	339	434	16916	4628	1340	1639	1150	9	85	160	3131	61	42	11	165	51
11	146	702	5262	4789	1469	5028	23439	3346	16	168	2750	6	10	9	97	41
12	410	413	18249	4799	106	2721	2684	218	87	167	3912	117	26	21	159	78
13	371	183	24866	4478	1251	5563	24062	1989	121	22	3989	14	3	20	146	44
14	391	376	10434	5407	1237	3207	32280	83	121	16	841	116	20	26	122	66
15	245	574	10653	4046	1107	1961	9333	61	52	67	289	207	47	28	66	70
16	67	496	20388	4499	839	27	33486	3025	45	62	2315	70	34	14	98	67
17	450	53	13504	3826	602	1024	20604	1619	71	40	5216	120	21	7	156	23
18	171	679	23490	4908	103	1014	28914	3382	138	42	232	105	33	20	115	13
19	123	298	7562	478	1210	2415	8773	2688	127	10	1485	379	47	1	130	78
20	407	56	16147	2655	1410	5578	33153	1205	101	165	815	167	1	3	143	4
21	385	726	1780	2587	8	2754	16709	757	108	8	4207	235	38	1	98	20
22	183	482	9820	3244	1454	3425	24302	780	15	9	3426	248	25	25	140	50
23	158	108	2156	5684	958	1401	20032	3222	118	150	3504	155	39	5	143	69
24	278	184	5599	1781	227	746	19708	3408	68	17	3689	431	22	19	92	20
25	489	500	20534	2584	509	2084	2703	1834	35	7	736	343	39	15	90	71
26	7	563	25553	1006	227	4035	31935	1908	173	163	195	385	9	26	78	30
27	312	532	15740	5476	994	362	27187	485	60	91	3557	218	44	26	145	38

Numbers within the table are the identifiers for roadway and bicycle facility segments. The numbers were created by a random number generator.

B-5. Examples of Site Sheets and Site Maps

Site sheets and site maps are used in the field to find the roadway segment and to record information about the site onto the installation sheet. It is not advisable to make up all site sheets and site maps too far in advance. For reasons explained in section 3.6.6, sites can be rejected in the field (and therefore, new ones added), equipment can malfunction or other problems can prevent a predetermined cluster of sites from being counted when scheduled. Therefore, the set of sites that remain to be counted changes often. So, to avoid confusion in the field, it is necessary to frequently update the site sheets and the site maps with current information.

It has been the experience of the BMT project, that site sheets and site maps which are used more than four days in the field become too confusing with notations of which sites have been counted and which sites have not. Thus, remaking the site sheet and site maps with current information is advisable.

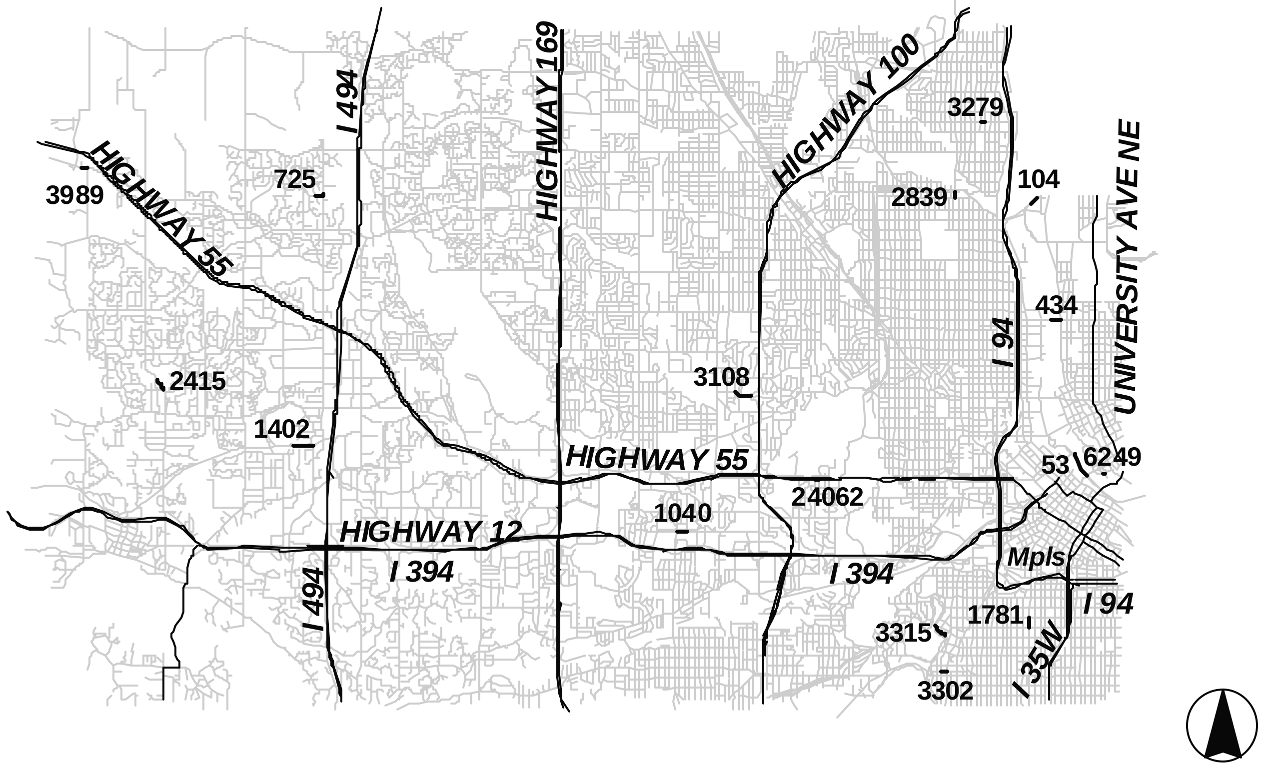
Summer 1998
SITE SHEET
Sample-Based Estimation of Bicycle Miles of Travel

Project Manager Name & Phone Number

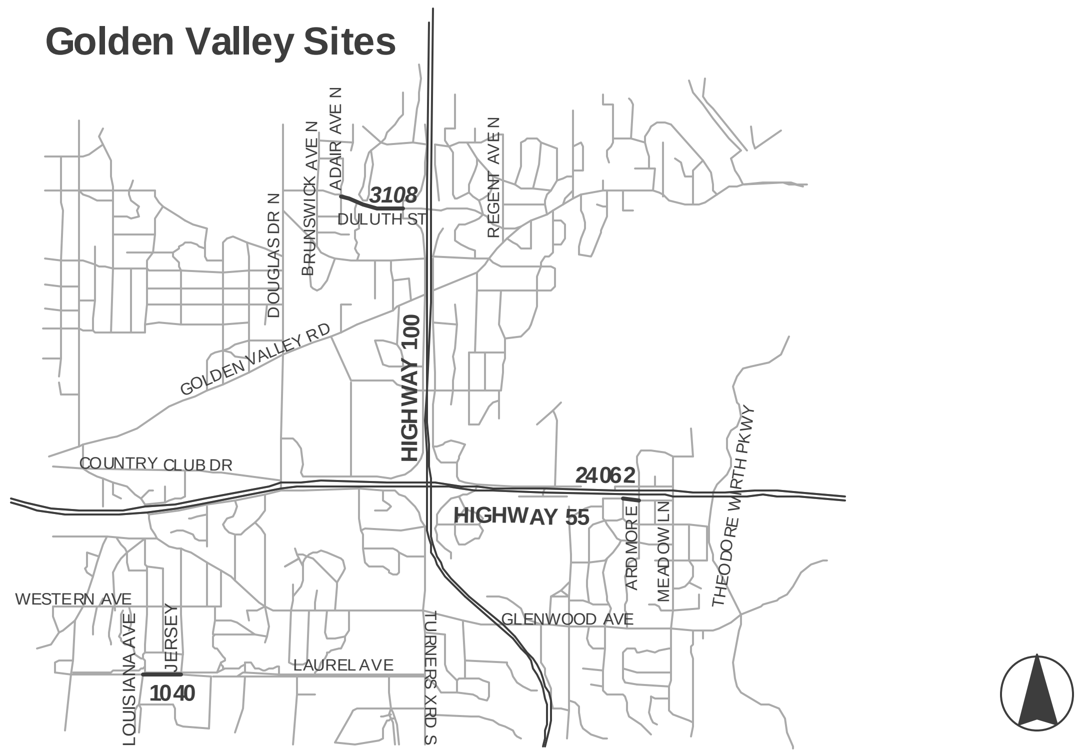
Addr1	Addr2	Street Name	Alternate Street Name	Bicycle Facility Name	City	Subarea	Type	ADT	ID#
0	4239	Hwy 55 Service Rd			Golden Valley	S2		0	24062
1	90	Hamel Rd			Medina	S3		0	3989
1925	2098	County Rd 101 N		County Rd 101 N	Plymouth	S2	OFF		2415
0	0	Bicycle Facility		West River Rd	Minneapolis	S1	OFF		53
901	998	52nd Ave. N.			Minneapolis	S1		0	3279
1	44	Merriam St.			Minneapolis	S1		0	6249
2401	2498	Blaisdell Ave			Minneapolis	S1		7600	1781
1501	1598	Lagoon Ave			Minneapolis	S1		16500	3302
4401	4498	Humboldt Ave N	Cnty Rd 57		Minneapolis	S1		0	2839
6841	6998	Laurel Ave			Golden Valley	S2		6100	1040
0	2601	Lake of the Isles Pkwy E			Minneapolis	S1		6800	3315
5701	5898	Duluth St	Cnty Rd 66	Duluth St	Golden Valley	S2	OFF		3108
1	32	Lowry Ave NE	Cnty Rd 153	Lowry Ave NE	Minneapolis	S1	OFF		434
0	0	Bicycle Facility		37th Ave. NE	Minneapolis	S1	OFF		104
14301	14404	44th Ave N		44th Ave N	Plymouth	S2	ON		725
0	0	Bicycle Facility		Luce Line Trail	Plymouth	S2	OFF		1402

General Site Map

Golden Valley, Plymouth & N. Minneapolis Sites



Detailed Site Map



B-6. Installation Sheet

Installation sheets, shown on the next page, are filled out in the field to keep track of when and which cameras were installed at each site.

Summer 1998

EQUIPMENT INSTALLATION RECORD

Sample-Based Estimation of Bicycle Miles of Travel

Project Manager Name & Phone Number

	Date		**Time**							
TAPE#	**IN**	**OUT**	**ON**	**OFF**	**CAM #**	**LOCATION**	**CITY**	**SUB AREA**	**TYPE***	**ID#**

* Type = ON
OFF
<5000
≥5000

B-7. Count Sheet

An example of the sheet used to keep track of the counts taken from videotape is found on the next page. Research assistants found it convenient and more accurate to stop every fifteen minutes to record the count. It was also simple to record the weather seen during the fifteen-minute count period. Both of these additional recordings can provide information beyond BMT, regarding daily fluctuations and weather on bicycle use.

Subarea	Type*	ID#

Summer 1998

BICYCLE COUNT WORKSHEET

Sample-Based Estimation of Bicycle Miles of Travel

Count Date ______________________ Jurisdiction ______________________________
Include Day

Location ____

Start Time ____________________ End Time ____________________ Tape # ________

Counted By ____ Total ________

Note when darkness occurs in margin

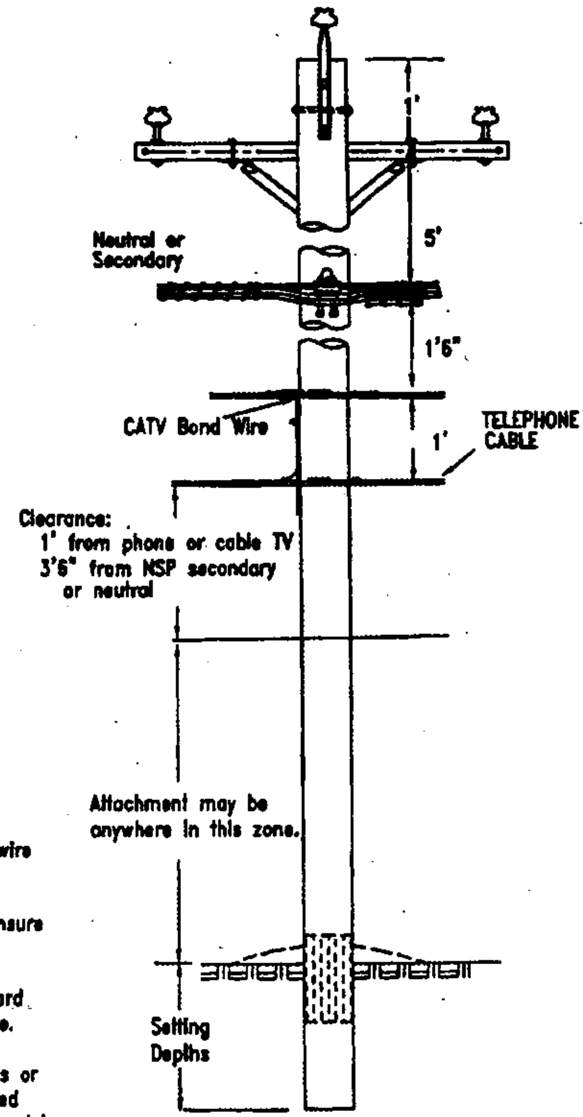
Date	Interval Begin	Interval End	Count	Weather Notes
	05:30	:45		
	:45	6:00		
	06:00	:15		
	:15	:30		
	:30	:45		
	:45	7:00		
	07:00	:15		
	:15	:30		
	:30	:45		
	:45	8:00		
	08:00	:15		
	:15	:30		
	:30	:45		
	:45	9:00		
	09:00	:15		
	:15	:30		
	:30	:45		
	:45	10:00		
	10:00	:15		
	:15	:30		
	:30	:45		
	:45	11:00		
	11:00	:15		
	:15	:30		
	:30	:45		
	:45	12:00		
	12:00	:15		
	:15	:30		
	:30	:45		
	:45	P 1:00		
	13:00	:15		
	:15	:30		

Date	Interval Begin	Interval End	Count	Weather Notes
	13:30	:45		
	:45	2:00		
	14:00	:15		
	:15	:30		
	:30	:45		
	:45	3:00		
	15:00	:15		
	:15	:30		
	:30	:45		
	:45	4:00		
	16:00	:15		
	:15	:30		
	:30	:45		
	:45	5:00		
	17:00	:15		
	:15	:30		
	:30	:45		
	:45	6:00		
	18:00	:15		
	:15	:30		
	:30	:45		
	:45	7:00		
	19:00	:15		
	:15	:30		
	:30	:45		
	:45	8:00		
	20:00	:15		
	:15	:30		
	:30	:45		
	:45	9:00		
	21:00	:15		
	:15	:30		

Type = On; Off; <5000; or if >5000, record actual ADT

Appendix C POWER COMPANY REQUIREMENTS

Exhibit B



NOTES:

1. Attachment must be below lowest wire by distances listed in drawing.
2. Mount 3'6" below lowest wire if unsure of type of wire.
3. Do not attach to poles with U-Guard or conduits running down the pole.
4. Unit may be mounted on fiberglass or aluminum streetlight poles, provided finish on pole is protected from metal bands with appropriate material between band and pole.

VIDEO TRAFFIC SURVEY

NORTHERN STATES POWER COMPANY DELIVERY SYSTEM MANUAL	DRAWN G. SUPPES	APPROVED	FILE CLR-2T	DATE 7/98	OVERHEAD DISTRIBUTION NSP Page CLR-2T

Appendix D PROTECTION OF HUMAN SUBJECTS

The observation of public behavior is regulated by federal policy. Failure to obtain permission to observe human behavior as part of a research project can terminate the research even if all data is collected. The BMT project found that our methods fell within acceptable policy guidelines as described in section 3.6.4.

The following is University of Minnesota policy:

> University of Minnesota and federal policies require that research involving human subjects be reviewed to take into consideration:
>
> 1.The rights and welfare of the individual(s);
>
> 2.The appropriateness of the method(s); and
>
> 3.The balance of risks and potential benefits of the investigation.

These websites are recommended for understanding federal policy regarding human subjects and the observation of public behavior.

Research Subject Protection Program
http://www.research.umn.edu/subjects/index

Protecting Human Subjects Guide: How to Apply for Review
http://www.research.umn.edu/subjects/humans/guide/humans3

Office of Human Subjects Research at the National Institutes of Health
http://ohsr.od.nih.gov

Appendix E BICYCLE COUNTS AND LOCATIONS

BICYCLE COUNTS AND LOCATIONS

Addr1	***Addr2***	***Street Name***	***Alternate Name***	***City***	***Name of Bicycle Facility***	***Facility Location***	***ADT***	***12hr Count '98***
0	0	Diamond Path	Cnty Rd 33	Apple Valley	Diamond Path	On	4700	10
11711	11670	River Hills Dr W		Burnsville	River Hills Dr W	On	0	32
11703	11618	River Hills Dr		Burnsville	River Hills Dr	On	0	9
414	301	Southcross Dr W		Burnsville	Southcross Dr W	On	6800	8
14025	13986	County Rd 11		Burnsville	County Rd 11	Off	7700	44
1201	1310	131st St E		Burnsville			0	7
12999	12806	Nicollet Ave		Burnsville			17500	31
2350	0	Highway 13 E		Burnsville			23000	7
24998	24001	Chippendale Ave W	Hwy 3	Castle Rock Twp	Chippendale Ave W	On	4400	7
913	964	Wescott Rd		Eagan	Wescott Rd	Off	7800	96
5502	5559	Willson Rd		Edina			0	4
3899	3790	58th St W		Edina			0	47
6213	6200	Tracy Ave		Edina			7700	46
7731	7600	Parklawn Ave		Edina			10000	14
5445	5400	France Ave S	Cnty Rd 17	Edina			14500	36
5899	5800	Xerxes Ave S	Cnty Rd 31	Edina/Mpls			12300	20
19698	19401	Chippendale Ave W	Hwy 3	Empire Twp	Chippendale Ave W	On	6200	11
20798	20501	Colorado Ave		Empire Twp	Colorado Ave	Off	0	52
5700	5899	Duluth St	Cnty Rd 66	Golden Valley	Duluth St	Off	15300	13
4373	0	Hwy 55 Service Rd		Golden Valley			0	1
7071	6882	Laurel Ave		Golden Valley			6100	13
0	0	Bicycle Facility		Greenfield	Lk Rebecca Pk Reserve	Off	0	66
0	0	Bicycle Facility		Greenfield	Lk Rebecca Pk Reserve	Off	0	103
100	0	Highway 55		Hastings			13800	0
7598	7567	Boyd Ave E		Inver Grove Hghts			0	53
17297	17498	Jersey Way		Lakeville			0	4
872	831	Mcknight Rd S	Cnty Rd 68	Maplewd/St Paul	Mcknight Rd S	On	4900	15
1960	1969	Larpenteur Ave E	Cnty Rd 30	Maplewood	Larpenteur Ave E	On	8600	20
2640	2719	White Bear Ave	Cnty Rd 65	Maplewood			24500	38

BICYCLE COUNTS AND LOCATIONS

Addr1	***Addr2***	***Street Name***	***Alternate Name***	***City***	***Name of Bicycle Facility***	***Facility Location***	***ADT***	***12hr Count '98***
0	0	Bicycle Facility		Medina	Baker Pk Reserve	Off	0	21
0	0	Bicycle Facility		Medina	Baker Pk Reserve	Off	0	171
0	0	Bicycle Facility		Medina	Baker Pk Reserve	Off	0	233
4368	4399	Willow Dr		Medina			0	2
3500	4099	Arrowhead Dr		Medina			0	0
1999	1800	Ridge Dr S		Medina			0	0
945	840	Foxberry Farms Rd		Medina			0	17
73	2	Hamel Rd		Medina			0	1
1600	2099	Highway 55		Medina			15800	7
800	1199	Olson Memorial Hwy	Hwy 55	Medina			17700	2
2582	2551	Delaware Ave	Cnty Rd 63	Mendota Heights			2900	33
1199	1100	5th St Se		Minneapolis	5th St Se	On	0	419
1098	1001	2nd St S		Minneapolis	2nd St S	On	0	143
899	800	5th St Se		Minneapolis	5th St Se	On	0	467
673	698	10th St S		Minneapolis	10th St S	On	0	72
200	299	Harvard St Se		Minneapolis	Harvard St Se	On	0	154
599	500	20th Ave S		Minneapolis	20th Ave S	On	5600	452
4399	4300	Minnehaha Ave	Cnty Rd 48	Minneapolis	Minnehaha Ave	On	6700	47
1799	1700	Park Ave	Cnty Rd 33	Minneapolis	Park Ave	On	9500	193
401	498	10th St S		Minneapolis	10th St S	On	9600	131
960	999	15th Ave Se		Minneapolis	15th Ave Se	On	9800	1054
398	301	4th St S		Minneapolis	4th St S	On	10100	56
4067	4000	Minnehaha Ave	Cnty Rd 48	Minneapolis	Minnehaha Ave	On	10200	35
499	400	University Ave Se		Minneapolis	University Ave Se	On	12600	153
851	800	University Ave Se		Minneapolis	University Ave Se	On	15300	401
600	699	15th Ave Se		Minneapolis	15th Ave Se	On	15300	968
1599	1500	University Ave Se	Cnty Rd 36	Minneapolis	University Ave Se	On	16500	468
1699	1600	4th St Se	Cnty Rd 37	Minneapolis	4th St Se	On	19500	193
999	960	University Ave Se	Cnty Rd 36	Minneapolis	University Ave Se	On	21500	801

BICYCLE COUNTS AND LOCATIONS

Addr1	Addr2	Street Name	Alternate Name	City	Name of Bicycle Facility	Facility Location	ADT	12hr Count '98
959	852	University Ave Se		Minneapolis	University Ave Se	On	21500	837
0	0	Bicycle Facility		Minneapolis	U Of M Transitway	Off	0	256
0	0	Bicycle Facility		Minneapolis	Minnehaha Creek	Off	0	355
0	0	Bicycle Facility		Minneapolis	Lake Harriet	Off	0	2382
0	0	Bicycle Facility		Minneapolis	U Of M - West Bank	Off	0	541
0	0	Bicycle Facility		Minneapolis	37th Ave Ne	Off	0	65
0	0	Bicycle Facility		Minneapolis	U Of M - West Bank	Off	0	911
0	0	Bicycle Facility		Minneapolis	U Of M - West Bank	Off	0	1018
0	0	Bicycle Facility		Minneapolis	U Of M - East Bank	Off	0	688
0	0	Bicycle Facility		Minneapolis	Minnehaha Creek	Off	0	750
0	0	Bicycle Facility		Minneapolis	West River Rd	Off	0	261
0	0	Bicycle Facility		Minneapolis	River Pkwy W	Off	0	144
799	0	River Rd E		Minneapolis	River Rd E	Off	4800	233
739	0	River Rd E		Minneapolis	River Rd E	Off	4800	572
699	0	River Rd E		Minneapolis	River Rd E	Off	4800	471
299	0	River Rd E		Minneapolis	River Rd E	Off	4800	97
0	3850	River Pkwy W		Minneapolis	River Pkwy W	Off	6200	406
0	3800	River Pkwy W		Minneapolis	River Pkwy W	Off	6200	760
2	33	Lowry Ave Ne	Cnty Rd 153	Minneapolis	Lowry Ave Ne	Off	13100	74
4400	4499	Humboldt Ave N	Cnty Rd 57	Minneapolis			0	40
5899	5824	Thomas Ave S		Minneapolis			0	4
2599	1100	Essex St Se		Minneapolis			0	53
2499	2300	4th St Se		Minneapolis			0	32
2198	2145	1st St S		Minneapolis			0	55
1001	1098	48th St E		Minneapolis			0	38
999	928	8th St Se		Minneapolis			0	384
999	900	52nd Ave N		Minneapolis			0	28
914	999	23rd Ave Se		Minneapolis			0	9
815	800	Huron St Se		Minneapolis			0	47

BICYCLE COUNTS AND LOCATIONS

Addr1	***Addr2***	***Street Name***	***Alternate Name***	***City***	***Name of Bicycle Facility***	***Facility Location***	***ADT***	***12hr Count '98***
700	799	9th Ave Se		Minneapolis			0	54
698	601	Godward St Ne		Minneapolis			0	8
599	500	7th Ave Se		Minneapolis			0	93
500	0	9th Ave Se		Minneapolis			0	86
499	450	21st Ave S		Minneapolis			0	374
199	100	2nd St Se		Minneapolis			0	72
199	0	East River Rd		Minneapolis			0	238
43	2	Merriam St		Minneapolis			0	137
0	4850	Lake Harriet Pkwy W		Minneapolis			4600	88
2901	2962	Stinson Blvd	Cnty Rd 27	Minneapolis			6100	21
1299	1200	Como Ave Se		Minneapolis			6300	212
3501	3598	42nd St E		Minneapolis			6600	118
1000	1077	Fulton St Se		Minneapolis			6600	57
800	899	Fulton St Se		Minneapolis			6600	136
150	199	Pleasant St Se		Minneapolis			6700	901
2667	0	Lk Of The Isles Pkwy E		Minneapolis			6800	484
2499	2400	Blaisdell Ave		Minneapolis			7600	132
3999	3900	Nicollet Ave	Cnty Rd 52	Minneapolis			9500	63
2117	2000	University Ave Se	Cnty Rd 36	Minneapolis			9800	116
784	799	10th Ave Se		Minneapolis			10300	69
1000	1029	Washington Ave Se	Hwy 122	Minneapolis			11000	163
900	999	Washington Ave Se	Hwy 122	Minneapolis			11000	469
427	400	19th Ave S		Minneapolis			13000	399
0	0	20th Ave S		Minneapolis			15400	256
1801	1824	Central Ave Ne	Hwy 65	Minneapolis			16000	98
1500	1599	Lagoon Ave		Minneapolis			16500	120
1099	1000	4th St Se	Cnty Rd 37	Minneapolis			20000	411
8399	8130	County Rd 110 W		Minnetrista	County Rd 110 W	On	0	6
4238	4201	County Rd 44		Minnetrista	County Rd 44	On	0	6

BICYCLE COUNTS AND LOCATIONS

Addr1	*Addr2*	*Street Name*	*Alternate Name*	*City*	*Name of Bicycle Facility*	*Facility Location*	*ADT*	*12hr Count '98*
6999	6800	County Rd 110 W		Minnetrista	County Rd 110 W	On	2100	11
514	401	County Rd 110 N		Minnetrista			2400	10
998	801	County Rd 110 N		Minnetrista			6300	24
7400	7999	Highway 7		Minnetrista			10900	6
6779	6700	County Rd 110 W	Cnty Rd 110 W	M'trista/Mound	County Rd 110 W	On	2100	1
6699	6520	Bartlett Blvd	Cnty Rd 110 W	M'trista/Mound	Bartlett Blvd	On	2100	12
798	401	North Shore Dr W	Cnty Rd 19	M'trista/Orono			5000	21
2798	2843	Helen St	Cnty Rd 70	North St Paul	Helen St	On	2200	7
2349	2300	7th Ave	Cnty Rd 29	North St Paul	7th Ave	On	5300	18
2798	2811	Mcknight Rd	Cnty Rd 68	North St Paul	Mcknight Rd	On	10500	42
0	2193	Division St N		North St Paul			12000	13
2256	2399	6th Ave N	Cnty Rd 6	Orono	6th Ave N	On	5700	24
0	0	Bicycle Facility		Orono	Luce Line Trail	Off	0	278
1262	1201	North Arm Dr	Cnty Rd 151	Orono			0	16
2336	2329	Shadywood Rd	Cnty Rd 19	Orono			5600	78
2198	2091	Shadywood Rd	Cnty Rd 19	Orono			5600	46
1200	1375	6th Ave N	Cnty Rd 6	Orono			5700	47
1704	1601	Shadywood Rd	Cnty Rd 19	Orono			6900	47
14405	14300	44th Ave N		Plymouth	44th Ave N	On	0	0
0	0	Bicycle Facility		Plymouth	Luce Line Trail	Off	0	134
1924	2099	County Rd 101 N		Plymouth	County Rd 101 N	Off	12000	39
29698	29301	Randolph Blvd	Hwy 56	Randolph	Randolph Blvd	On	0	0
28998	28501	Dickman Ave	Cnty Rd 83	Randolph			0	2
0	0	Bicycle Facility		Richfield	Roosevelt Pk	Off	0	2
6749	6700	Stevens Ave		Richfield			0	2
6749	6726	Lyndale Ave S		Richfield			12300	87
6349	6300	Lyndale Ave S		Richfield			17500	75
12358	12235	Robert Trl S	Hwy 3	Rosemount	Robert Trl S	On	8800	17
13248	13101	Shannon Pkwy		Rosemount	Shannon Pkwy	Off	0	29

BICYCLE COUNTS AND LOCATIONS								
Addr1	***Addr2***	***Street Name***	***Alternate Name***	***City***	***Name of Bicycle Facility***	***Facility Location***	***ADT***	***12hr Count '98***
0	0	Shannon Pkwy		Rosemount	Shannon Pkwy	Off	3450	80
3998	3501	150th St W	Cnty Rd 42	Rosemount	150th St W	Off	20000	67
4384	4355	Upper 145th St W		Rosemount			0	14
2888	2915	Rice St	Hwy 49	Rosev/Lit.Canada			16000	63
0	0	Bicycle Facility		Roseville	Bennett Lk	Off	0	19
2400	2535	Fairview Ave N	Cnty Rd 48	Roseville	Fairview Ave N	Off	15000	39
1478	1459	Commerce St		Roseville			0	4
651	678	Mound Ave		Shoreview	Mound Ave	Off	0	59
1024	725	County Rd I W	Cnty Rd 3	Shoreview	County Rd I W	Off	5400	37
244	233	Nichols Ct		Shoreview			0	21
0	0	Bicycle Facility		South St Paul	S St Paul River Trail	Off	0	11
3730	3809	Edgerton St		Vadnais Heights	Edgerton St	On	2350	30
0	0	Bicycle Facility		Vadnais Heights	Lk Vadnais	Off	0	128
701	624	Hiawatha Ave		Vadnais Heights			0	14
16998	16501	Emery Ave		Vermillion Twp			0	0

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[17] This area of the University of Minnesota has been the subject of a number of surveys and counts on bicycle use, all indicating high bicycle use compared to non-University areas of the region. One 2-day, ad-hoc, bicycle count taken in the fall of 1994 in the heart of the University of Minnesota's largest campus (East Bank in Minneapolis) showed that on the measured days, 10-21% of all vehicles on the count streets were bicycles. The data for this count is reported in The University of Minnesota Bicycle Transportation Plan, 1996

[18] Ibid, p. 32.

[19] Ibid, p. 34.

[20] Reference in Guide to Urban Traffic Volume Counting, Preliminary as follows:
Crow, Edwin L., Davis, Francis A., and Maxfield, Margaret, (1960). Statistics Manual, Dover Publications Inc., New York. See Chart IX, p. 277.

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[27] DOQs are aerial photographs that have been adjusted to account for the curvature of the earth. DOQs make it possible to accurately scale (measure length on) aerial photographs. In other words, DOQs are like maps because a measurement taken on a DOQ will equal the same measurement taken on a map of the same scale. This is not true of aerial photographs.

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