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Public transportation accessibility of San José State University : Fall 2004

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PUBLIC TRANSPORTATION ACCESSIBILITY OF

SAN JOSÉ STATE UNIVERSITY – FALL 2004

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ABSTRACT

PUBLIC TRANSPORTATION ACCESSIBILITY OF SAN JOSÉ STATE UNIVERSITY – FALL 2004

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San José State University (SJSU) students pay a fee to get unlimited rides on Valley Transportation Authority buses and light rail but only 21% of them are using public transportation. The aim of this thesis is to develop a methodology that will find the level of accessibility of SJSU, and to determine if the percentage of transit users could be increased and by how much. Accessibility is defined in terms of the ease of movement between two places: SJSU Campus and each student's home. The variables needed to calculate accessibility include the distance between the student's home addresses and the nearest stop; if the students can take transit depending on their class schedules and the availability of transit at the moment that is required; and the amount of time spent on the commute. The results reveal that the percentage of accessibility and the number of students using transit is equal.

Dedicated to

my husband, Enrique

my parents, Julio & Nora

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CHAPTER I

INTRODUCTION

At San José State University (SJSU), promoting alternative forms of transportation among the campus community is the objective of Transportation Solutions Center (TS). The University requires that all regular full- or part-time students pay "mandatory fees" when registering for classes. After the Associated Students fees are paid, which include the transportation charge, students get an EcoPass sticker that validates the student ID card and allows them to take unlimited rides on Valley Transportation Authority (VTA) buses and light rail in Santa Clara County for six months. Open University students, faculty, and staff can also get a sticker at a charge.

Knowing which students could be using transit instead of driving to the university would be especially helpful for the Transportation Solutions Center at SJSU. In order to fulfill its work, this office uses, among others, two tools: a yearly survey to measure the usage of public transportation, and the "direct transit analysis" which estimates the percentage of students who could be taking transit. This analysis uses a half-mile buffer around the express or limited stops and light rail stations and a quarter-mile buffer along the direct bus routes to SJSU. The students living inside the buffers receive an e-mail or letter to let them know which bus routes or light rail they could take to go to the University. The direct transit analysis can be improved by adding time constraints (individual class times, bus and light rail schedules) and using only the stops or stations to create the buffers, because these are the places where people can actually board buses or light rail.

According to the online survey elaborated by TS, the percentage of students taking advantage of the EcoPass was 21.23% in Fall 2004 and 17.68% in Fall 2003, as illustrated in Table 1.1. Having these percentages as a base line, the purpose is to find out if the amount of students taking transit could increase and by how much. After geocoding student addresses, mapping bus stops, routes, and light rail stations to perform various analyses, as well as being users of public transit in Santa Clara County, the concept of accessibility required exploration.

Table 1.1 Transportation mode to travel to/from SJSU

	Fall 2003		**Fall 2004**	
	Percentage	Subtotals	Percentage	Subtotals
Express bus 180 (VTA) only	0.57%		0.68%	
Bus (VTA)	8.15%		10.95%	
Light rail (VTA)	8.96%		9.60%	
VTA Transit		**17.68%**		**21.23%**
Carpool with other SJSU students or employees	5.67%		5.91%	
Drive alone	51.48%		47.41%	
Drive to park & ride lot and take SJSU Shuttle	4.72%		4.87%	
Driving		**61.87%**		**58.19%**
Other		**20.45%**		**20.57%**
Totals		**100.00%**		**100.00%**

An accessibility analysis would measure how well served the SJSU students are, depending on the number of direct lines they can take to go to the University, the number of required connections to other bus routes or the light rail, and the frequency of busses passing through the bus stops closer to their origins or destinations. The study would require comparing how much time it will take for somebody to go from home to SJSU (and come back!) on the weekdays, during the daytime, in the evening, or at night. In Chapter II accessibility and other concepts will be reviewed in order to evaluate the performance of a transportation system. The need is to obtain a reasonable measurement of accessibility that could be found with a simple methodology. This method should include variables like distance between the students' homes and the nearest bus stop or station, class schedules, bus and light rail timetables, and the amount of time spent on the commute.

Many students approach the Transportation Solutions Center with their home addresses and their class schedules to find out if taking transit would be an option for them. The idea is to answer that question not just for one student, but for the whole student population at once. Hence our target population is the students registered at SJSU for Fall 2004, who live in California and have at least one class between Monday and Thursday. The analysis presented in this work will set the VTA service for Fall 2004 as a fixed variable and will show if the accessibility of SJSU campus (defined as the percentage of students able to use public transportation) is higher than the percentage of students actually using VTA buses and light rail system.

Details of the methodology used to find how accessible the SJSU Campus is to its students will be explained on Chapter III. This is done to facilitate the replication of this analysis in the future, either by the Transportation Solutions Center or anyone who might find this approach useful. Chapter IV presents the results of the analysis, in the form of maps and percentages. Finally, Chapter V is dedicated to the future improvements that can be done and the conclusions of this study.

CHAPTER II

INDICATORS FOR EVALUATING THE PERFORMANCE OF A TRANSPORTATION SYSTEM

"Travel is not an end in itself but a means to an end." (Krygsman, 2004)

Related to this investigation, aspects reflect the ease with which transportation users overcome distance are: how far must they travel, how long travel takes, and how much travel costs. In order to evaluate the performance of a transportation system, the indicators should include the elements of distance, time, cost, and ease of movement. As the U.S. Department of Transportation (USDoT) proposes, mobility and accessibility are concepts that "provide the foundation to create indicators that evaluate the performance of a transportation system, and both are attributes, not of the transportation system itself, but of the people, places and firms that it serves" (USDoT, 1997). Accessibility, connectivity and mobility are concepts developed in geography of transportation, urban and regional studies, transportation engineering and mathematics, in areas like graph theory, networks and topology. These concepts can have very different meanings. A description of what each concept means and its indicators follows.

Connectivity

In order to apply graph theory to the analysis of a transportation network, the network must be converted into a graph form. When a network is abstracted as a set of edges (links) that are related to a set of vertices (nodes), a basic question is the degree to which all pairs of vertices are interconnected. The degree of connection between all vertices is defined as the connectivity of the network (Taafee & Gauthier, 1973).

The completeness of a network is measured by the connectivity index. The connectivity index compares the actual connections that exist in a given network (A) with the total number of links possible (P) (Campbell, 2001). The formula: 100(A/P) gives a percentage of completeness by dividing the actual number of links by the possible number of links. The connectivity index works well for comparing how to go from one city to another using airplanes, trains or intercity buses. Connectivity is not a definition for use in this particular analysis because the student addresses are too many to be considered as origin nodes linked to the final destination node, the SJSU Campus. Bus stops or light rail stations seemingly are vertices connected by links. However, it would not make sense to count every single link between stops along a bus route for obtaining the actual number of links (A) and then try to connect all the bus stops with bus routes to find (P). This analysis would require too much work in editing layers and process it with custom programming.

On the other hand, the network representation with edges and vertices is useful in providing public transportation users with personalized travel advice. Wu and

Hartley (2004) developed two types of algorithms that can accommodate public transportation users' preferences, single-purpose shortest path (for finding the route of earliest arrival time or latest departure time, minimum walking time or minimum bus transfers) and K-Shortest path, which is based on a multi-purpose network search that computes a number of ranked shortest routes in one time. Each algorithm needs a network representation of nodes and arcs, where the nodes are bus stops and arcs represent the time taken to travel between each pair of nodes either by bus or foot. Figure 2.1 has six bus stops and six links that are connected by two bus routes. Because the bus stops are also connected by walking, the figure shows 15 additional links with dashed lines.

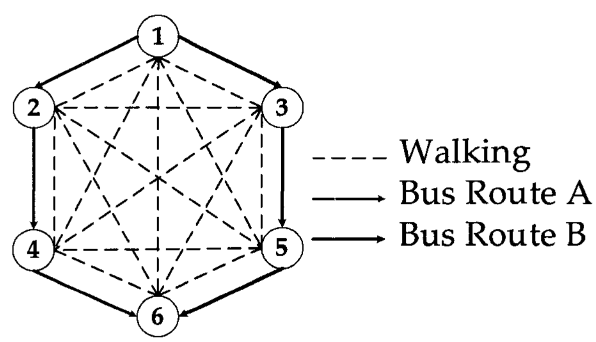

Figure 2.1 Transportation network connected either by buses or by walking

The input data for the algorithm are a description of the bus transportation network (timetables, description of links between bus stops), the bus stop where the trip begins (source node) and the bus stop where it ends (destination node). The way to represent the links is to assign a cost (in time) to every link. Route finding for bus travel is schedule-based, which means the length (in time) between any pair of nodes has to be calculated from the bus timetables. Route finding for foot travel requires the distance between two points to be translated into walking time.

Wu and Hartley (2004) proposed other considerations to improve the efficiency of path finding:

- First, no congestion exists in the traffic system.
- Second, all passengers are able to get on and get off buses at any stops.
- Third, the buses depart from and arrive at every bus stop on time. Arrival and departure times for a non-time point are extrapolated from the schedule of neighboring time points.
- Fourth, walking time for transfer at a node is constant. People typically do not want to walk too much if they choose to use transit, then walking is restricted to ten minutes.
- Finally, if the departing time is 7:00 a.m., the algorithm may only search for arriving time no later than 9:00 a.m., because in practice, passengers usually will not catch a bus if it takes more than two hours to arrive at their destinations, if there are other means of transportation available.

The aim of the investigation is to determine if more students could be taking transit to and from SJSU. The study did not seek to prepare a trip plan for each one of the students and therefore avoided the creation of all the links between the bus stops that would have had time as an attribute. The other considerations to improve the efficiency of path finding were taken into account in our methodology.

Mobility

Mobility refers to the potential for movement. A number of factors can affect personal mobility, including the availability and cost of transportation and infrastructure. Mobility is also affected by the knowledge of available transportation and logistical options. Natural events, like floods, can reduce mobility temporarily. Physical restrictions, like poor eyesight, narrow the transportation options for some people.

Proxy measures, such as availability of a car, can give only a partial indication of personal mobility. Empirical studies usually rely on the concept of revealed mobility, which could be defined as the number of trips taken or miles traveled over some unit of time. Revealed mobility is an indicator of achieved movement. This assumes that people with high mobility will travel more than people with low mobility. In economic terms, high mobility indicates a low cost of travel measured in either time or money. People tend to travel more as travel becomes cheaper. However, some inconsistencies emerge between the concept of mobility and its indicator revealed mobility. If a person who commutes by car moves to a house that is closer to work, the number of miles traveled per week will go down and his revealed mobility will decrease, as well, but that does not necessarily mean that the person has become less mobile (USDoT, 1997).

Revealed mobility indicators are what Transportation Solutions Center uses when surveying the student population to know how they commute to SJSU. It is a useful measurement to observe the behavior in one particular point in time, but it is not adequate for predicting changes.

Accessibility

Even though the concept of accessibility is commonly found in relation to the Americans with Disabilities Act (ADA) of 1990, this study does not focus on that aspect. The ADA protects persons with disabilities from discrimination in, among other things, employment, provision of public services and accommodations, and transportation. The ADA requires public transportation vehicles to be accessible to people in wheelchairs or with disabilities: fixed-route service is to be made available to the disabled; paratransit is to be provided when fixed-route transit does not meet a customer's needs or is inappropriate to the situation.

Several definitions for accessibility are found in academic research. First, Morrill defined accessibility as "the relative degree of ease with which a location may be reached from other locations" (1970). In this case, how easy is it to reach SJSU from where its students live? Second, Burns (1979) focused on "the freedom of individuals to decide whether or not to participate in different activities." He presented three components of accessibility, each with its own limitations:

- The transportation component implies the means of transportation available to individuals and the speed at which this transportation allows them to overcome space. Limitation: Individuals can travel between locations only so fast, and therefore, their movements use time. In other words, the transportation mode available to individuals does not allow them to move instantaneously.
- The temporal component involves the availability of activities at different times of the day and the times in which individuals participate in certain activities. Constraint: Different activities are not available at all times and at all locations. To be precise, the availability of activities is irregularly distributed in time and space.
- The spatial component involves the availability of activities in geographical space and the locations of specific activities that individuals participate in. Restriction: Individuals can only be at one location at any given time.

This broader concept of accessibility, defined as the ability to participate in a variety of activities, must take time into account as a finite resource. Transit is slow compared with the car, frequently requires one or more transfers, and may not provide convenient service. The Nationwide Personal Transportation Survey prepared by the United States Department of Transportation in 1990 found that the average speed of public transportation was 18 mph, while private transportation was 35 mph. Moreover, only two percent of daily trips in urbanized areas in the U.S. were taken by transit in 1990 (USDoT, 1994).

A third definition of accessibility is proposed by Ashiru, Polak, and Noland (2003). For them, "accessibility is a measure of the overall utility that an individual derives from participating in one or more linked activities within an integrated land-use-transport environment." The utility that an individual gets from actual activity participation can be reduced by elements of disutility, like non-travel related delays such as time spent waiting for the bus, but also time spent waiting to start the activities once one has arrived at the destination too early. In addition, late commencement of an activity due to late arrival will result in more disutility being incurred by the individual.

Accessibility Indicators

For Baradaran and Ramjerdi (2001) accessibility measures are classified according to their supporting theories, complexity in constructions, and amount of data needed.

> Different accessibility indicators can be employed to describe and summarize characteristics of the physical infrastructure (e.g., accessibility to certain links, the network, or specific mode or modes). These conventional indicators, often referred to as objective or process indicators, reveal the level of service of the infrastructure network from the suppliers' perspective, regardless of their utilization. On the other hand, the importance of recognizing perceived accessibility by individuals as the real determinant of behavior is emphasized by many researchers, and it is argued that proof of access lies in the use of services. The inherent conflict between the choice of process indicators (objective indicators) and outcome indicators (perceived measures that reflect behavior)

gives rise to a great range of indicators with different degrees of behavioral components. (Baradaran & Ramjerdi, 2001)

The following discussion summarizes the classifications of Baradaran and Ramjerdi, Miller (1999), Miller and Wu (1999), and Miller and Shaw (2001) for accessibility indicators. In addition, a second classification of accessibility measures discussed by the U. S. Department of Transportation is reviewed.

Travel-Cost

According to Baradaran and Ramjerdi, these indicators include all that measure the ease with which any land-use activity can be reached from a location using a particular transportation system and are utilized to measure the performance of the transportation infrastructure. The indicator is some approximation of transport cost, either network or Euclidean distance, travel time, or travel cost. The general formula is:

$$A_i = \sum_{j \in L} \frac{1}{f(c_{ij})}$$

where

A_i is the measure of accessibility at location i,
L is the set of all locations, and
$f(c_{ij})$ is the deterrence function and
c_{ij} is a variable that represents travel cost between nodes i and j.

Space-Time or Constraints-Based Approach

This approach was developed by Hägerstrand (1970) within the space-time framework and is based on the fact that individual accessibility has both spatial and temporal dimensions. Potential and actual opportunities for an individual are not only constrained by the distance between them, but also by the time constraints of the individual. Potential Path Space (PPS) is described as the space-time prism that delimits all locations in space-time and can be reached by an individual based on the locations and duration of mandatory activities (e.g., home, work) and the travel velocities allowed by the transportation system (Miller, 1999). Assume an individual located at time t_0 in node (X_0, Y_0). Again assume that at time t_1 the individual has to be back at the same node. Then the available time for all activities is given by $t = t_1 - t_0$. As can be seen in Figure 2.2, the space-time prism or PPS is represented as the volume contained by two cones. The projection of PPS on the two-dimensional XY-space represents the potential path area (PPA) that corresponds to the area that an individual can move within, given the time budget (Barandaran & Ramjerdi, 2001).

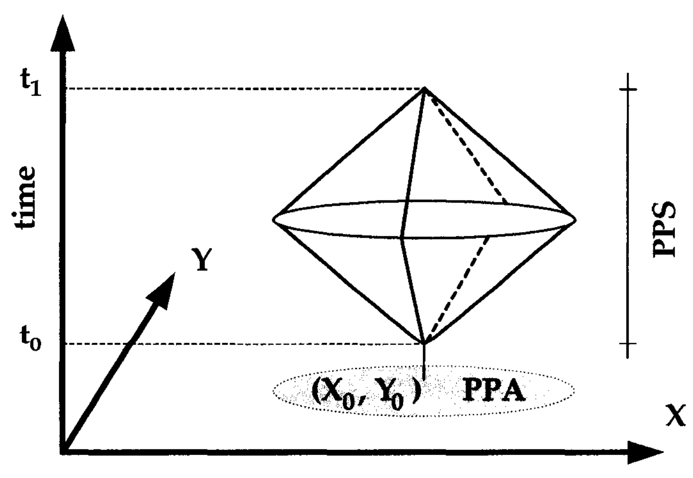

Figure 2.2 Space-time prism (PPS) and potential path area (PPA)

Gravity or Opportunities Approach

Also known as attraction accessibility measures (Miller & Wu, 1999), these indicators present a score for an individual or a place. The value is based on spatial opportunities available, the weight of how attractive these opportunities are, and the required travel costs or times (Miller & Shaw, 2001). This approach is the most utilized technique among accessibility measures and is among the first attempts to include the behavioral aspects of travel. A simple equation is:

$$A_i = \sum_j W_j f(\beta c_{ij})$$

where

A_i is the accessibility of travel origin i

W_j is the attractiveness of destination j

$f(\beta c_{ij})$ is a general function that represents travel cost between nodes i and j

User Benefits or Utility-Based Surplus Approach

These indicators also try to include individual behavior characteristics in accessibility models. For Ben-Akiva and Lerman (1979), "accessibility logically depends on the group of alternatives being evaluated and the individual traveler for whom accessibility is being measured." This measurement calculates the benefits that an individual will receive by selecting the alternative which maximizes his/her utility from a choice set.

Composite Approach

Miller (1999) derived new measures by combining space-time, attraction-accessibility and user-benefit approaches into a composite model within a transportation network. These models are called space-time accessibility measures (STAMs) and are based on the benefit an individual gets from participating in discretionary activities (like shopping or entertainment), after finishing with his/hers mandatory or fixed activities. Some of the variables used to define the STAMs are destination attractiveness, available time for participation in activities (stop and start times), location, distance and travel times from and to fixed activities.

Relative and Integral Accessibility Measures

The accessibility indicators can also be classified as relative or integral (USDot, 1997). Both relative and integral accessibility depend on the locations of the point of evaluation, the activities that can be reached from it, and the structure of the transportation network. A well connected transportation system helps to create accessibility. However, if the traffic flow exceeds the capacity of the network, congestion may set in, resulting in poor accessibility even between points that are well connected.

A relative measure would evaluate the accessibility of a person's workplace from home by determining the length of time it takes to commute. Relative accessibility may be based on distance, travel time, or travel cost in a "many-to-one" relationship, e.g.

commuters to downtown. Nowadays, several locations offer extensive opportunities for shopping, employment and entertainment, so indicators of relative accessibility to the nearest facility are more useful.

An integral measure of accessibility incorporates information about activities at different locations. For example, an integral measure of accessibility can be found by summing up the travel times from one neighborhood to all the area's major shopping centers. This measure is only meaningful when used to compare two or more neighborhoods. To compare the access level of a group of people, the travel time from their homes to all the shopping facilities could be measured separately and then averaged. The person with the lowest average time has the most accessibility.

Accessibility Indicator for SJSU

The accessibility indicators described in this chapter require too much data, like knowing all the places the students need to travel, the attractiveness of all destinations, and the level of utility the user would get from going to those places. A simpler and more reasonable measurement for accessibility is needed for the students at SJSU. They go to classes using the best option available: driving, walking, bicycling, carpooling, public transit, etc. Finding a value for accessibility for each one of the students implies evaluating not only one means of transport but all of them. It also requires taking into account that the SJSU Campus is not the only location that students want to reach, but all other locations they go for work, shopping or entertainment. However, this analysis will explore if students can go to SJSU using public transportation, namely VTA buses and light rail, by focusing on only three variables:

- The distance between the students' home addresses and the nearest bus stop or light rail station. Does the group of students have access to a bus stop in the vicinity of their homes? The stop should not be farther than half-mile. Euclidean distance was selected to make the calculations simpler. However, pedestrians must use the sidewalks and cannot cross highways in urban areas.
- Students' class schedules and transit schedules. If the need is to be at SJSU by a certain time, is the bus stop in a half-mile radius from a student home being serviced by a bus traveling to campus that will arrive 10 to 25 minutes before the classes start? Will a bus departing from SJSU 10 to 25 minutes after classes end, take the same student to a bus stop in a half-mile radius from his home?
- The amount of time spent on the commute. How much time is required for each student to go to the university and come back? The total time spent on the commute door to door should be below four hours.

For this analysis, accessibility is defined in terms of the ease of movement between two places, SJSU Campus and each student's home. For this study, the accessibility indicator is the percentage of students that live in a half-mile buffer around a stop or station that is being served at the time they need to be taking transit to travel to the SJSU Campus and can also take transit to return home.

The group of students that meets all the requirements in the variables declared earlier would become the target population for a specific marketing campaign from the office of Transportations Solutions. These are students who could be taking transit instead of driving. The final decision about taking transit depends on them.

According to Murray (1998) the concepts of access and accessibility are inter dependent for a public transport system to be successful and well utilized.

> Access is the opportunity for system use based upon proximity to the service and its cost. If the distances or barriers to access a service are too great at either the trip origin or destination, then it is unlikely to be utilized as a mode of travel. Similarly, if the cost is either too expensive (i.e. cheaper modes exist) or unaffordable then utilization of the service is also unlikely. Accessibility is the suitability of the public transport network to get individuals from their system entry point to their system exit location in a reasonable amount of time.

In summary, access refers to the distance between the students' homes and the bus stops. Usually, the walking distance is considered to be 400 meters. For this study, the measurement was extended to half-mile because the SJSU public is composed mostly of young adults without mobility difficulties. The monetary cost in this case is irrelevant, because the cost for the EcoPass sticker is less than four dollars per month for unlimited rides in a six month period.

With respect to accessibility, the analysis considers the departure and arrival times for all the stops on the network composed of the 20 direct routes that serve SJSU as it can be appreciated in Figure 2.3. Differentiation between accessibility measures at different times of the day is necessary when the level of service varies during the day.

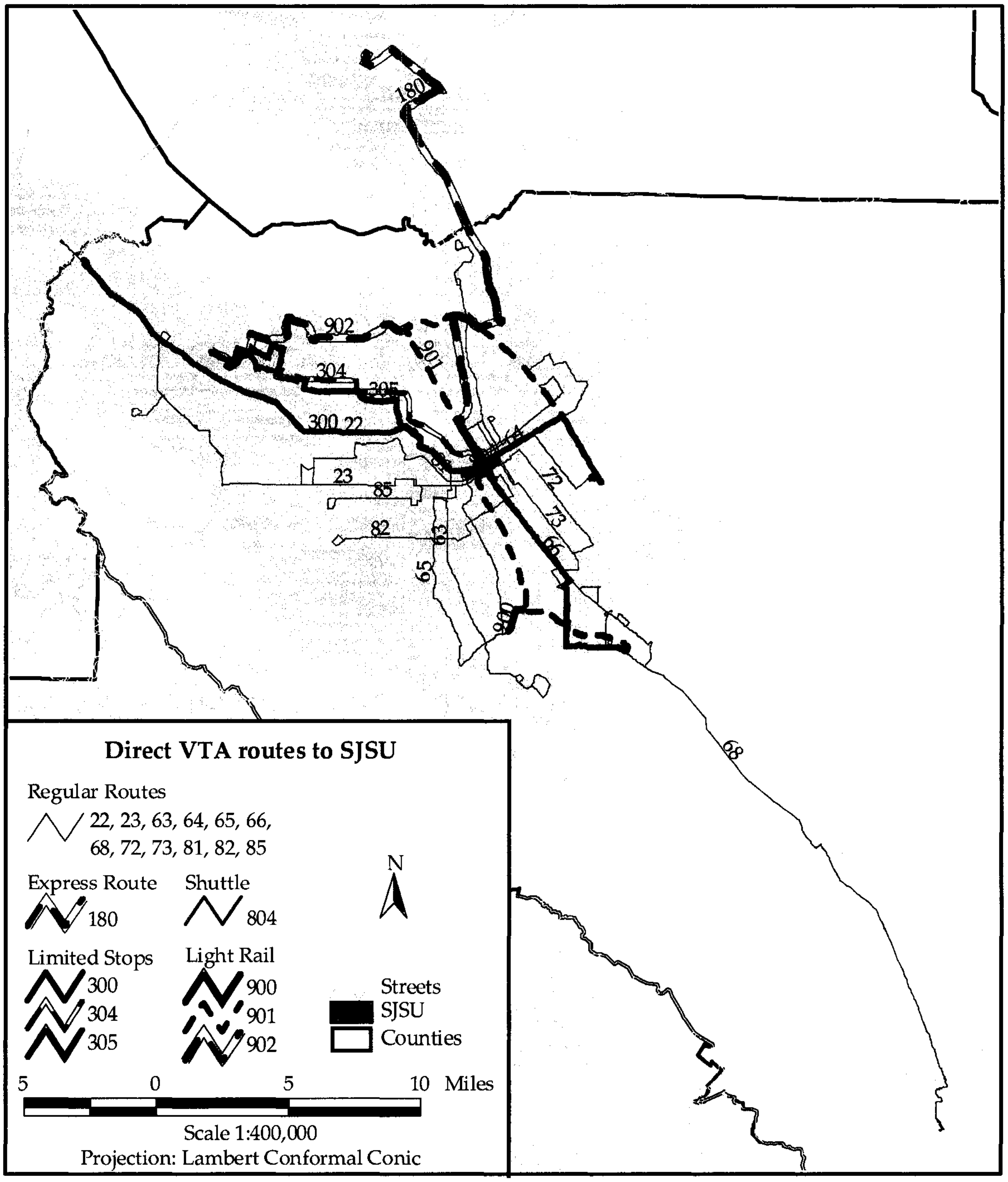

Figure 2.3 Direct VTA routes to San José State University, California

Even though many technical papers try to solve public transportation problems using GIS, no recipe reveals how to build a model that will answer the question: How many students can go from home to the University using transit, and how long is going to take them? This study's solution, presented in the next chapter, uses a fixed network for every time frame of fifteen minutes, for both the incoming and outgoing trips to SJSU.

The analysis will present the percentage of students able to take transit to and from SJSU as a measure of integral accessibility to a place. For the study's purposes, accessibility is considered an attribute of a location, SJSU. Analysis will consider it an integral measure of accessibility because all the student population will be summarized to obtain the final value and compared to the percentage of students taking transit according to the results of the survey shown in Table 1.1. Not all students need to be at SJSU at the same time and each person has different alternatives to commute, but this analysis will focus on public transportation and evaluate if the service is available for each single student at the time they need it. This will evaluate accessibility as an attribute of the students, who create it through their daily activities and movements (Kwan and Weber, 2003).

CHAPTER III

METHODOLOGY TO ESTIMATE THE ACCESSIBILITY OF SJSU

After a careful review of the methodologies available to evaluate the accessibility of a network or place, the conclusion surfaced that none of the proposed methodologies would answer this question in a simple manner: With the VTA Service for Fall 2004, can the percentage of students that take transit be increased and by how much? The idea is to find out how many students can actually use transit, taking into account the time their classes start or end; in contrast to a direct transit analysis that is being used at Transportation Solutions. The direct transit analysis is based on the geometric distance between where the students live and the express or limited bus stops and light rail stations (using a half-mile radius) or a direct bus line (a quarter-mile radius). Unfortunately, that method does not consider if the stops are inbound or outbound, relative to the SJSU campus. The accessibility approach proposed in this work addresses the inbound/outbound problem in order to improve the accuracy of the results. Additionally, to reduce the complexity and amount of calculations, the following restrictions were applied to the analysis:

- The distance from the student home address to a bus stop or light rail station should not be more than half-mile, which translates into a ten-minute walk.
- The time frame for transfers should be between four to fifteen minutes.

- The bus or light rail should arrive at the nearest stop or station between twenty five to ten minutes before classes start. If classes start at 9:00 a.m., the student should arrive between 8:35 and 8:50 a.m.
- The bus or light rail should depart from the nearest stop or station between ten to twenty five minutes after classes end. If classes end at 8:00 p.m., the student should be able to take a bus between 8:10 and 8:25 p.m.
- On the global student schedule, there were 36 different start times and 96 different end times for classes. To make queries easier, these times were aggregated, using 15-minute intervals, into 35 start times and 51 end times. Only the active stops were queried in each interval to obtain a fixed network.

Two kinds of data are required to conduct the analysis, spatial and temporal data. The spatial data correspond to Fall 2004 and is composed of shapefiles: bus and light rail lines, bus stops and light rail stations, students, streets and the location of SJSU. This geographic information needs to be in the same coordinate system, as described in Table 3.1.

The temporal data includes students' class schedules for Fall 2004 and a database with the time schedule for each route of the public transportation provider, VTA. The major challenge is to prepare and clean the data. An explanation on how this was accomplished follows.

Table 3.1 Horizontal coordinate system

Projected coordinate system name: NAD_1983_StatePlane_California_III_FIPS_0403
Map Projection Name: Lambert Conformal Conic
Standard Parallel 1: 37.066667
Standard Parallel 2: 38.433333
Central Meridian: -120.5
Reference Latitud: 36.5
False Easting: 2,000,000
False Northing: 500,000
Planar Coordinate Information
Planar Distance Units: Mile_US

Bus and Light Rail Lines

The first task was to create a new shapefile of bus lines to replace the version elaborated over a different street layer that will coincide with the newer StreetMap version. As illustrated in Figure 3.1, the green line representing bus line 10 and all the other bus lines in red do not always run over the white lines representing the street layer. To fix this, all Bay Area streets from the StreetMap were selected and saved as a shapefile. With this new shapefile, all the segments that form each bus line were picked and saved in a shapefile for each route. The routes as geographic features are not needed in our analysis but they are useful to present the maps and also to locate the stops on the right side of the street.

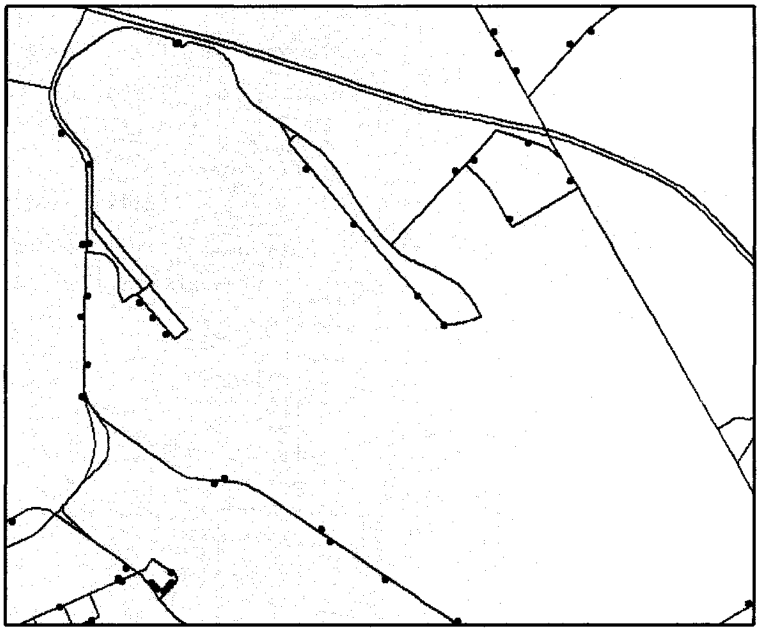

Figure 3.1 Bus lines and street lines mismatch

The elements of study are 17 VTA direct bus routes (12 local, 1 shuttle, 1 express and 3 limited stop) and 3 VTA light rail routes. Even though only one light rail route is direct, the other two that require a connection are also considered as direct when the transfer time was between four and fifteen minutes only. For a list of all the direct routes to SJSU see Table 3.2.

Table 3.2 Direct routes to SJSU

RouteID	Route Name
22	Eastridge Transit Center to Palo Alto/Menlo Park
23	Downtown San José to San Antonio Shopping Center
63	Almaden Valley to San José State University
64	Almaden LRT Station to Penitencia Creek LRT Station
65	Almaden LRT Station to San José State University
66	Santa Teresa Hospital to Milpitas/Dixon Rd.
68	Gilroy/Gavilan College to San José Diridon Station
72	Santa Teresa LRT Station/E. Branham to Downtown San José
73	Snell & Capitol to Downtown San José
81	McKee & Capitol to Vallco Park
82	Westgate to Hedding & 17
85	Lawrence Expwy. & Moorpark to 10th & Hedding
180	Express - Fremont BART Station to San José Diridon Station
300	Limited Stop - Eastridge Transit Center to Palo Alto Transit Center
304	Limited Stop - South San José to Downtown Mountain View
305	Limited Stop - South San José to Downtown Mountain View
804	Downtown Area Shuttle Light Rail Shuttle
900	Light Rail - Ohlone/Chynoweth to Almaden
901	Light Rail - Alum Rock to Santa Teresa via Baypointe
902	Light Rail - Mountain View to Baypointe

Bus Stops and Light Rail Stations

All the stops for each direct route were obtained. Such data was gathered from the previous stops shapefile and the printed maps that the VTA provide to Transportation Solutions. Sometimes the buses have different patterns during the day, like when the bus makes a turn during peak hours to pick up or drop off passengers near a high school. Usually each route has at least two patterns: North- and Southbound or East and Westbound. More than one pattern in each direction sometimes occurred.

In our study, 16 routes had two patterns, the DASH had only one, Routes 63 and 72 had three patterns and route 23, four patterns.

Establishing the patterns for each route helped to create a database in which all the stops displayed the approximate time the bus is going to be at each particular stop. The few time points that appear on the VTA schedule will be used to calculate the times for the intermediate stops. Once each of the patterns was recognized as having all the stops in consecutive order, the table was saved with two columns: the [StopID] and the [Order] in which the stops are served by the bus or light rail. An example can be found on Figure 3.2.

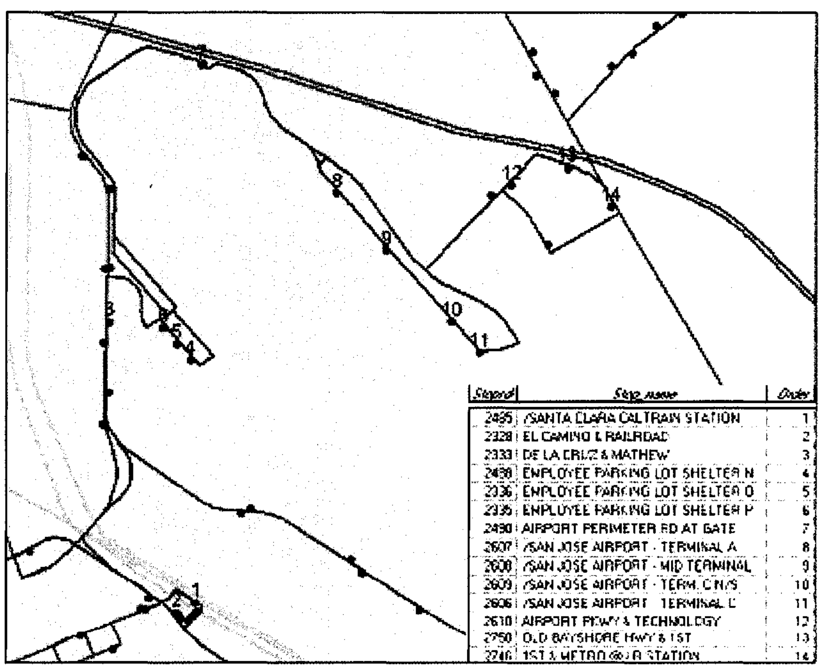

Figure 3.2 Order of stops for a pattern

StreetMap

This layer of spatial information is needed to find where the SJSU students live. ArcView extension Streetmaps was used to geocode the students' addresses. However, the version available for this study only used geographic coordinate system, GCS_North_American_1983. After running the geocode function in ArcView 3.1, the projection of the students' shapefile was changed from geographic coordinates to a projected coordinates system, NAD 1983 State Plane California III.

Students' Addresses

In Fall 2004, 32,218 students were registered at SJSU, either as full-, part-time or Open University students. Using the "home address" or the "mailing address" if the first one was missing, the number and percentage of students living in the 13 counties closer to SJSU was calculated, as can be seen in Table 3.3. The EcoPass benefits mainly students living in Santa Clara and Alameda counties (VTA Route 180 only), which represent almost 75% of the population.

The next step was to geocode all students with addresses in California. To do so, the student database was cleaned, pruned and all records with P.O. Boxes, incomplete or missing address removed. After running the geocode function in ArcView, a home location was determined for 29,152 students; just over ninety one percent of the 31,938 students who live in California.

Table 3.3 Enrollment by county

County	Students	Percentage
Alameda	3,458	10.73%
Contra Costa	617	1.92%
Marin	68	0.21%
Monterey	598	1.86%
Napa	36	0.11%
San Benito	223	0.69%
San Francisco	1,132	3.51%
San Joaquin	262	0.81%
San Mateo	1,596	4.95%
Santa Clara	20,652	64.10%
Santa Cruz	1,040	3.23%
Solano	189	0.59%
Sonoma	121	0.38%
Total for 13 counties - Bay Area	**29,992**	**93.09%**
Students in other counties in California	**1,946**	**6.04%**
Students from outside of California	**280**	**0.87%**
Grand Total	**32,218**	**100.00%**

Students' Class Schedules

Of the 32,218 Students registered in Fall 2004, the schedules for only 30,662 students were received. One of the reasons for this discrepancy is that sometimes the classes do not have established hours, such as a thesis seminar for which the advisor will meet the students in office hours. The majority of students have at least one class between Monday and Thursday; over 72% of the students with schedules will be on campus any of these four days, as shown in Table 3.4. Only 648 students do not come to

SJSU between Monday and Thursday, which indicate that 30,014 students are on campus on any of those four days and represent 97.89% of the population.

Table 3.4 Number of students with schedules on campus by day

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Total Students
22,517	23,042	22,714	22,356	7,920	820	379	30,662
73.44%	75.15%	74.08%	72.91%	25.83%	2.67%	1.24%	100%

All the records that did not have a day with "YES" for columns [Monday], [Tuesday], [Wednesday], or [Thursday] were removed from the schedule database. The records without a starting or ending time had to be eliminated too. By crossing the 29,152 geocoded students in California with the table containing the schedules, 26,785 students were found to have classes at least one day between Monday and Thursday. This number will be the universe of students for our final analysis.

In the following figures, the 26,785 students are represented by the time they need to be on campus, the time their classes end for the day, and the amount of students on campus at any given time during the day. As revealed by the Figure 3.3, most students have classes that start in the morning, at 9:00 a.m. or 10:30 a.m. The line tends to decrease as the time goes by during the day, with the exemption of a peak at 18:00 hours.

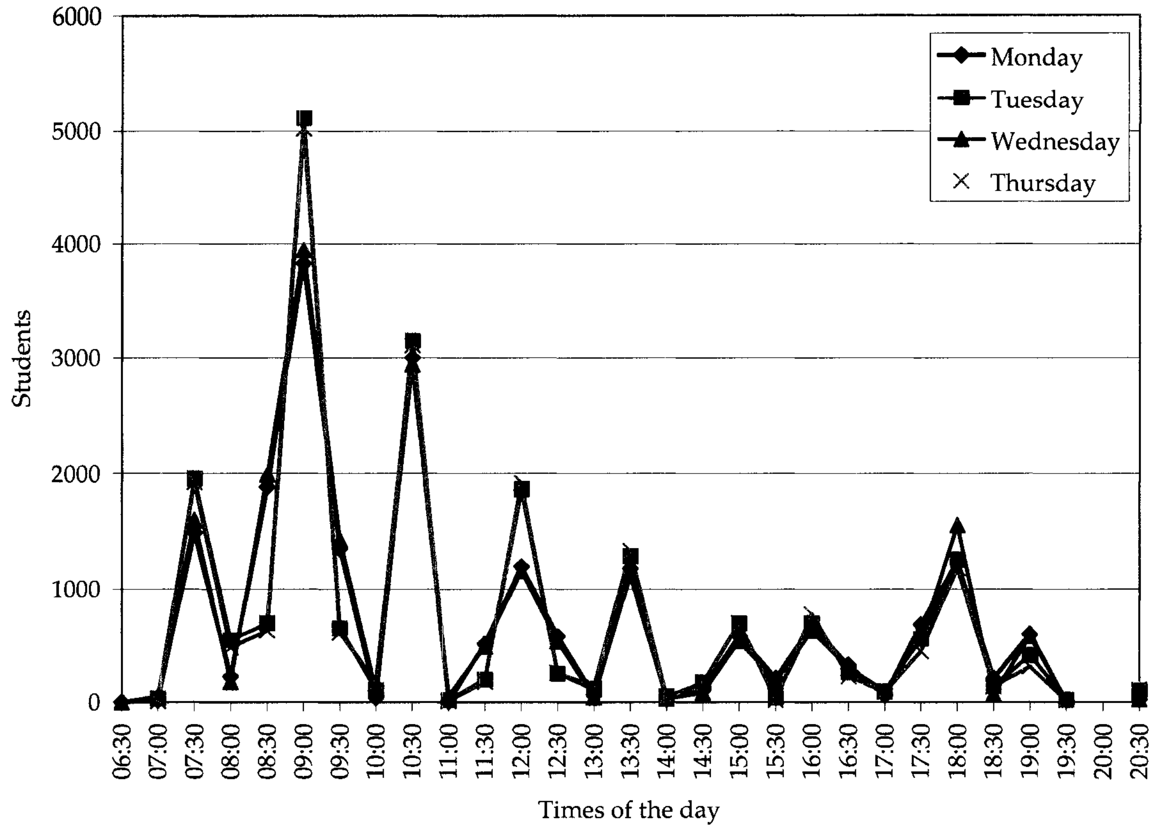

Figure 3.3 Students arriving at SJSU Monday-Thursday

Figure 3.4 shows that most students leave in the early afternoon, at 15:00 and 13:30 hours. A big group also goes home at 21:00 hours. Figure 3.5 illustrates that more than 7,000 students are on campus by 9:00 a.m. With only 5,704 parking spaces available for students at SJSU, as stated on Table 3.5., the expectation is that all parking spaces will be taken before 9:00 a.m. and parking garages remain full until at least 16:30 hours.

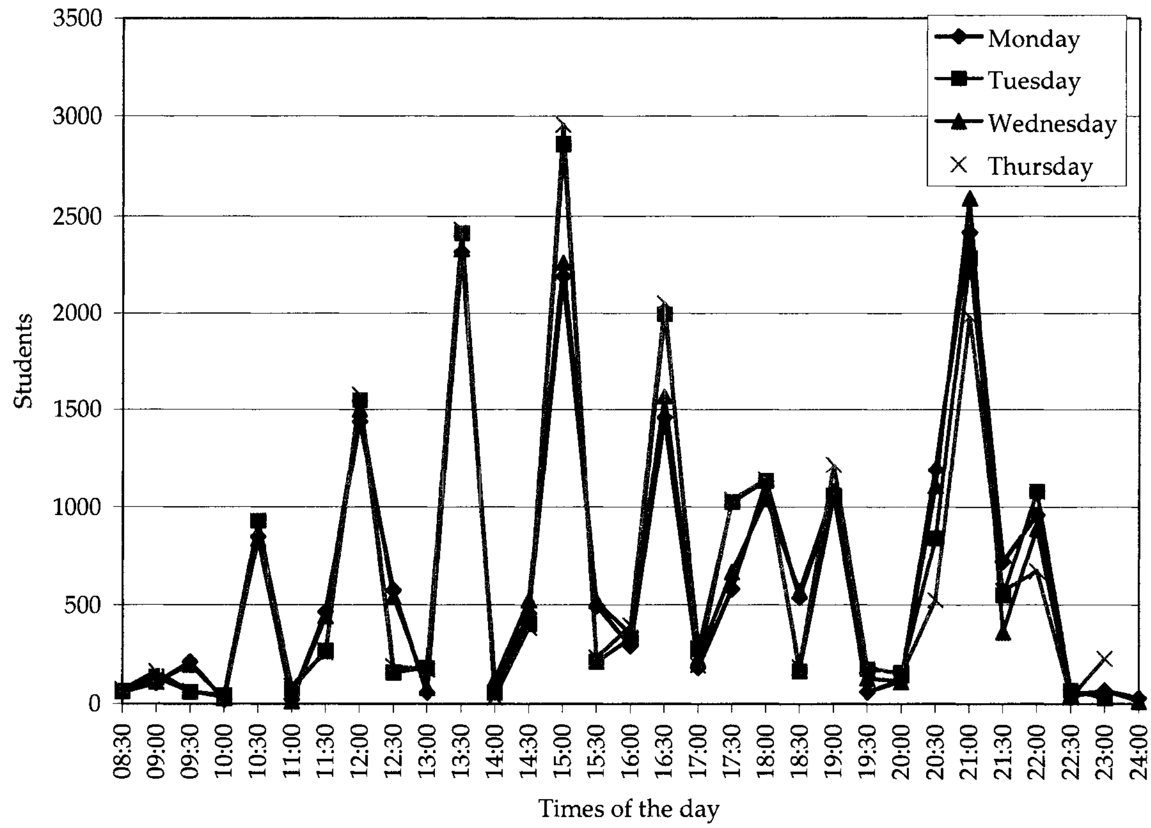

Figure 3.4 Students leaving from SJSU Monday-Thursday

Table 3.5 Parking spaces at SJSU

General/Students	5,704
Employees	1,080
Repair Permit	69
Disabled	177
Special Purpose	465
Total	7,495

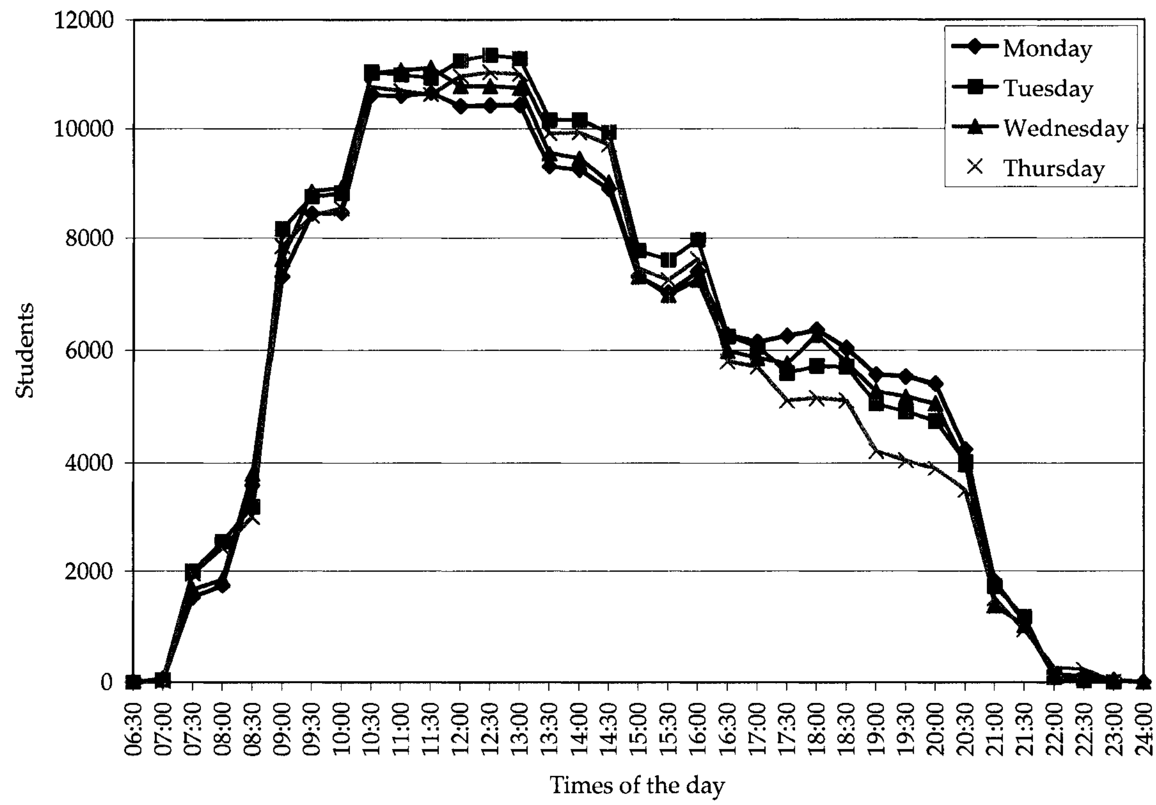

Figure 3.5 Students on campus Monday-Thursday

Even though the schedule database could be queried four times, one for each day, instead an "average" day was created, taking into account the earliest time a student had to be in class and the latest time his classes end on any day between Monday and Thursday. First, the hours needed to be changed in format from a.m. and p.m. to numbers in 24 hours and the minutes where represented as decimals. On Figure 3.6, the value "09:30:00 AM" is equivalent to "9.30" and "04:15:00 PM" is equal to "16.15".

Class_term	Student_ID	Class_start	Class_end	Mond	Tues	Wedn	Thur	Start	End
2044	11	09:30:00 AM	10:20:00 AM	Y	N	Y	N	9.30	10.20
2044	11	10:30:00 AM	12:20:00 PM	N	Y	N	Y	10.30	12.20
2044	11	03:00:00 PM	04:15:00 PM	Y	N	Y	N	15.00	16.15
2044	11	08:00:00 AM	09:15:00 AM	N	Y	N	Y	8.00	9.15
2044	12	12:00:00 PM	01:15:00 PM	Y	N	Y	N	12.00	13.15
2044	12	09:00:00 AM	10:15:00 AM	Y	N	Y	N	9.00	10.15
2044	12	12:00:00 PM	01:15:00 PM	N	Y	N	Y	12.00	13.15
2044	12	01:30:00 PM	02:45:00 PM	N	Y	N	Y	13.30	14.45
2044	12	04:30:00 PM	05:45:00 PM	N	Y	N	Y	16.30	17.45
2044	13	01:30:00 PM	02:45:00 PM	N	Y	N	Y	13.30	14.45

Figure 3.6 Schedule database

Using the [Student_ID] column, the schedule table could be summarized by the minimum [Start] time and the maximum [End] time for each student. These results were joined to the geocoded students table, allowing all information to be available in just one table, as observed in Figure 3.7. As an example, even if the student with ID 11 does not need to be at SJSU everyday at 08:00 and leave at 16:15, using these "average" times is a good approximation as what a typical day for this particular student would look like in terms of his/her transportation needs.

Student_ID	Start	End
11	8.00	16.15
12	9.00	17.45
13	10.30	21.20
14	9.30	20.50
15	9.00	20.50
16	18.00	20.45

Figure 3.7 Geocoded students with schedule

Bus and Light Rail Schedules

Most of the bus and light rail schedules remain unaltered every weekday, with most of the changes for Saturday and Sunday. Two reasons exist to build the schedule database for Monday through Thursday only. The first one is that some routes, like 22 and 64, have special schedules for Fridays that would have required an adaptation of the schedule database. Second, as indicated before, is that almost 98% of the population needs to come to SJSU at least one day between Monday and Thursday. Being Monday though Thursday the busiest days at SJSU, the schedule database was built for those days only.

The processes of acquiring, cleaning and presenting the temporal data follow. The first step was to download from the Internet the VTA bus and light rail schedules and save the data for each route in an Excel spreadsheet. The second step consisted of cleaning the tables by changing the format and some values. Because the original tables were in an HTML format, the p.m. times were shown in bold characters but all the information was stored internally as a.m. values only.

Next, with the help of the tables created to establish the order of stops in pattern form (see Figure 3.2), the intermediate stops could be added to the Excel spreadsheet, insert new columns as needed, and then calculate the time for each intermediate stop using the Time Points. The formula used to calculate the times that appear in red on Table 3.6 was:

$$\frac{(\text{Time Point B} - \text{Time Point A})}{(\text{Number of intermediate stops between Time Points} + 1)}$$

Table 3.6 Adding intermediate stops

StopID		2485	2328	2333	2488
StopName		Santa Clara Caltrain Station	El Camino & Rail Road	De La Cruz & Matthew	Parking Lot Shelter N
Order		1	2	3	4
Time Points		Time Point A			Time Point B
TripID	T010E001	5:14	5:16	5:18	5:20
	T010E002	5:40	5:42	5:44	5:46
	T010E003	5:57	5:59	6:01	6:03

To prepare the final table in Excel the values of [StopID] and [Times] of each row had to be transposed and saved in one column, as seen in the example, Table 3.7. In the Excel table, the time values are saved internally as a.m. or p.m., even though they appear with the 24 hours format, like 5:30 or 20:00. Exporting directly from Excel to Access did not work well, so first the tables were saved in text format and then these text files were imported into Access to create the database.

Two columns with different formats to reflect the times in the schedule table resulted: String or character, like "05:15", and number with two decimals, as in "5.15". The string format worked well for most of the queries, but did not help to find averages which were needed to prepare the map of travel times for students starting or ending classes at specific hours.

Table 3.7 Bus schedule example

TripID	StopID	Times
T010E001	2485	5:14
T010E001	2328	5:16
T010E001	2333	5:18
T010E001	2488	5:20
T010E001	⋮	⋮
T010E002	2485	5:40
T010E002	2328	5:42
T010E002	2333	5:44
T010E002	2488	5:46
T010E002	⋮	⋮
T010E003	2485	5:57
T010E003	2328	5:59
T010E003	2333	6:01
T010E003	2488	6:03
T010E003	⋮	⋮

The bus and light rail schedules were transformed from HTML files into a database of four DBF tables: Routes, Pattern, Trip and Schedule. To complete the database the PatternStop table and the Stops shapefile were also included. The fields and relationships are shown in Figure 3.8.

Note, three fields on the Stops Shapefile need to be populated. [FinalStop] are the stops closer to SJSU that are either the last stop for an incoming bus or light rail or the first stop for an outbound service. All the Final Stops had a known value in the [Order] field of the PatternStops table. For example: "([PatternID] = "P022E") and ([Order] <= 88)" returns all the stops that will take students into the university. Likewise the query "([PatternID] = "P022E") and ([Order] >= 88)" selects all the outbound stops for the pattern "P022E". By linking the PatternStop table with the Stops shapefile, is it possible to save the [PatternID] value in the appropriated column: [In-Pattern] or [Out-Pattern].

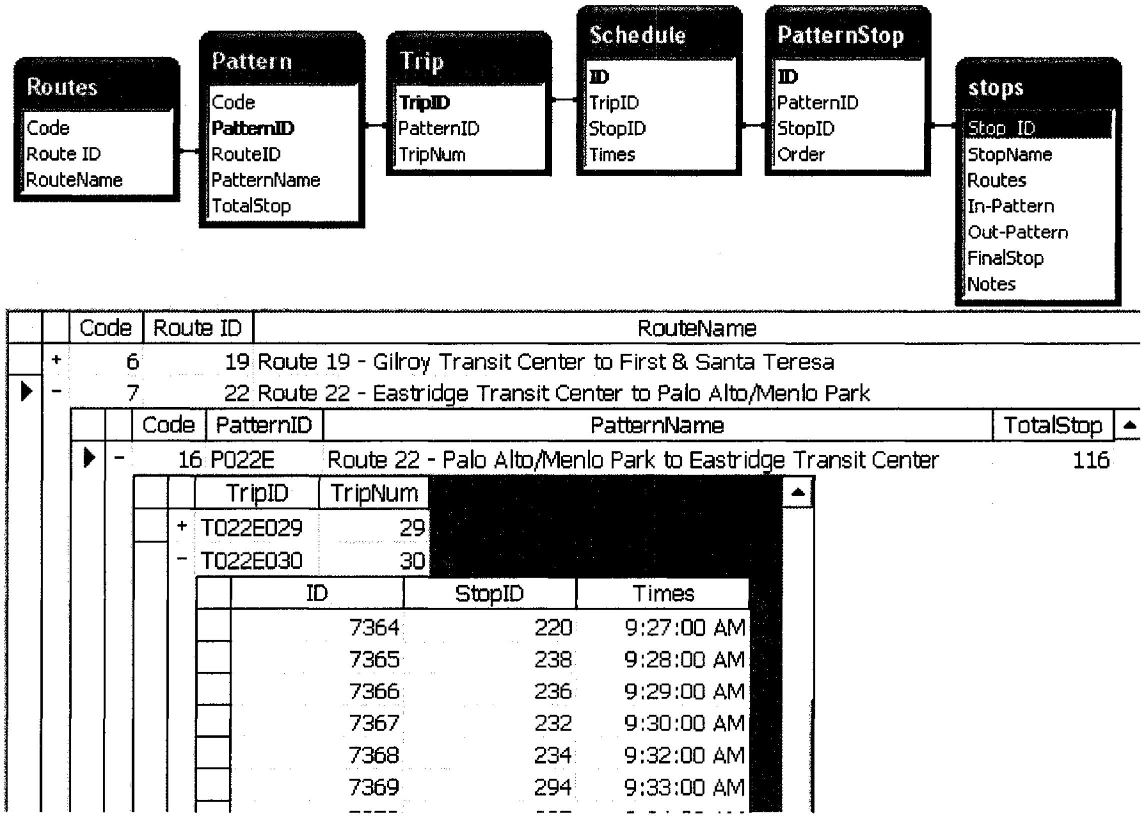

Figure 3.8 Tables and relationship of the database

Analysis

At this point, all the tables needed to query the database were available, but a couple of additions were required to make the process easier. Two more tables were needed to make the network static: one that has all the inbound direct stops and the other that contains all the outbound direct stops. The FinalStop table is a subset of Stops shapefile. A copy of Schedule is needed to save partial queries. The last correction consists of adding a [NewID] field to all the tables that participate in the query but Trip. The [NewID] value is the addition of the values of two columns: [PatternID] and [StopID] as string. To find which stops are active for the arrival or departure time, we established a procedure that is explained by Figure 3.9 and the following queries.

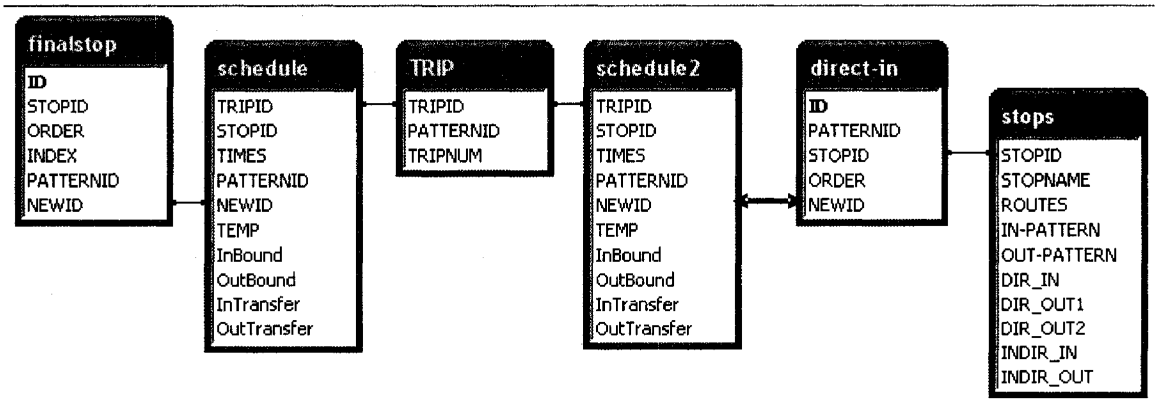

Figure 3.9 Tables required to find the inbound stops by time

i. Select all records in the FinalStop table. Because all the tables are linked, the records in the other tables will be highlighted as well.

ii. From the selected records in the Schedule table, keep only the ones in which the value on the [Times] column is between 25 to 10 minutes before classes start or 10 to 25 minutes after the classes end. For example, the query needed if 06:30 a.m. is the time that the classes start, is: "([Times] > "06:05") and ([Times] <= "06:20")". For other arrival or departure times and their corresponding time intervals in which buses should arrive or leave, see Tables 3.8 and 3.9.

Table 3.8 Arrival time intervals

Classes Start	Buses or Light Rail should arrive at SJSU	Nr. of active stops 883	Nr. of students
06:30	06:06 - 06:20	426	5
07:00	06:36 - 06:50	512	237
07:15	06:51 - 07:05	669	33
07:30	07:06 - 07:20	607	3148
07:45	07:21 - 07:35	613	25
08:00	07:36 - 07:50	622	682
08:30	08:06 - 08:20	580	2069
...	...	...	...
19:00	18:36 - 18:50	571	504
19:15	18:51 - 19:05	563	11
19:30	19:06 - 19:20	460	4
20:30	20:06 - 20:20	359	38

Table 3.9 Departure time intervals

Classes End	Buses or Light Rail should depart	Nr. of active stops 865	Nr. of students
08:10 - 08:20	08:30 - 08:44	516	24
08:40 - 08:50	09:00 - 09:14	609	44
09:10 - 09:20	09:30 - 09:44	636	22
...	...	...	...
14:25 - 14:35	14:45 - 14:59	573	41
14:40 - 14:50	15:00 - 15:14	684	2257
14:55 - 15:05	15:15 - 15:29	670	16
15:10 - 15:20	15:30 - 15:44	683	288
15:25 - 15:35	15:45 - 15:59	648	38
15:40 - 15:50	16:00 - 16:14	689	327
...	...	...	...
23:40 - 23:50	00:00 - 00:14	216	29

iii. On the table Schedule2, add the arrival (or departure) time on the [Temp] column and save the table.

iv. The table Direct-In is linked to and from Schedule2. After refreshing the relationship in the Direct-In table, return to the table Schedule2 and from the highlighted records, select only the ones with the specified arrival (or departure) time on the [Temp] column.

v. On the Stops shapefile, add the specified arrival (or departure) time to the fields [Dir_IN] (or [Dir_OUT]) and save.

vi. Repeat this process for all the student arrival and departure times.

On step iv, copying the value from the [Temp] column into a new field is recommended, for In- and Out-Bound stops. This information can later be use by selecting all the records that have a value in this field and then summarize the Schedule2 table by the [StopID]. This resulting table has been used to prepare Figures 3.10 and 3.11, which show how many times per day the stops are being serve by a bus or light rail.

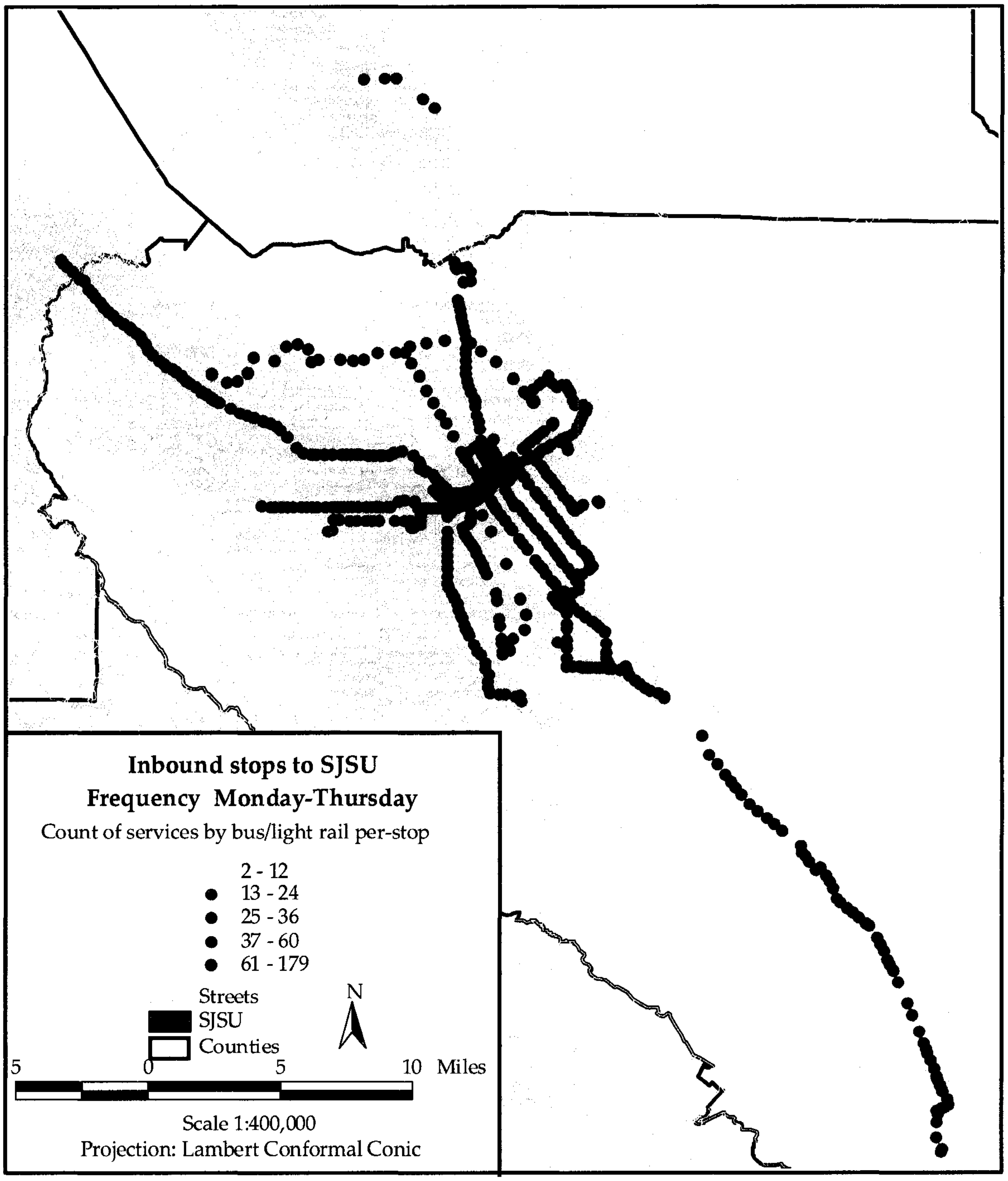

Figure 3.10 Inbound stops to SJSU

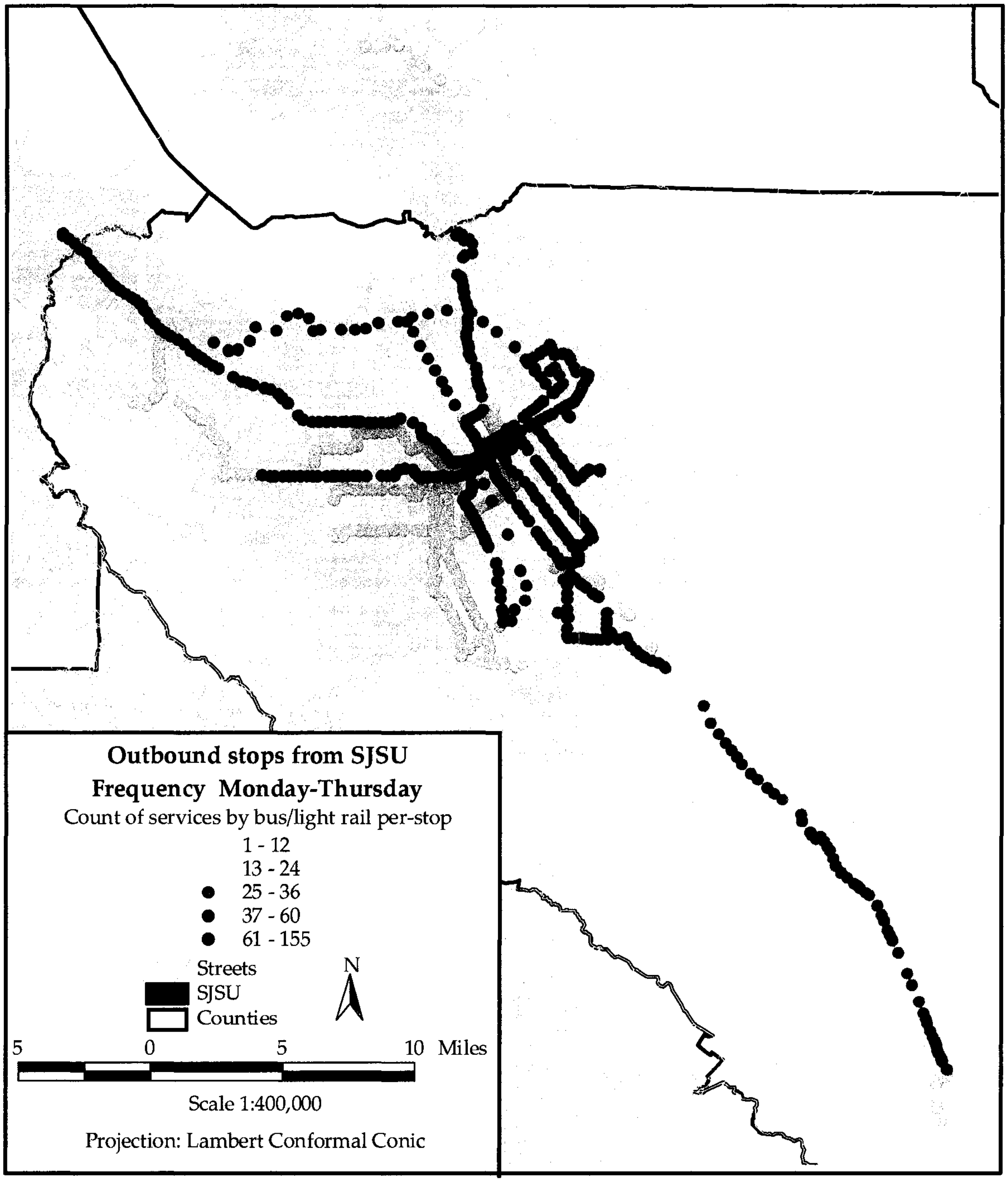

Figure 3.11 Outbound stops from SJSU

Even though almost 50 bus lines serve SJSU indirectly, only the two indirect light rail lines were included for analysis. The stations Baypoint (ID = 900044) and Ohlone (ID = 900003) are the transfer points between routes 902 and 900 to route 901. Using the same database, the query "([StopID] = 900044) and ([OutBound] = "08:20")" is applied to the Schedule table. If one record is selected, we retain the [Times] value, in this case is "09:09". The time frame to take a connection was determined to be between four to fifteen minutes. The next query on the same Schedule table is: (([PatternID] = "P902W") and ([StopID] = 900044) and ([Times] >= "09:13") and ([Times] < "09:24")), which selects all the P902W stations on the Schedule2 table. The value of "08:20" is then added in the [OutTransfer] field. This process was done for all the times in the [OutBound] column and repeated using the [InBound] and [InTransfer] fields. This information had to be transfer to the Stops shapefile, adding the specified arrival (or departure) time to the fields [Indir_IN] (or [Indir_OUT]).

Once the stops were separated by the times they were active, it is possible to see if the students who need to be on campus or leave from SJSU at a specific time can take transit. This can be done by finding at least one stop that is active near their home addresses, in a half-mile radius. With this information, maps could be prepared and are presented in the following chapter.

CHAPTER IV

RESULTS

As stated in the previous chapter, 26,785 is considered the universe of students because they are the ones with an address in California and had class schedules, which include at least one day between Monday and Thursday. By using the direct transit analysis from Transportation Solutions Center, analysis revealed that 7,711 students (28.79%) live half-mile from any of the 298 express or limited bus stops (Express bus 180, Limited stop buses 300, 304 and 305) and light rail stations or a quarter-mile from a direct bus line (Routes 22, 23, 63, 64, 65, 66, 68, 72, 73, 81, 82, 85, 804). By incrementing the distance to half-mile from a direct bus line, the number of students increases to 11,036 (41.20%). In both cases, the students living in a half-mile radius from the SJSU campus are not considered. This group represents 5.82%, which is equal to 1,558 students who live within walking distance from SJSU.

For this analysis, the bus lines were not used, while the bus stops and stations were used because those are the places where passengers can actually board the bus or light rail. Approximately 40.89% (10,953) students live half-mile or less from a direct bus stop or light rail station and also live more than half-mile from the SJSU campus. Without taking into consideration the schedules yet, and doing the same direct transit analysis but differentiating between the 883 inbound and 865 outbound stops, study determined that 448 (1.67%) students can take transit to go to SJSU but have no return stop near their homes, and 213 (0.8%) can take transit from SJSU to return home but have no inbound stop near their addresses. 10,292 (38.42%) students could take transit in both directions.

After cleaning and preparing the student data, by adding to the students shapefile the times their classes start and end, and by having the In- and Out-bound stops for every time frame, now it is possible to analyze the availability of public transportation at the specific times that students would need it according to their class schedules. Analysis determined that only 5,690 (21.24%) students can take transit in and out of SJSU. Even though at least one stop is less than half-mile from their home, 1,777 (6.63%) students cannot take transit to be at SJSU at the time their classes start or to go back home when their classes end. For 2,453 (9.16%) students, service is available to go to SJSU but none to return home. Finally, the people who can take transit to return home but find no service to get to SJSU are 1,033 (3.86%). For a graphic representation of these results, see Figures 4.1 to 4.4.

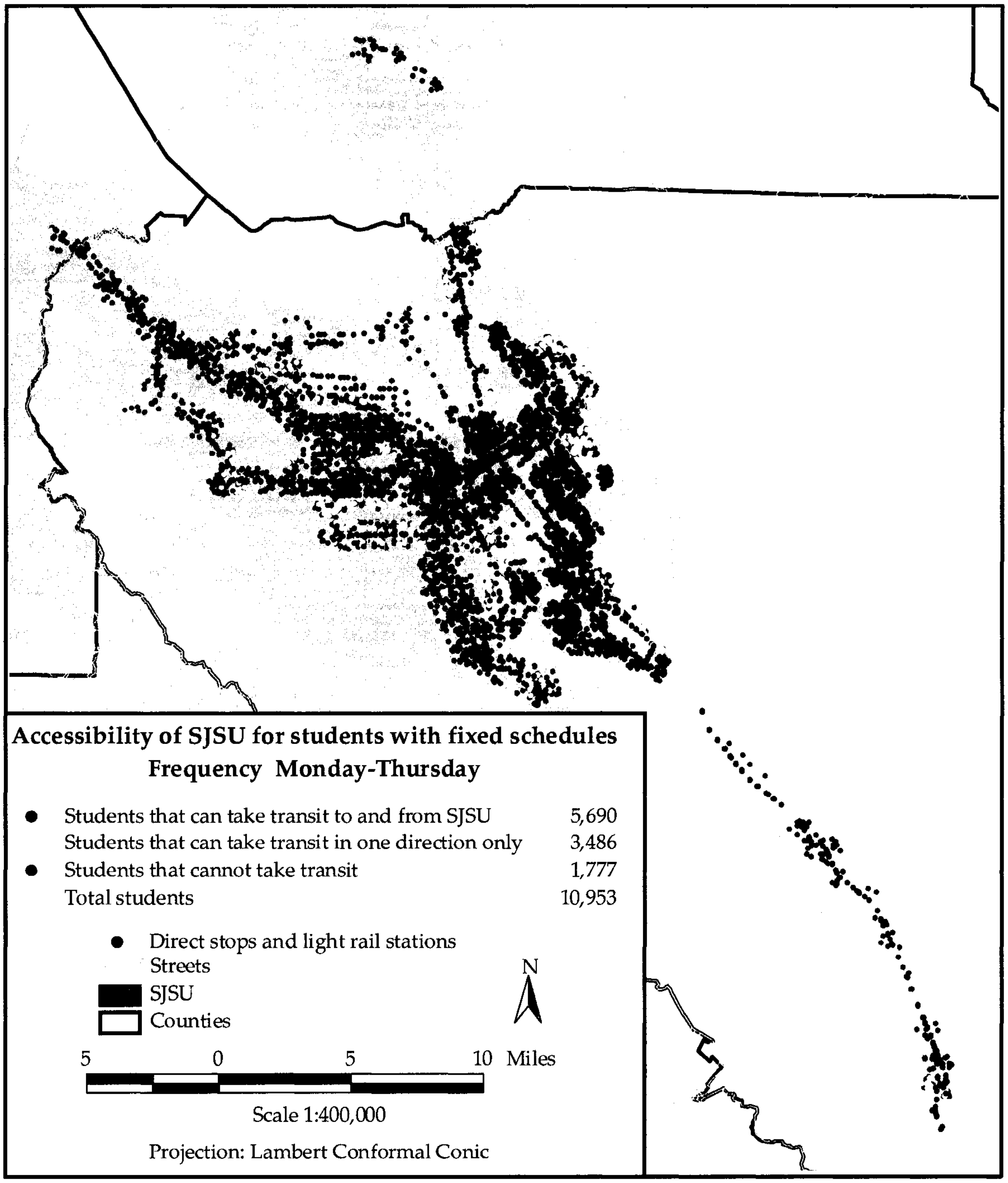

Figure 4.1 Accessibility of SJSU for students with fixed schedules

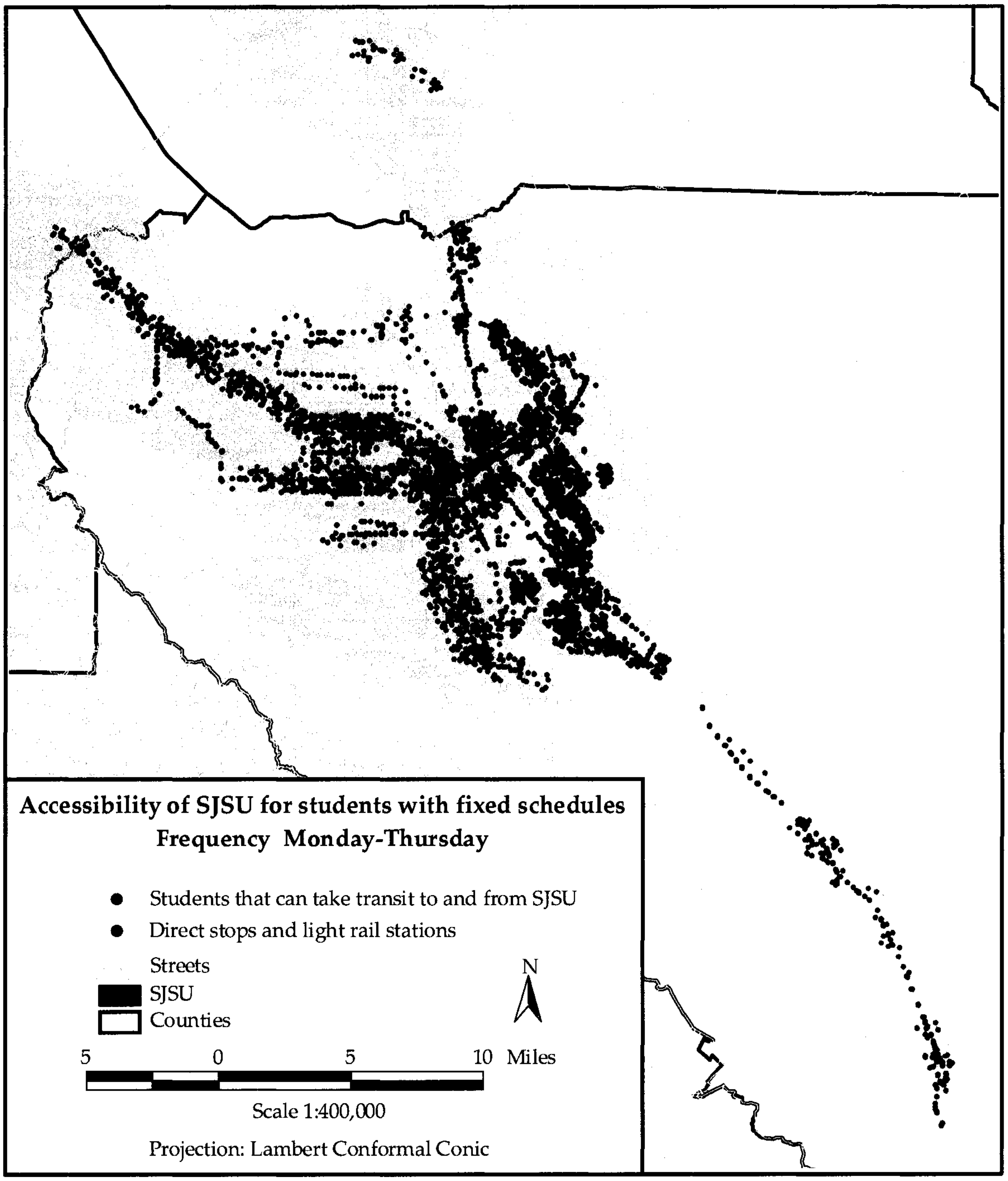

Figure 4.2 Students that can take transit to and from SJSU

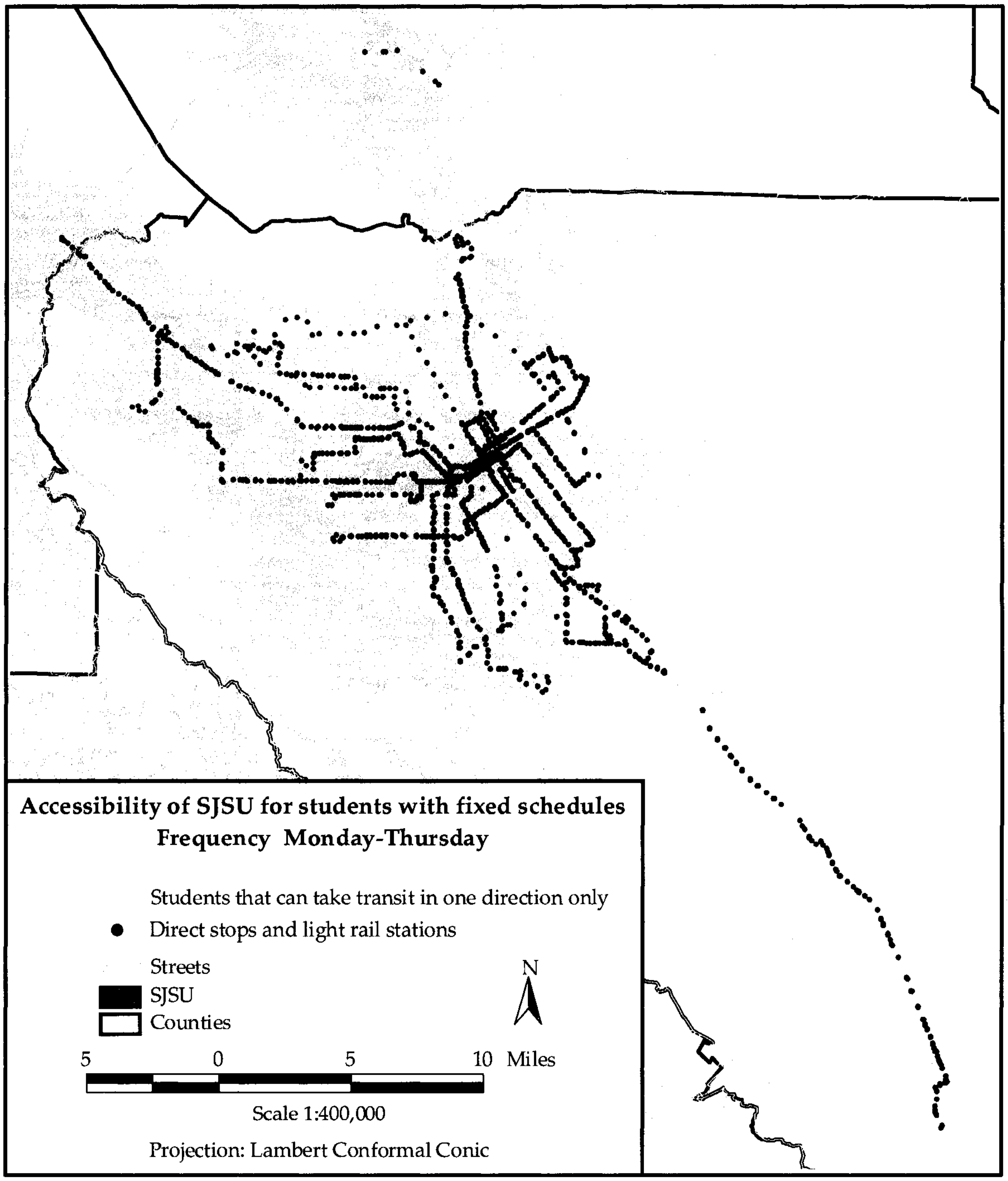

Figure 4.3 Students that can take transit in one direction only

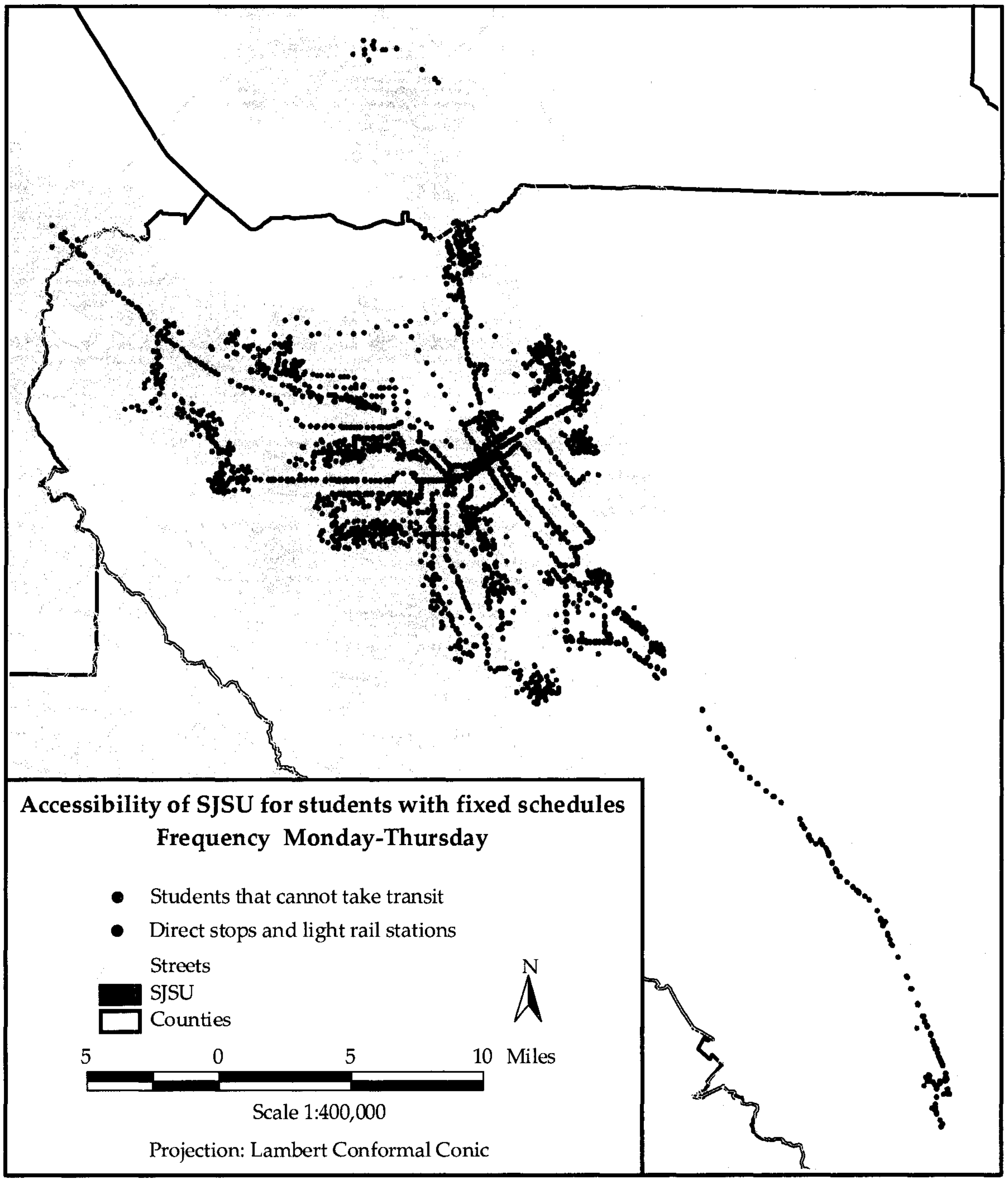

Figure 4.4 Students that cannot take transit

Comparing the survey for Fall 2004 which shows the transportation mode that SJSU students use with our accessibility results, VTA service represents 21.23% and 21.24% respectively, as shown in Table 4.1. The two percentages coincide, even though the differences in the partial percentages for the three services do not. First, not all the students who live on a half-mile radius of a bus stop or bus station will take transit. Another possible explanation is that students get dropped off at a light rail station, use a bicycle to get to the closest station, or drive to a park and ride location. Note, the survey asked to choose the transportation mode that the students use in the longest part of their trip to campus only.

Table 4.1 Use of transit and accessibility - Fall 2004

	Survey		Accessibility	
	Students	Percentage	Students	Percentage
Express Bus 180	29	0.68%	41	0.15%
Bus	465	10.95%	4,359	16.27%
Light Rail	408	9.6%	1,290	4.82%
Total students taking transit or able to	902	21.23%	5,690	21.24%
Total (universe)	4,248	100%	26,785	100%

After calculating the accessibility percentage with distance and schedules, maps and reports could be created to show the travel time for the students to arrive at the University at different times during the day. To calculate the duration of the trip, the format of the [Times] column on the Schedule table must be converted from string to number. Then select all the records that have the same value on the [InBound] or [OutBound] fields, and summarize the table by [StopID], using the maximum InBound value and the minimum OutBound value. The maximum InBound value gives the last time a bus will pass by certain bus stop in order to arrive at SJSU at the desired time. The minimum OutBound value represents the alternative that will allow students to get home as soon as possible after their classes end. Figure 4.5 presents an example of the schedule table and its summarized table of all the stops that will have a bus passing by, in order for students to be at SJSU for classes that start at 09:00 a.m.

schedule2.dbf

Stopid	Time-String	Time-Number	InBound	OutBound
770	07:45	7.45	-09:00-	-
770	07:55	7.55	-09:00-	-
772	07:56	7.56	-09:00-	-
772	07:46	7.46	-09:00-	-
802	07:57	7.57	-09:00-	-
802	07:47	7.47	-09:00-	-

in0900.dbf

Stopid	Max_T01
770	7.55
772	7.56
802	7.57

Attributes of Students.shp

Student_ID	Start	Board	Get_off
1	09:00	7.06	0.00
2	09:00	7.21	0.00
3	09:00	7.36	0.00
4	09:00	7.51	0.00
5	09:00	8.06	0.00
6	09:00	8.21	0.00
7	09:00	8.36	0.00

Figure 4.5 Schedule, summarize and student tables

The summarized table can now be joined to the Stops shapefile. The stops are drawn with a graduated color legend using the boarding times (see [Max_T01] in table in 0900.dbf) forming groups of 15 minutes. Then, after selecting all the stops in one group, beginning with the ones that are farther from SJSU, select the students that are in a half-mile radius and give them the smallest value for that group. This can be done using the "select by theme" option in ArcView.

Figures 4.6 and 4.7 represent the most popular times for classes to start and end, 9:00 a.m. and 20:45 hours. As shown by the data in Table 4.2, one third of the students whose classes start at 9:00 a.m., and two thirds of the students whose classes end at 20:45 hours, cannot take transit, even though they live on a half-mile radius from a direct bus stop or light rail station. The average travel time for the ones taking transit is 33 and 28 minutes.

Table 4.2 Students taking transit at the most popular times

Classes start at 9:00		
Students	Percentage	Travel Time (minutes)
830	31.75%	N/A
205	7.84%	Less than15
654	25.02%	16 - 30
562	21.50%	31 - 45
287	10.98%	46 - 60
48	1.84%	60 - 75
27	1.03%	76 - 90
1	0.04%	91 - 105
2,614	**100.00%**	**33**

Classes end at 20:45		
Students	Percentage	Travel Time (minutes)
1,402	63.30%	N/A
164	7.40%	Less than15
353	15.94%	16 - 30
198	8.94%	31 - 45
67	3.02%	46 - 60
24	1.08%	61 - 75
7	0.32%	76 - 90
2,215	**100.00%**	**28**

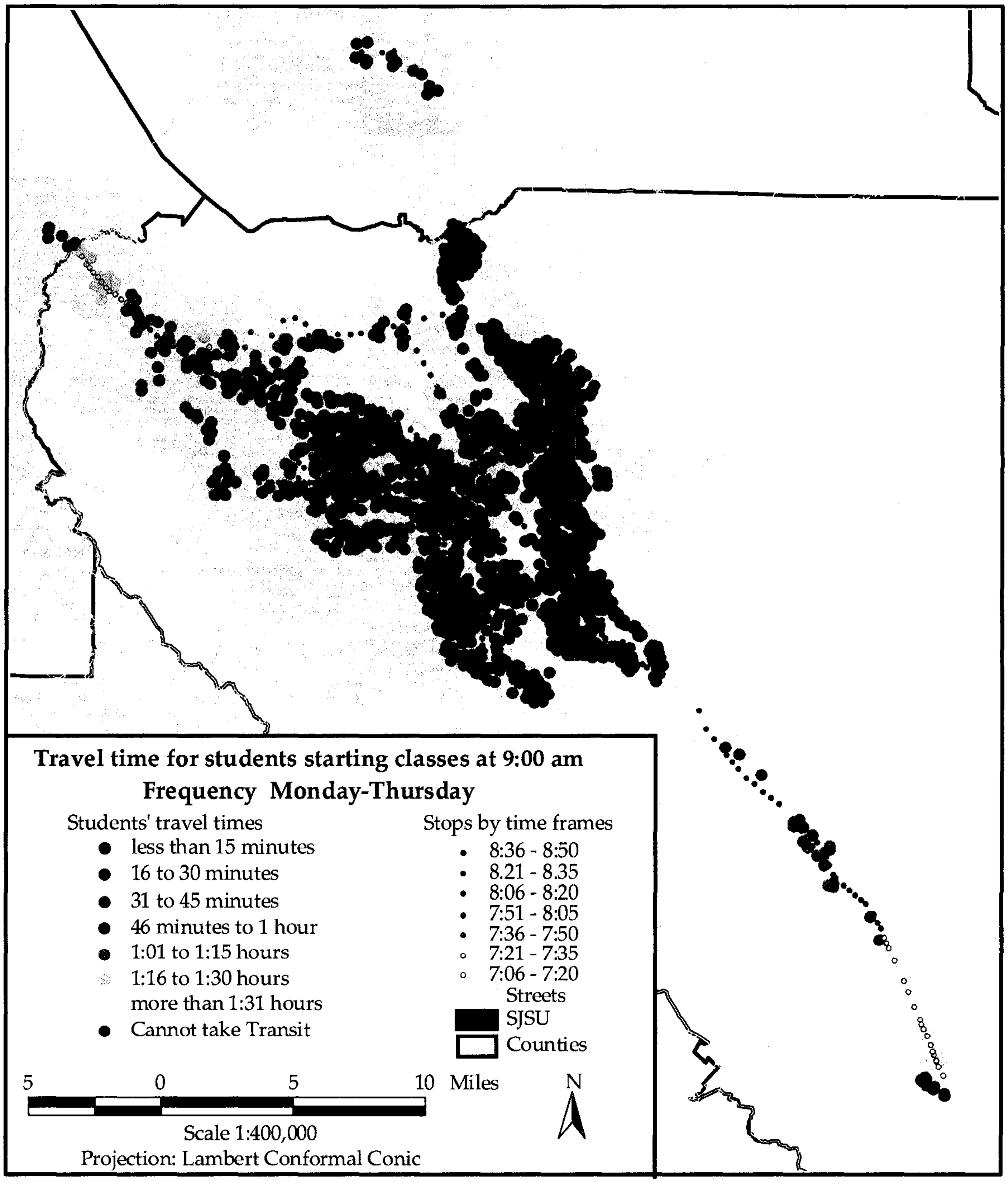

Figure 4.6 Travel time for students starting classes at 9:00 a.m.

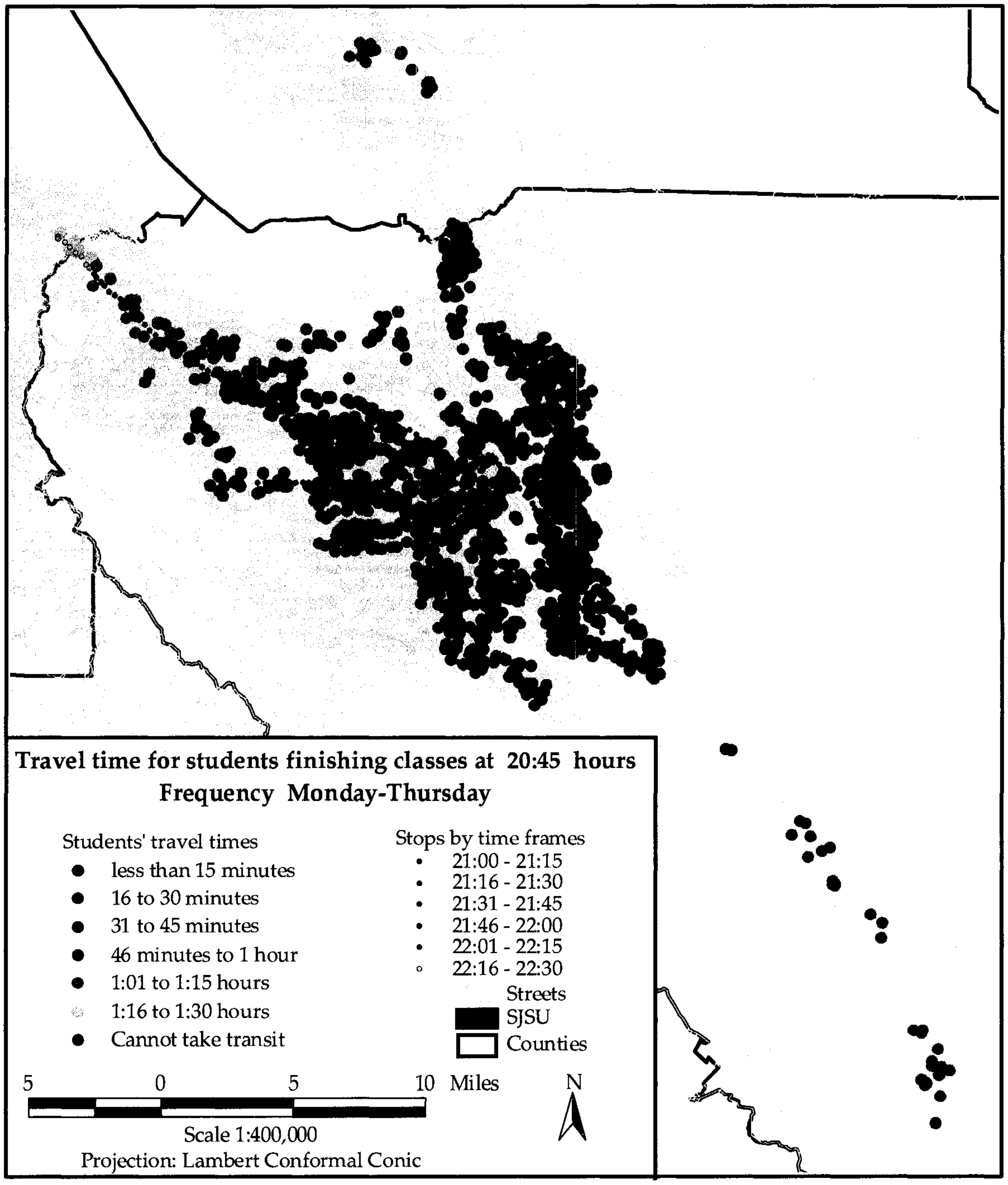

Figure 4.7 Travel time for students finishing classes at 20:45 hours

Figures 4.8 and 4.9 are maps that represent the times when most of the stops are active, for both directions, inbound and outbound. When classes start at 16:15 hours, 678 of 833 inbound stops are active. In the outbound direction, 694 stops out of 865 are active when classes end at 16:40 hours. Very few students need to travel at these times, making the percentage of students that cannot take transit equal to zero in the first case and 16% in the second. The average travel time for the ones taking transit is 57 and 35 minutes.

Table 4.3 Students taking transit at the times when most stops are active

Classes start at 16:15		
Students	Percentage	Travel Time (minutes)
1	25.00%	31 - 45
1	25.00%	46 - 60
2	50.00%	61 - 75
4	**100.00%**	**57**

Classes end at 16:40		
Students	Percentage	Travel Time (minutes)
10	15.87%	N/A
7	11.11%	Less than15
16	25.40%	16 - 30
18	28.57%	31 - 45
8	12.70%	46 - 60
3	4.76%	61 - 75
1	1.59%	76 - 90
63	**100.00%**	**35**

Accessibility including Travel Time is an analysis that would provide the Transportation Solutions Center at SJSU a powerful tool when it comes to negotiate not just the price of the ECOPass program with VTA, but the service that they provide. Most of the routes do not run after 6:00 p.m., cutting the possibility of many students to return home using transit.

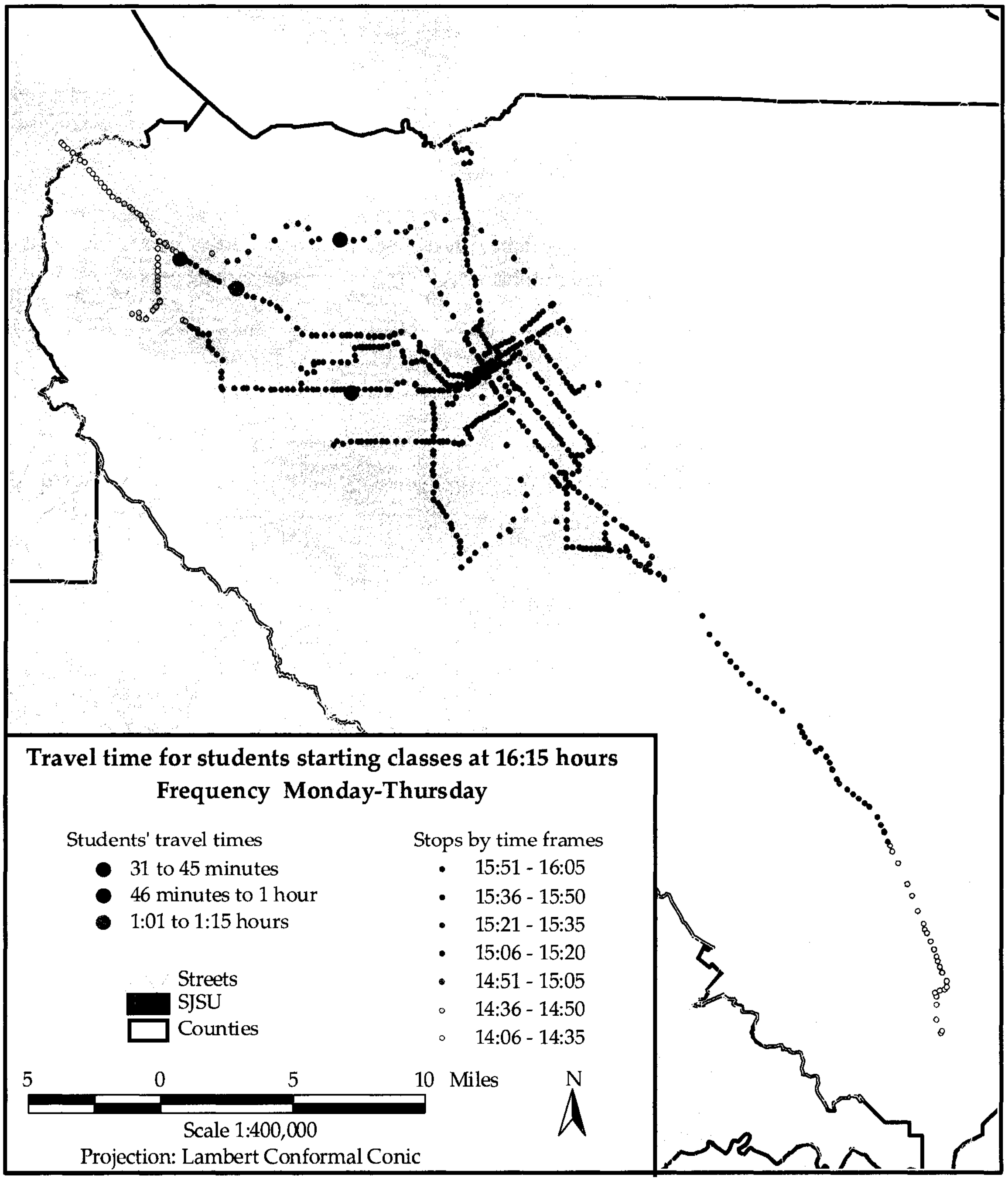

Figure 4.8 Travel time for students starting classes at 16:15 hours

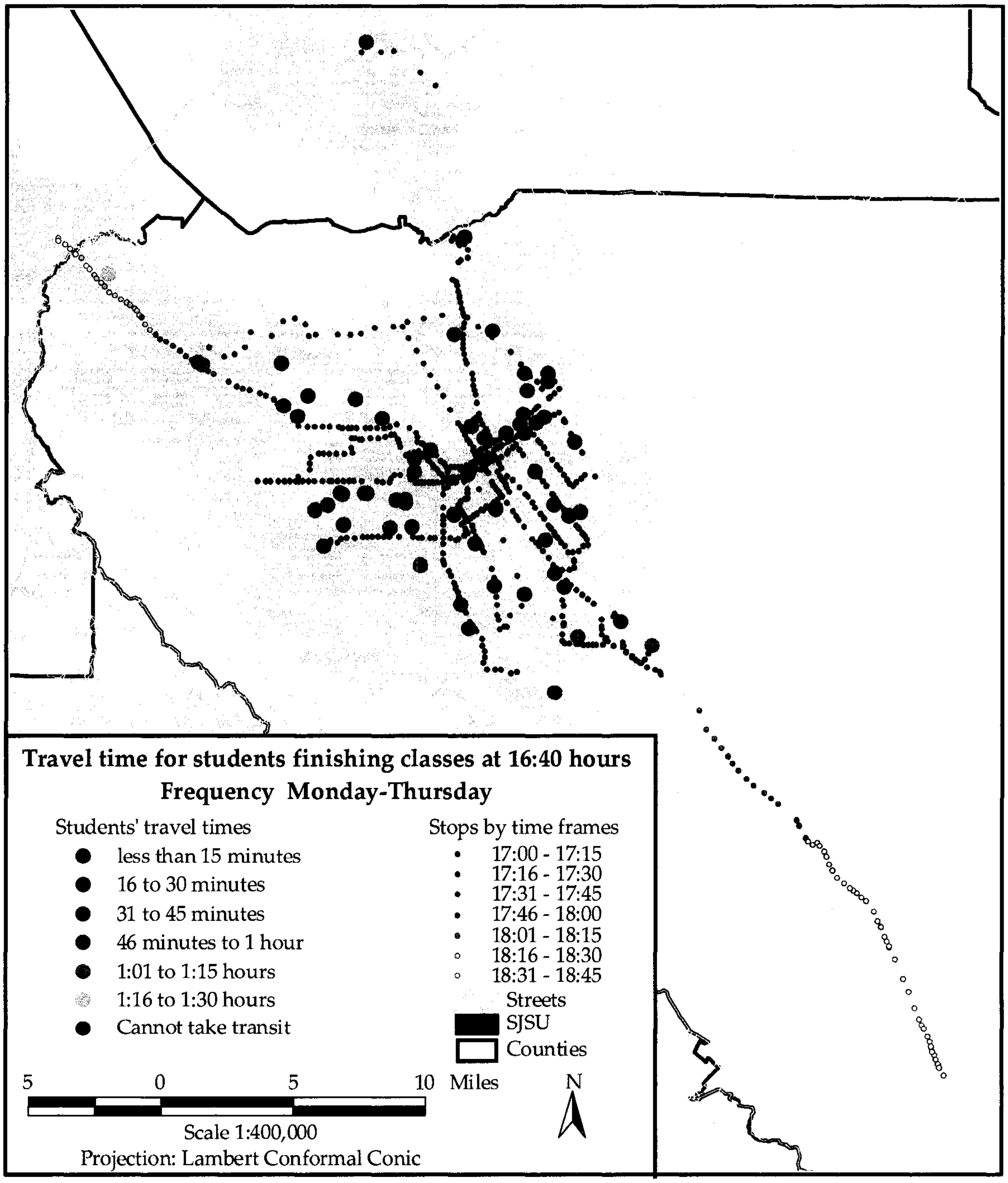

Figure 4.9 Travel time for students finishing classes at 16:40 hours

CHAPTER V

CONCLUSIONS

The study sought to find how many students could be taking transit instead of driving and how much that percentage could increase, compared to the 21.23% of students taking VTA, as the survey for Fall 2004 indicated. Yet the accessibility percentage was expected to be much higher than the 21.24% obtained. A wide gap between both numbers would have suggested a need for the Transportation Solutions Center to work harder and promote the use of transit among SJSU students. To obtain the same percentage means that everybody that has a class schedule that matches the transit schedule is taking public transportation. No amount of encouragement to leave the car at home would push the percentage any higher because no service is available at the time is needed.

As a matter of fact, getting 21.24% as a percentage for accessibility, means that the ridership could only go down, especially if VTA continues to cut back its service by reducing routes or some trips here and there. The transit service should be monitored by preparing the accessibility and travel time analysis every year or semester. Long rush hour driving commutes sometimes prompt commuters to consider switching to public transportation. The problem is that the frequency of service is very low, most of the direct bus routes run just once or twice per hour. Probably the best way to increase ridership would be to increase the frequency of the bus routes, in order to attract more passengers. Moreover, SJSU student ridership could increase even more if the VTA service is improved by the addition of new bus routes or light rail lines.

Getting the data in the appropriate format is cumbersome. Obtaining the shapefiles (bus lines and stops, light rail lines and stations) directly from VTA or the Metropolitan Transportation Commission is recommended. MTC also possess the schedules in an access database format for the entire Bay Area. Having the geographical and the temporal data would make the monitoring of public transit easier.

Though 4,250 bus stops and light rail stations are in the Fall 2004 data, only 1619 stops were analyzed, the ones served by direct routes to SJSU. Besides the two indirect light rail routes, no other indirect bus route was included. This could be an improvement for future studies, only if VTA coordinates its bus and light rail schedules to create convenient timed transfers between routes, where the waiting time for transfers is between four to fifteen minutes.

A third aspect that has to be resolved is the need to develop some programming shortcuts that will facilitate the multiple queries necessary to produce the maps of accessibility and travel times. The process, as described in Chapters III and IV, is long and time consuming. Having an alternative to populate the tables with the appropriate values, almost automatically, would make this project feasible.

REFERENCES

Ashiru, O., Polak, J. W., & Noland, R. B. (2003). *Development and application of an activity based space-time accessibility measure for individual activity schedules.* Retrieved March 17, 2006, from http://econpapers.repec.org/paper/wiwwiwrsa/ersa03p137.htm

Baradaran, S., & Ramjerdi, F. (2001, September/December). Performance of accessibility measures in Europe. *Journal of Transportation and Statistics, 4 (2/3),* 31-48.

Ben-Akiva, M., & Lerman, S.R. (1979). *Disaggregate travel and mobility-choice models and measures of accessibility, Behavioral travel modeling.* Edited by D. Henscher and P.R. Stopher. London: Croom Helm.

Burns, L. (1979). *Transportation, temporal and spatial components of accessibility.* Lexington, MA: Lexington Books.

Campbell, J. (2001). *Map use & analysis.* New York: McGraw-Hill.

Hägerstrand, T. (1970). What about people in regional science? *Papers of the Regional Science Association, 24,* 7-21.

Kwan, M., & Weber, J. (2003). Individual accessibility revisited: Implications for geographical analysis in the Twenty-first Century. *Geographical Analysis, 35 (4),* 341-353

Krygsman, S. (2004). Activity and travel choice(s) in multimodal public transportation systems. Doctoral dissertation, Utrecht University, Utrecht, The Netherlands. Retrieved March 17, 2006, from http://igitur-archive.Library.uu.nl/dissertations/2005-0118-104341/index.htm

Miller, H. J. (1999). Measuring space-time accessibility benefits within transportation networks: Basic theory and computational procedures. *Geographical Analysis, 31,* 187-212.

Miller, H. J., & Wu, Y.H. (1999). GIS software for measuring space-time accessibility in transportation planning and analysis. *GeoInformatica, 4,* 141-159.

Miller, H. J., & Shaw, S.-L. (2001). *Geographic information systems for transportation: Principles and applications.* New York: Oxford.

Morrill, R. L. (1970). *The spatial organization of society.* Belmont, CA: Wadsworth.

Murray, A. T., Davis, R., Stimson, R. J., & Ferreira, L. (1998). Public transportation access. *Transpn Res.-D, 3 (5)*, 319-328.

Taaffe, E. J., & Gauthier, H. L. (1973). Geography of transportation. Englewood Cliffs, NJ: Prentice-Hall.

United States Department of Transportation, Bureau of Transportation Statistics (1997). *Transportation Statistics Annual Report.* Washington, DC.

United States Department of Transportation, Federal Highway Administration (1994). *1990 NPTS Databook, Nationwide Personal Transportation Survey.* Washington, DC.

Wu, Q., & Hartley, J. (2004, September/December). Accommodating user preferences in the optimization of public transport travel, *International Journal of Simulation, 5 (3/4)*, 12-25.