Title

Spatial and Temporal Utility Modeling to Increase Transit Ridership

Authors
Church, Richard L.
Noronha, Val
Lei, Ting
et al.

Publication Date
2005-06-20

CALIFORNIA PATH PROGRAM
INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

Spatial and Temporal Utility Modeling to Increase Transit Ridership

Richard L. Church, Val Noronha, Ting Lei, Wils Corrigan, Shaunna Burbidge, Jim Marston

California PATH Research Report
UCB-ITS-PRR-2005-22

This work was performed as part of the California PATH Program of the University of California, in cooperation with the State of California Business, Transportation, and Housing Agency, Department of Transportation; and the United States Department of Transportation, Federal Highway Administration.

Final Report for Task Order 5102

June 2005

ISSN 1055-1425

California Partners in Advanced Transit and Highways (PATH)

Spatial and Temporal Utility Modeling to Increase Transit Ridership

---

Final Report

Grant Number SA4318

Richard L Church
Val Noronha
Ting Lei
Wils Corrigan
Shaunna Burbidge
Jim Marston

2005 June 20

Vehicle Intelligence & Transportation Analysis Laboratory
NCGIA/Department of Geography, University of California
Santa Barbara CA 93106-4060 USA
www.ncgia.ucsb.edu/vital

Acknowledgements

This research was supported by the California Partners in Advanced Transit and Highways (PATH) under Grant Number SA4318 from the University of California, Berkeley, funded by the California Department of Transportation under Agreement Number 65A0161.

The research was related to and benefited from research conducted by the National Consortium on Remote Sensing in Transportation (Infrastructure Management), at the University of California, Santa Barbara, supported by the United States Department of Transportation (Research and Special Programs Administration) and the National Aeronautics and Space Administration (NASA), contract DTRS-00-T-0002.

In the design, conduct and execution of the research we are grateful for the contribution of Professor Mike Goodchild and the assistance of Ashleigh Day, who served as an undergraduate intern. We thank more than 2300 UCSB faculty, staff and students who participated in the travel survey and offered a variety of valuable comments.

We are grateful to UCSB Transportation and Parking Services, UCSB Transportation Alternatives Board, UCSB Human Resources, UCSB Social Science Survey Center, The Daily Nexus, Santa Barbara Metropolitan Transit District, Santa Barbara County Association of Governments, Coalition for Sustainable Transportation and Coastal Rail Now, for their cooperation and support. We thank Tele Atlas North America Inc (formerly Geographic Data Technologies Inc) for the use of detailed street network data.

The report was prepared in cooperation with the State of California, Business Transportation and Housing Agency, Department of Transportation and the U.S. Department of Transportation Federal Highway Administration.

Abstract

The objective of this research project was to develop a better understanding of the possible alternatives that a large employment center, like the University of California at Santa Barbara, can adopt in order to better utilize transit, mitigate traffic, and reduce demand for on-site parking. Although this project was oriented to the UCSB campus, the techniques and approaches developed in this project were designed to be equally applicable elsewhere. There were three major elements of this project: 1) develop an understanding of commuting employees through the use of a survey, 2) identify spatially whether there exist areas in which transit service is competitive or nearly so to the use of the single occupant vehicle (SOV), and 3) identify whether there are areas in which special express bus routes could provide competitive access to the University. The survey involved more than 2300 university students, faculty, and staff. The survey revealed a number of important points including that nearly 30% of the staff and faculty have never used transit, do not know where their nearest route or bus stop is, and have no knowledge of how to obtain such information. It is clear that converting some employees to using transit will require both incentives and better information. The project also identified a number of other important features of those commuting to work at the University, including the fact that most go directly to and from work without making multi-purpose trips. This fact alone makes it easier to develop special express bus routes to serve the University or convert employees to transit riders. The survey also revealed that a sizable minority ride their bikes to the University. Although data from the survey could not be used to show that there is a statistically significant pattern of ridership within the context of access to Class 1 bike routes, there is reason to believe that a more comprehensive study might reveal whether this occurs. Such a finding could help in understanding the role of bikes in commuting to work, when safe routes are available. The project also focused on the provision of transit services by mapping access times in the journey to the University and the journey to home from the University. Overall, access times are quite large, especially when comparing transit service times to that of using a personal vehicle. As a part of this research, a methodology was developed to map access times, using bus routes, schedules, and time of day. The model identifies for all areas of a region surrounding a large employment center, approximate combined walk and transit travel times. Mapping the ratio of transit service times to personal vehicle travel times to the University, allows one to map those areas where transit service is competitive to using a personal vehicle (i.e. ratio is close to or less than 1). Map results tend to indicate that most of the south coast region is poorly served by transit when commuting directly to the University, where the public transit trip takes at least twice the time as compared to using a personal vehicle. There are, however, some areas that are served with good access to the University; a program might be designed to encourage those residents who live in such areas to use transit. Finally, a special routing model was developed that can be used to design express bus service routes. This model was applied to the South Coast Region about the University, and several routes of high employee coverage were identified. Express routes that are relatively short and which could potentially serve a large number of university employees with commuting service to and from the University may make it possible to reduce SOV trips to the University. All of the tools developed as a part of this project were designed within the context of future application at other centers of large employment. This research was supported by the California Partners in Advanced Transit and Highways (PATH) under Grant Number SA4318 from the University of California, Berkeley, funded by the California Department of Transportation under Agreement Number 65A0161.

Executive Summary

The project set out with two major objectives: (1) to promote the use of transit (as opposed to single occupancy vehicle) for the journey to work throughout North America, with particular focus on large employment centers, and (2) to address a parking crisis at the University of California, Santa Barbara (UCSB). Both objectives could be served by studying commuting patterns at UCSB and developing models to capture the utility elements of time and distance that affect mode choice.

There were three major components to the research. The first was a survey questionnaire administered to the campus community. Although we planned for both hardcopy and web based instruments, the web based version proved extremely popular, and only a handful of hardcopy responses were received. More than 2300 responses were received in all, representing 5–10% of faculty, staff, graduate students, postdocs and undergraduates. No attempt was made to stratify the sampling process—the survey was publicized throughout the campus community and respondents opted in. The response rate was therefore probably higher among those who cared about transportation and sustainability issues. This did not impact the research negatively because the principal purpose of the survey was not to profile the campus community, but to gain numerical estimates on travel time and relative weightings of time and cost. Nevertheless, being one of the most extensive surveys of travel on the campus, many of the findings are useful to campus and local planners.

The survey produced a wealth of useful data on travel habits, e.g. the street address (sometimes multiple addresses) from which respondents travel; the schedule on each day of the week; trip chaining; modal choice, reasons for the choice and impressions of service; travel time; departure from campus during the day for lunch/errands; and telecommuting. The survey directed respondents to various sections depending on their mode. There respondents were asked their reasons for mode choice, and other questions specific to the mode.

In terms of findings relevant to the study, the results mostly reinforced intuitive beliefs regarding travel choices, while producing numerical estimates on various aspects of travel behavior. It emerged that among those who live within 1 km of a bus stop, there is not an appreciable difference in distance between those who use the bus and those who do not. Roughly one third of solo drivers do not know where the nearest bus stop is, have never taken a bus anywhere in the world, and cite among their reasons for driving: "I do not know the bus schedule." Our approach is not to be judgmental about modal choice, but to discover the reasons behind it. Given that those who drive have a negative image of bus travel, while those who do ride the bus are largely satisfied with it, we propose that ridership could probably be promoted by enticing drivers to find their bus stop, pick up the schedules and ride the bus *just once*. We suggest organizing a "Transit Week" event, where drivers are offered a substantial prize for their first ride, and follow-up rewards for sustaining their interest in the mode.

A second major area of effort was to develop maps of transit accessibility. This is not simply distance to the bus route, but also the effectiveness of the bus option, in reaching one's destination by a given time. We developed an innovative GIS tool that analyzed the bus routes and schedules, and determined for any given arrival time, say 08:30, the corresponding departure time from any point in the city, taking into consideration walk time along the street network, and transfers between routes. Similarly for a departure time of say 17:00, the system determined arrival time at any point in the city. Mapping these time surfaces, we were able to document which parts of the city are well served by transit. Furthermore, comparing the accessibility surface with travel time reported by survey respondents, we mapped the ratio of travel time by mode. It emerged that in much of the geographic area of the city, transit time exceeds driving time by a ratio of 2:1 to 5:1, except in the vicinity of the university and the transit center (direct express buses serve the University from the transit center, and after factoring in the time spent searching for a parking spot, drive time actually exceeds transit time).

A third component was to design an express route to serve parts of the city from where travelers have relatively little choice but to drive. One option would have been to "eyeball" a route, based on maps of travel demand. We chose instead to define the problem generically, and to develop an optimization algorithm to solve it. The problem is formally called a "Maximum covering shortest route problem with limited numbers of bus stop locations." The objective is to align a route on the street network so as to maximize the number of customer

locations within walking distance, while limiting the number of stops in order to ensure reasonable travel time. Our focus was on the methodological aspects of the algorithm rather than on the specific route recommendations it produced.

The project was originally conceived as an 18-month study, and because of funding constraints was reduced to 9 months. An important aspect of the research that could not be pursued in this timeframe was inter-agency economics, i.e. examining the economics of a transit agency serving areas of marginal ridership, in the interests of achieving broader community objectives such as reducing congestion, air pollution and parking demand. Realistic policy recommendations could be made only with thorough economic analysis, therefore our approach was to develop generic, innovative methodologies rather than to delve into specifics of local policy.

In that regard, the research produced two major methodological breakthroughs: accessibility mapping and designing a heuristic solution to the express bus route design problem.

Nevertheless, the study raised awareness of transportation and parking issues on campus, and a number of respondents commented that the survey had prompted them to re-examine their choices. We have been in communication with a number of local agencies—UCSB's Transportation and Parking Services (TPS) and Transportation Alternatives Board (TAB), the Santa Barbara Metropolitan Transit District (SBMTD), the Santa Barbara County Association of Governments (SBCAG), the Coalition for Sustainable Transportation (COAST) and Coast Rail Now—regarding the study, its findings and future planning possibilities. In particular, SBMTD is planning an express route in northern Santa Barbara County, and we were able to respond to an agency request for travel demand data from that region, based on the survey findings.

Table of Contents

List of Illustrations

List of Tables

Glossary

Caltrans	California Department of Transportation
COAST	Coalition for Sustainable Transportation
DOT	Department of Transportation
ESRI	Environmental Systems Research Institute, Redlands CA
GDT	Geographic Data Technologies Inc
GIS	Geographic Information System
GPS	Global Positioning System
MSO	Management Services Officer
SBCAG	Santa Barbara County Association of Governments
SBMTD	Santa Barbara Metropolitan Transit District
SOV	Single Occupancy Vehicle
TAB	Transportation Alternatives Board, UCSB
TPS	Transportation and Parking Services, UCSB
UCSB	University of California, Santa Barbara
VITAL	Vehicle Intelligence and Transportation Analysis Laboratory, UCSB

Chapter 1—Issues in Transit Utilization and Parking

Two urgent problems motivate this research. One is the predominant use of Single Occupancy Vehicles (SOVs) in the daily commute to work in the United States, which results in traffic congestion and environmental problems in our cities. This is a matter of considerable concern in the Santa Barbara area, where Caltrans and local planners are currently contemplating the addition of traffic lanes on US Highway 101, to ease congestion in the area (there is also an active lobby against the widening of the highway, and promoting alternative solutions). The second problem is the parking crisis at the University of California, Santa Barbara. The problems are clearly related. This research sets out to address both problems, by gaining a better understanding of the utility issues in choice of travel mode, and proposing innovative solutions.

1.1 Transit utilization

SOV use in the U.S. is higher than in other countries (Hanson 1995), but there are circumstances that contribute to this. Residential neighborhoods in North America all laid out to achieve a number of objectives, including safety and esthetics, and this generally results in sprawling urban structures that are not economically serviceable by transit, and residential street configurations (crescents and cul-de-sacs) that are unfriendly to transit because they make pedestrians walk extended distances to the nearest artery where transit is available.

In dense, high rise cities such as Hong Kong, bus routes are plentiful and services run frequently, with the net result that commuters consider the bus a realistic and viable choice. In contrast, in a relatively small U.S. city like Santa Barbara, the economics of transit do not permit frequent services, and commuters faced with a poorer level of service accordingly opt for other modes. However, if we view the commuting trip from the destination end, large employers such as universities and major industrial plants represent a rare concentration of commuters, in both space and time, and therefore an ideal opportunity to focus efforts on transit utilization. Moreover, large employers may have data on their employees' place of residence and other factors that play a role in modal choice, and these data can be used to understand travel behavior and to offer alternative transportation options that best meet the needs of commuters.

The City of Santa Barbara and the surrounding area of California's South Coast have experienced phenomenal increases in property prices over the last decade, with the median house price currently roughly a million dollars. Consequently many workers now live in surrounding communities such as Ventura to the east, and Buellton and Santa Maria to the north. This eliminates the options of walking and biking to work, and adds to the commuting burden in the region, not just on city streets but also on inter-city highways.

Our approach to the issue of modal choice is not judgmental, but seeks to understand the choices and constraints that commuters face. There are those with no option but to take public transit because they do not own a car, and live too far away to walk or bike. At the other end of the scale are those who are well served by transit but steadfastly refuse to use it, for reasons entirely related to ego and personal comfort. Between these extremes are those who have a choice of mode, and are able and willing to switch, on occasion or on a regular basis. An effort to promote transit must target these individuals in the first instance. This project seeks to understand commuting patterns at the University of California, Santa Barbara (UCSB), using a survey, various institutional databases, and local transit schedules.

1.2 Parking at UCSB

The second problem that motivates this research is the parking crisis at the main UCSB campus. The academic standing of the institution has risen dramatically over the last decade, and this has unfortunately had some negative consequences for driving commuters. First, there has been an accelerated pace of new construction, for research centers and expanded facilities. New structures occupy land that was formerly devoted to open parking lots. Secondly, the enhanced reputation has brought with it larger student numbers and visitors, and therefore a greater demand for parking, at a time when supply is decreasing. Despite the recent construction of multi-story parking garages, adding more than 1000 spaces on the supply side, demand started to exceed supply in 2002, and the deficit is growing at roughly 1000 spots per year.

The capital cost of providing each spot in a new parking structure is roughly $25,000. University of California policy is not to subsidize the cost of employee parking; therefore, this capital cost must be recovered through parking fees, which currently stand at about $35 a month. Parking fees would have to double over a short time, to fund the construction of new garages. The challenge is therefore to manage demand so as to delay new garage construction. Current and future measures are discussed in the next section.

1.3 Current and Potential Solutions

UCSB has been aware of the impending parking crisis and has taken steps to alleviate it. A transportation alternatives program has been operating for several years, encouraging carpooling and biking, and there is an annual Bike to Campus Day. This activity has now been formalized and reorganized. Transportation and Parking Services (TPS) is the campus unit in charge of initiatives and management of parking, and a Transportation Alternatives Board (TAB) brings together faculty, staff and students, to consider new policies and measures.

Solutions to UCSB's parking crisis fall into 3 broad areas: improving parking management, improving the utility of existing alternatives to driving, and expansion of these alternatives. The latter measures benefit the community as well as UCSB, by reducing the number of SOVs.

1.3.1 Parking Management Options

Some parking management initiatives have already been implemented, or are in the process:

- Raise parking rates. Employees naturally consider this unfair, particularly considering that staff have few options because of housing costs. On the other hand, one could argue that the $440 annual cost of a parking permit is less than the annual cost of bus fares ($522), and significant rises in parking rates are inevitable.
- Re-stripe parking lots to accommodate more vehicles. This was done in 2001, resulting in a small increase in capacity.
- Stack/valet parking. Stack parking was implemented in 1998, as a temporary measure while new lot construction was in progress. In 2003 it was re-introduced in some lots, and it is likely to be a longer-term solution. The general principle of stack parking is to utilize aisle space. Upon arrival, drivers hand their car and keys to a valet, who "double-parks" the vehicle in an available aisle. This inevitably means that those who wish to leave during the day must (a) note the number of the vehicle parked in their way, (b) summon a valet to remove that vehicle. Valet parking ends at 18:00 hrs, and drivers are required to go to campus police to retrieve their keys after this time (drivers may carry a second set of keys to get around this problem). Valet parking can save time arriving on campus, because one no longer has to search for a spot. But it often delays departure from campus.

Figure 1. Valet-assisted "stack" parking may become a permanent feature of the campus

- Promoting shorter occupancy. Traditionally, daily parking permits could be purchased at kiosks at two campus entrances. In 2003, all campus spots were assigned numbers, and fixed/mobile solar-powered short-term permit dispensers were installed in all lots. A driver now parks in an available spot, notes the spot number, and buys time for that spot at a kiosk. The kiosk wirelessly communicates transactions to TPS, and enforcement officers have handheld devices that report the current payment status of each spot. Moreover, drivers can subscribe to a service that issues a notification to a cell phone when time is running low, and they can recharge the spot over the phone. UCSB is the first campus in the country to implement this technology. Facilitating shorter occupancy encourages drivers to minimize their use of parking space, effectively reducing demand.
- Reserved parking spots for carpoolers. For the 2003-2004 academic year, car poolers were assigned reserved spots, as an incentive. This policy has now been discontinued.
- Restricting parking permits. Undergraduate students living within 3 km of campus are refused parking permits.
- Off-site parking with shuttle. Parking lots with minimal day-time use (e.g. churches, shopping centers) could be used for UCSB vehicles, in return for compensation, with a shuttle services provided to campus.

1.3.2 Improving Utility of Alternative Transportation

A second set of measures, currently implemented or in process, seeks to promote alternatives to driving by addressing cost and time considerations:

- UCSB students ride the local transit service to campus at no charge. A flat fee is charged by the student union to subsidize this.
- Promote van pools. UCSB actively encourages car pooling and van pools, and offers free reserved parking to pool vehicles.
- Bus services ply from outlying communities. The Coastal Express and Clean Air Express, operated by the Santa Barbara County Association of Governments (SBCAG), offer an alternative to driving. For UCSB riders the bus service is not ideal because it stops in downtown Santa Barbara, adding 30 minutes to the trip. The MTD is now introducing a new service to communities to the north and west.
- Promote bikes: There are racks for 40,000 bikes on campus. UCSB offers showers for bike riders, as well as free membership to the recreational athletic facilities. To address the concerns of owners of expensive bikes, new bike lockers are being provided for a fee.
- Parking holidays: Drivers who switch from parking permits to any form of alternative transportation may claim up to 3 days of free parking each quarter.
- Provide emergency vehicles: The campus is acquiring a fleet of emergency vehicles for alternative transportation users.

1.3.3 Potential Solutions

In addition to the measures above, we propose that the following options, simple and advanced, could potentially be implemented in the future:

- Use of transponders, occupancy sensors, and in-vehicle or external displays, to notify drivers of the number and location of available spots.
- Demand-responsive pricing, that would favor parking on days and at times of low demand (Fridays, late afternoon). This would encourage discretionary and non-time-bound activities to be scheduled accordingly. Long-term parking permits could also be issued for specific days of the week.
- Scheduling classes and events at times of low parking demand.
- Providing “last mile” shuttle service to the train station. Currently, train service is limited and entirely unsuitable to commuting, with the first passenger train arriving at 12:00 hrs. The Coalition for Sustainable Transportation (COAST) and Coastal Rail Now are working with the railroads to introduce commuter rail service to Goleta station. If that initiative is successful, UCSB is committed to providing last mile services from Goleta station.
- Tracking and notification systems to improve the utility of bus services. In Santa Barbara this is of questionable value because buses tend to run on time.

- Organized telecommuting.
- Active campaigns to promote transit.

1.4 Research Questions

The solutions presented above are most self-evident and require little or no research. Missing from that set of solutions is the provision of better transit services, maximally responsive to the place and time of commuter demand.

The focus of this project is on provision of new express transit services to supplement existing service. As stated above, the key to increasing transit ridership is to target individuals who have multiple options, where the utility of transit is currently lower than that of other options, and where relatively small improvements in utility (cost, time, etc.) can achieve a change in mode choice.

Utility factors can be seen as lying on a scale, from those that we can influence, to those that we can't. Listed here are some likely utility factors:

- Place—proximity of bus routes and stops to place of residence;
- Time—including uncertainty of time, and suitability of schedules to traveler needs;
- Cost—at least visible and conscious cost factors (e.g. maintenance costs of automobiles tend to be invisible and may not feature in a traveler's calculations)
- Convenience, shelter, and security
- Trip chaining: e.g. the need to drop a child off at daycare or shop on the way home
- Comfort, professional image and need for personal control over one's schedule and movements.

Items at the top of the list are most easily influenced externally, e.g. by providing appropriate services. Those towards the bottom of the list are least easily influenced.

Improving utility amounts to offering service in the "right" places, at the "right" time, with the "right" quality of service (cleanliness, shelter, security). Generally the right time is one that minimizes total travel time, including waits at stops; the right place for a stop is one that minimizes walking distance. Areas that are poorly served at present need to be identified, and service deficiencies redressed. These are intuitively true, but the precise elements of utility and their relative dominance are matters for research to establish.

While all this improves options from the traveler's point of view, the economics of offering such service from the provider's standpoint also need to be addressed. Will new services gain a sufficient market of riders to make them economically viable? Given the high cost of expanding the parking supply at UCSB, the University may well find it advisable to subsidize an uneconomical route in cooperation with transit providers. (The economics of this cooperation are not within the scope of the current research project, but bear investigation in the future).

1.5 Research Approach

The approach taken in this research is first to establish the elements of utility in mode choice. We do this by means of an opt-in survey of faculty, staff and students. We ask respondents what mode of travel they use and the reasons for the choice. A few questions are designed to explore points of indifference between alternatives. Chapter 2 of this report describes the design and administration of the survey and discusses the responses.

Second, in Chapter 3, we examine the accessibility of locations in the city and surrounding area to existing transit service. This can be viewed as a level of transit service to UCSB. By geo-coding the transit routes and timetables, we can compute for any given arrival time on campus (say 08:30), the time at which one must commence one's trip, including walk time to the bus stop, transfers, and walk time at the destination end. We can therefore calculate travel time and represent it as a "3-D surface" (analogous to a contoured elevation map) that shows for any point in space the total travel time to UCSB. The surface for arrival at 09:00 is slightly different, because transit schedules change. A similar calculation can be run for a given departure time. By mapping mode choice on the accessibility map, we can estimate the number of travelers who are well served by transit but choose to drive, and conversely those who live further away but walk to the bus stop—the survey questions shed light on why respondents make these choices.

The third step is to compare travel times across modes, for different parts of the city at different times of day. This shows for example that over very short distances a bike is most effective (traffic lights and parking add to total travel time by car), the bus can be extremely fast from certain points, particularly on express routes, and the automobile is a reasonable option for places that are both too far to bike and far removed from transit routes. This information is useful for UCSB's Transportation and Parking Services (TPS) and Transportation Alternatives Board (TAB) in promoting alternatives transportation.

Chapter 4 combines the previous two components, comparing drive time as stated in the survey against travel time as calculated from the bus schedule, for a given time of arrival and departure. The results are presented as maps, showing ratios of bus time to drive time.

The fifth component of the project is to design, in the light of the above findings, express routes that best serve populations with a low level of service. This could be done by visual examination of the map or by algorithmic optimization. We define a covering problem that aligns a route so as to maximize demand served within walking distance, while minimizing trip time. The algorithm and route design are described in Chapter 5.

Chapter 6 presents conclusions and recommendations.

Chapter 2—UCSB Travel Survey

2.1 Survey Design

In the original project design, the survey was designed to poll drivers (identified from Parking records) to determine why they chose to drive and not take transit. For a number of reasons in the course of the study it became more meaningful to survey as large a portion of the campus body as possible, whether drivers or alternative transportation users, to gain a broader understanding of transportation to campus, and to benchmark the drivers' responses. Moreover, by using the internet as a survey instrument, it was possible to simplify the logistics of the survey, albeit at the cost of introducing elements of bias.

In general, the purpose of the survey was:

(a) to gather basic statistics on use of transportation: the number of times per week that respondents traveled at all; mode choice and variability in choice; stops en route to and from campus; mid-day departures; and possibilities for telecommuting

(b) to understand stated reasons for mode choice and to correlate mode choice with possible causal factors such as distance to the nearest bus stop, age and gender;

(c) to compare utility factors in decision making and to find points of indifference, e.g. the perceived time value of a bus transfer (as opposed to a direct route), and the relative utility of cost and time.

The survey was structured into 5 parts. Part A, to be completed by all respondents, contained 15 questions, mostly establishing the parameters of travel need: where they live, how often they travel to UCSB and at what times. The last question in Part A concerned the frequency of use of different modes of transportation. Based on this answer, the respondent answered additional parts: B (bus), C (carpool/rideshare), D (walk, bike and other), E (drive alone). Each of Parts B, C, D and E consisted of about 10 questions, the last of which was a freeform field for extended comments.

Part A sought home address (with street number rounded to the nearest 100, for privacy), alternate address from which commuting takes place (e.g. place of work, in-laws' house), gender, medical condition that affects choice of transportation, and day-by-day schedule for leaving the point of departure, arriving on campus, beginning work, and leaving campus. The schedule question also asked whether the respondent was required to come in, and whether he/she did come in, each day of the week. There were questions on activities en route to and from work (dropping off children at daycare, shopping), and how essential these activities were (this would allow us to correlate en-route activity with transit use). The following question asked how often the respondent left the campus during the week for lunch and errands, and again, whether this was essential or discretionary activity (this was to assess the need for emergency day-use transportation for non-drivers).

Parts B through E asked the reasons for mode choice, and some questions sought estimates of travel time to develop a travel time surface for each mode.

The text of the questionnaire is attached to the report as Appendix A. The questions are listed individually later in this chapter, with their respective responses.

2.2 Administering the Survey

Because clearance to begin the project was received much later than planned (April 2004 rather than Fall 2003), it became essential to accelerate the schedule of the survey so as not to exclude the 20,000 undergraduates and others who would be leaving campus during the summer months. Although undergraduates constitute a large proportion of all travelers to UCSB, many of them live in the relatively low-cost Isla Vista neighborhood adjacent to campus, or in campus housing, and reach campus by bike or walking. Undergraduates living within 5 km of campus are ineligible for parking permits, and undergraduate lots are generally those further removed from the center of campus. For these reasons our primary focus for many critical findings was on those who use the more central lots: faculty, post-doctoral researchers and graduate student assistants (who are permitted in academic parking lots) and staff. Nevertheless, the very large number of potential undergraduate responses would be extremely useful for calibrating models, for example relating distance to travel time.

The survey was designed for two media: hardcopy and web form (administering the questionnaire via the web and recruiting respondents by e-mail required specific Human Subjects approval). A web site was set up describing the study, with a pointer to the survey form. A Spanish version was made available in hardcopy and offered on the web site for download in PDF format, alongside an English PDF. The URL was initially circulated to faculty and graduate students within the Department of Geography, and the initial responses were used to refine the structure and wording of some questions. Next the URL was circulated by e-mail to all departments on campus via their respective Management Services Officer (MSOs), with a request to circulate it to faculty, graduates and undergraduates. Based on the responses, we conclude that very few if any undergraduates received this, but there was a 5–10% response rate from faculty and staff across campus.

We printed roughly 500 hardcopies of the survey, and 1000 copies of a 1-page flier describing the study and its URL. We handed these out in person at the most popular congregation points on campus, mostly to undergraduates. An article on the survey in the campus student newspaper, *The Daily Nexus*, helped the publicity (*www.ucsbdailynexus.com/news/2004/7673.html*). This effort yielded about 100 undergraduate responses, but required 10 hours of field presence and considerable prior work preparing a stall and banners.

To reach undergraduates en masse by e-mail, we were required to use a campus mass mailing service, for a $200 fee. There were administrative delays, and the e-mail was sent late on Friday night on the last day of the academic quarter, after the final exams. Given these circumstances, the response was most heartening: more than 700 responses in the first 24 hours, and more than 1500 during the week. In fact the 9.1% response from undergraduates eclipsed the 8.5% from faculty, 6.5% from graduate students, and 5.4% from staff.

One factor in the generally good response rates was that we offered prizes in a random draw: a MP3 player as first prize, and for runners-up, gift certificates to the University book store and a fruit juice vendor. To register for the prize drawing, respondents had to provide their name and contact phone number. More than 2% of respondents did not enter the drawing but provided complete answers to the questionnaire.

We had planned a GPS component in conjunction with the survey, to place GPS units in the vehicles of volunteer respondents, to record their route, departure and arrival times (particularly the amount of time taken to find a parking spot at different times of day), among other information items. Unfortunately this required a separate Human Subjects protocol to be approved, and the data would have had to be coarsened to protect respondent privacy (e.g. home address). There was also the potential that the respondent's vehicle may be driven by a minor in the course of the observation period. Due to Human Subjects concerns and the amount of effort required to instrument multiple respondents' vehicles, it was decided not to pursue this component. Travel time would be computed from the regular survey data. Nonetheless, the GPS component was publicized at the web site, and about 100 respondents volunteered.

2.3 Sources of Bias

There are several sources of bias in the survey, due to its design and the way it was administered, and the nature of some questions.

- Among non-undergraduates, awareness of the survey relied on the assistance of departmental MSOs, and this may not always have been effective. The response was much better in some departments than others. Because the survey publicity relied on e-mail, there were groups who could not reasonably have been notified, e.g. custodial staff. Although a Spanish version of the questionnaire was offered, no Spanish responses were received.

- By its very nature, the survey was of greater interest to those with a higher awareness of alternative transportation issues, and those with a long-term interest in the campus and efficiency of its operations. Because sampling was open and uncontrolled, the survey may present a picture of a campus more friendly towards alternative transportation than it really is.
- There was little insurance against multiple responses from the same person, and the prospect of a prize may have been an incentive for some to exploit this. As a partial defense, we notified respondents that their IP addresses would be recorded. We did not actually use IP address to filter out what may have been duplicate submissions. Considering the circumstances under which students use computers, it is not reasonable to conclude that multiple responses from the same computer belong to the same person, or that a determined person would not use different computers to submit multiple entries. A small number of records were deleted for lack of content, or because they were submitted at about the same time and had identical or nearly identical entries.

These sources of bias affect some conclusions, while they are irrelevant to others. For example, our figures indicate that 60% of all travelers to campus drive alone, whereas earlier surveys suggested 80%. This could suggest considerable progress in awareness of alternative transportation, or it could be the result of a biased sample. On the other hand, questions regarding travel time to campus from various parts of the city are not affected by such bias, and improbable responses are filtered out simply based on logic. In most instances the purpose of the survey was to calibrate models rather than to present findings. For example, on the matter of the subject's home address, we do not rely upon the survey to produce a representative map of home addresses, because this information is more easily produced from the complete listing of personnel records, obtained from Human Resources. Instead the survey yields information on travel time, and it serves to calibrate the travel time model for a sufficient number of spatially well distributed points. An uneven sampling does not affect this.

In general, the evidence was that respondents identified with the issues of travel and parking on campus and were even passionate about them: (a) there was a large proportion of free-form comments (545 in 2300 responses), and (b) there was good logical consistency, e.g. those who claimed Bike as their predominant form of transportation also filled out Part D; modal split percentages were in general entered painstakingly, and summed to 100% in nearly all cases.

2.4 Survey Results

Not all the survey responses were of direct relevance to the aims of the study; however, they serve to understand the commuting picture, and serve information needs of UCSB Transportation and Parking Services (TPS), the Santa Barbara County Association of Governments, the Metropolitan Transit District, and alternative transportation advocacy groups such as the Santa Barbara Bike Coalition.

This section treats each question individually, describing its purpose, sources of bias, and principal results. This is a rich set of data and the results could be analyzed in many ways with a variety of cross-tabulations. Only a few results, most relevant to the project goals, are shown.

2.4.1 Part A—General

This introductory section was designed to be answered by all respondents. It sought information on home and other locations, and daily commuting schedules.

1. My status at UCSB is

❑ Undergraduate Student ❑ Graduate Student ❑ Staff ❑ Faculty ❑ Other ______________

Purpose: Classification of respondent, subsequent correlation with Human Resources data.

Sources of bias/error: Misunderstanding. It was not practical to include all classifications, and some undergraduates who had just completed their exams classified themselves as “Other.” “Postdoc” was added as a category in the on-line version.

Principal findings:

Table 1. Respondent status groups

Status	Respondents	% of campus total
Faculty	88	8.5%
Staff	329	5.4%
Grad	194	6.5%
Undergrad	1617	9.1%
Postdoc	40	
Other	37	
Blank	11	
Total	2316	

The lower response rate from "staff" is because the publicity for the survey probably reached full-time staff, not part-time staff. Full time staff are roughly half of all staff.

2. Please enter your street address, rounded to 100. For example, instead of 116 Pine Lane, write 100 Pine Lane (no suite numbers required). This is to protect your privacy. If you do not feel comfortable providing even this information, please skip this question.

Street Address: ______________________________

City: ______________________________

If your trip to UCSB regularly originates at or returns to a **place other than home** (e.g. work), please enter that address here. Treat this place as "home" except for questions 4 and 5 below. Note: this does not refer to intermediate stops on the route. If you have 2 or more other addresses, check here ❑ and use the dominant one.

Street Address: ________________________

City: ________________________

Purpose: To geocode the respondent's origin on a map, to determine proximity to transit, and to correlate travel time with distance. The alternate address (e.g. place of work, in-laws' house) question was designed to resolve apparent errors and inconsistencies in cases where the home address is an unrepresentative origin.

Sources of bias/error: Inaccuracy due to rounding of address to the nearest 100 does not create a significant error. Some respondents provide their campus address.

Principal findings: Only 142 respondents (4%) left the address field blank. The map of respondents (Figure 2) shows a concentration of undergraduates in the Isla Vista neighborhood west of campus, a few further west in the Ellwood region, and more in the downtown area to the east. Faculty, staff and postdocs are more evenly distributed throughout the Goleta and Santa Barbara areas.

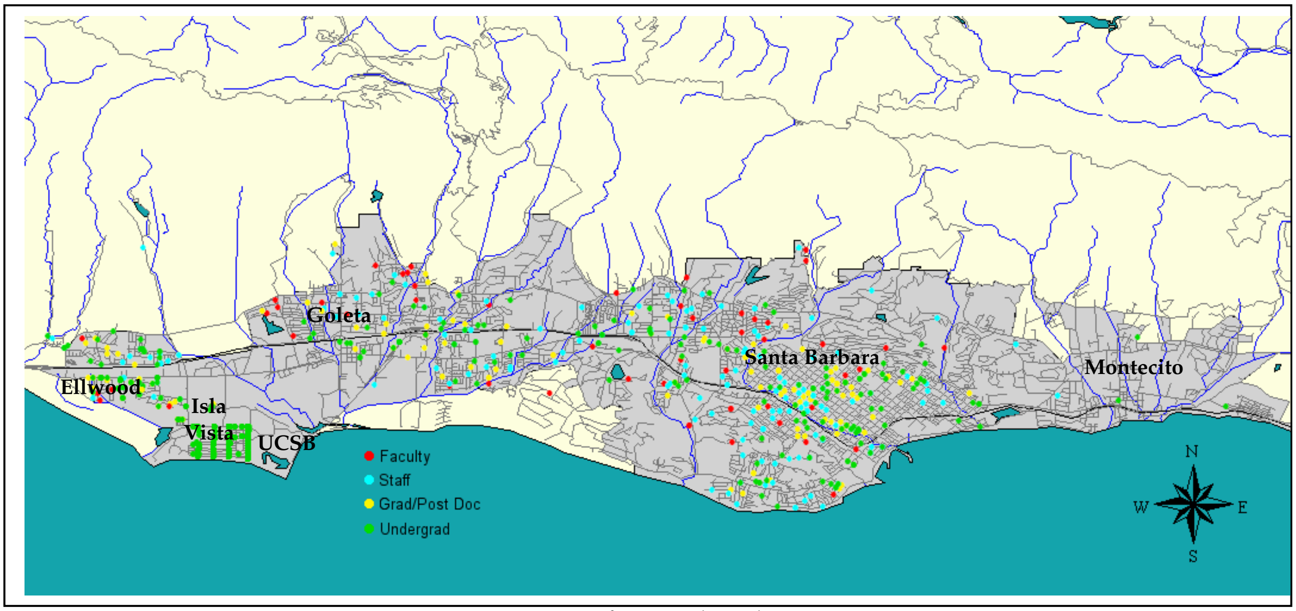


Figure 2. Map of respondents by status

3. I am

❏ Female ❏ Male age … ❏ below 35 ❏ 35-55 ❏ over 55

Purpose: To classify the respondent and observe correlations with transit use, particularly with regard to willingness to walk to a bus stop, and sense of security.

Sources of bias/error: A very small proportion of respondents declined to answer the question: 31 declined gender, 42 declined age. It is impossible to estimate the number of deliberate misrepresentations.

Principal findings: Undergraduate respondents were predominantly female. Other respondents were evenly balanced by gender.

Table 2. Respondent status

Status	Respondents
Male	916
Female	1369
Below 35	1899
35-55	300
Over 55	75

4. I have a long term impairment or medical condition that affects my choice of transportation

❏ No ❏ Yes → ❏ Visual/Hearing/Speaking ❏ Difficulty/inability to walk ❏ Other ________________

Purpose: To isolate impaired respondents for separate calculation of perception factors.

Sources of bias/error: No unusual sources.

Principal findings: 56 respondents (2.4% of respondents) claimed physical disabilities that affected their choice of mode. They offered a range of details from reasonable (bad knees, diabetes, hypoglycemia, lumbar herniation, pregnant, cannot ride bicycle) to trivial (“lazy and always late”).

5. My usual schedule for arriving at UCSB is

	I come in from	Leave (out the door) at		Arrive at office/class at	Begin work/class at	I'm not **required** to come in	I **do not** come in
Monday	❑ Home ❑ Other	:	❑ pm	:	:	❑	❑
Tuesday	❑ Home ❑ Other	:	❑ pm	:	:	❑	❑
Wednesday	❑ Home ❑ Other	:	❑ pm	:	:	❑	❑
Thursday	❑ Home ❑ Other	:	❑ pm	:	:	❑	❑
Friday	❑ Home ❑ Other	:	❑ pm	:	:	❑	❑

6. My usual schedule for leaving UCSB is

	Departure time		I go from UCSB to
Monday	:	❑ pm	❑ Home ❑ Other
Tuesday	:	❑ pm	❑ Home ❑ Other
Wednesday	:	❑ pm	❑ Home ❑ Other
Thursday	:	❑ pm	❑ Home ❑ Other
Friday	:	❑ pm	❑ Home ❑ Other

Purpose: Breakdown of travel/parking demand by day of week, computation of travel time from different origins, at different times of day.

Sources of bias/error: No unusual sources. Some responses had to be edited because there were different ways of formatting time—a drop-down method of entry was considered too laborious for respondents.

Principal findings: Questions 5 and 6 produced extremely rich data, useful to local agencies and UCSB-TPS. We were able to respond promptly to a request from the Santa Barbara Metropolitan Transit District, for tabulations of arrival time by city of origin, to help plan a new service from northern Santa Barbara County (Santa Maria, Lompoc, Buellton) to UCSB. The following are sample tabulations of the data.

Arrival time reflects the rigidity/flexibility of duties. Staff are typically first to arrive, and are governed by strict work hours.

Table 3. Average travel time by hour

	Arrival 08:00	Arrival 08:30	Arrival 09:00	Arrival 10:00
Faculty	00:32:25	00:24:26	00:26:53	00:36:18
Staff	00:31:42	00:36:31	00:25:25	00:30:00
Graduates/postdocs	00:30:49	00:25:25	00:25:13	00:29:48
Undergraduates	00:19:30	00:27:27	00:19:12	00:19:19
Overall Average	00:22:56	00:28:26	00:21:01	00:22:36

An unexpected and unexplained finding is that the percentage of all respondents who depart from or return to a location other than home declines, significantly and consistently, during the course of the week.

Table 4. Non-home arrivals and departures

	M	T	W	TH	F
Depart from	5%	4%	4%	3%	3%
Return to	3%	2%	2%	1%	1%

8. I regularly make these stops on the way to/from UCSB (check all that apply)

❑ I drop off/pick up family/friend **off campus** at daycare/school/work ❑ Shopping ❑ Other __________

How important are these stops? ❑ Important part of my schedule ❑ I could easily get by without doing this

I make these stops on the way from …	Home to UCSB	UCSB to home
Monday	❑	❑
Tuesday	❑	❑
Wednesday	❑	❑
Thursday	❑	❑
Friday	❑	❑

9. I leave campus during the day for lunch/errands

❑ 5 or more times a week ❑ 1-4 times a week ❑ Rarely ❑ Never

How important are these trips? ❑ Important part of my schedule ❑ I could easily get by without doing this

Purpose: Questions 8 and 9 are designed to correlate transit use with multi-purpose activity, and thereby to temper expectations based strictly on map analysis, i.e. commuters may apparently be located on a transit route, but if they have intermediate destinations, or a need to travel in the course of the day, transit may not serve their needs adequately. Question 9 estimates the need for a day-use vehicle fleet.

Sources of bias/error: Despite the clear wording of the question, some respondents may confuse drop-off with carpooling.

Principal findings: Nearly 10% of all respondents drop somebody off on the way to work. Among non-undergrads, the figure is 14%—this is to be expected because a larger proportion of these respondents are likely to have families. More than twice as many respondents make stops on the way from work than on the way to work.

Table 5. Stops en route

	All respondents		**Non-undergraduates**	
	Home to UCSB	UCSB to home	Home to UCSB	UCSB to home
Mon	9%	20%	12%	25%
Tue	9%	19%	11%	26%
Wed	9%	21%	12%	25%
Thu	9%	20%	11%	25%
Fri	7%	19%	10%	22%

Table 6. Mid-day trips

Status	**5/wk**	**1-4/wk**	**Rarely**	**Never**	**Could get by without it (%)**
Faculty	2	5	59	21	80%
Staff	16	74	178	56	67%
Grads/postdocs	6	37	131	58	78%
Undergrads	293	616	444	212	60%
Total	317	732	812	347	63%

Senior faculty place greater value on the social-professional lunch off campus. Currently this is slightly constrained by parking difficulties, i.e. the difficulty of finding a parking spot after lunch; a switch to transit would make this much more difficult, and this may be an issue in mode choice. (Anecdotally, a Nobel laureate at UCSB reports that he drives from home to within 2 km of a bus stop, takes a brisk walk, and uses transit for the final leg to work).

The off-campus lunch habit can be accommodated by a flexible parking fee structure that allows a regular user of alternative transportation to park for the occasional day.

10. Things I consider in my choice of transportation

	Not a factor	Small factor	Big factor
Low cost	❑	❑	❑
Quick travel time	❑	❑	❑
Flexibility to leave/arrive whenever I choose	❑	❑	❑
Comfort/convenience	❑	❑	❑
Safety	❑	❑	❑

Purpose: Stated factors in mode choice

Sources of bias/error: Stated choice may differ from revealed choice.

Principal findings: Faculty and staff consider travel time and flexibility to be the biggest factors in their choice of transportation mode with cost, comfort and convenience, and safety represented slightly less than the aforementioned categories. For graduate students, post docs, and undergraduates, the trio of cost, travel time, and flexibility are equally represented as the biggest factors while comfort, convenience, and safety are considered a big factor by fewer respondents. When separating responses by sex and age, far more females than males consider safety to be a big factor when choosing a transportation mode. The other factors are represented in about equal proportions, recalling that there are about half again as many female as male respondents.

Table 7. Stated considerations in mode choice, "big factor" citations by status

Status	Cost	Travel time	Flexibility	Comfort/ convenience	Safety
Faculty	20	59	72	36	37
Staff	170	227	215	170	192
Grads/postdocs	156	155	176	104	80
Undergrads	1111	1264	1144	853	624
Total	1457	1705	1607	1163	933

Table 8. Stated considerations in mode choice, "big factor" citations by age and gender

Age/Gender	Cost	Travel time	Flexibility	Comfort/ convenience	Safety
Female	882	1058	979	753	653
Below 35	790	914	826	642	529
35-55	78	113	130	90	103
Over 55	12	28	20	19	20
Male	568	643	624	409	275
Below 35	484	528	507	332	192
35-55	67	82	82	52	60
Over 55	10	25	29	23	21

11. The bus stop nearest to my home is

Stop/street ___________________________ on MTD Route #_____ ❑ Check here if you don't know

Walking time to this stop is ❑ <3 minutes ❑ 3-8 minutes ❑ 8-12 minutes ❑ >12 minutes ❑ Don't know

Purpose: To measure walking time; to compare respondent's estimate of "nearest" stop with that inferred by geographic analysis; to estimate numbers for whom transit may be an option but have not investigated it to the point of knowing where the nearest stop is.

Sources of bias/error: Minimal. This input is easily verified by geographic analysis. The interpretation of "nearest to my home" may vary. A respondent may take a route that gets to work earliest, but the stop for that route may not be the shortest walk.

Principal findings: Average walking time is 5.26 minutes for transit users, and 5.34 for non-users. This calculation assumes that ">12 min" is represented as 15 minutes. Table 9 reports only on those who live within 1 km of a bus stop in the Santa Barbara, Goleta and Carpinteria areas. Shorter distances dominate among transit users—this is expected. Notably, shorter distances also dominate among non-users. Based on the averages and distribution, it is reasonable to conclude that there is not a large difference in level of service (measured strictly by walking distance to the nearest stop) for users and non-users. There are more "Don't know" responses among non-users, as expected.

Table 9. Nearest bus stop, by utilization (limited to those living within 1 km of a bus stop)

	< 3 min	3-8 min	8-12 min	>12 min	Don't know
Transit users	70	58	20	16	1
Non users	421	255	114	86	334
Total	491	313	134	102	335

Table 10. Nearest bus stop, by status

	< 3 min	3-8 min	8-12 min	>12 min	Don't know
Faculty	10	20	7	7	11
Staff	52	61	23	22	29
Grad/postdoc	69	55	29	6	20
Undergrad	360	177	75	67	274

12. I have access to an automobile and can afford to drive myself to UCSB (and pay parking fees)

❑ Not at all ❑ 1-3 days per week ❑ 4 or more days per week

Purpose: To correlate with mode choice. To estimate numbers who do not have the option to drive.

Sources of bias/error: Minimal.

Principal findings: As expected, most faculty and staff have access to a private vehicle, while most undergrads and many grads do not. One could speculate that this is mostly an affordability issue, but it is also true that students tend to live within walking or biking distance of campus.

Table 11. Access to a private vehicle

Status	Not at all	1-3 days/week	4 or more days/week
Faculty	9	7	68
Staff	35	41	239
Grads/postdocs	75	41	93
Undergrads	800	351	387
Total	919	440	787

13. In my opinion, because of the nature of my duties, telecommuting/working from home would be a practical option if my supervisor allowed it

❑ Not at all ❑ 1-2 days per week ❑ 3 or more days per week

My supervisor would probably ❑ approve ❑ not approve ❑ I don't know

Purpose: Telecommuting is an attractive option from a travel/parking management standpoint. On the other hand there are drawbacks to telecommuting, particularly in collaborative situations, and while institutional policy may encourage it, individual supervisors may not. This question investigates the conflict between the respondent and his/her supervisor's view.

Sources of bias/error: Minimal.

Principal findings: Omitting undergraduates, 342 of 689 respondents (just under 50%) consider telecommuting to be a practical option. If all of those respondents did telecommute the minimal amount according to their responses, 490 trips to and from campus could be avoided each week. Extrapolating to the campus population, that is roughly 1000 trips each day. While faculty and grads expect supervisor approval of telecommuting by a wide margin of 3:1, only half of staff respondents expect approval—this is to be expected, given the nature of duties of the respective groups. A surprisingly large number of undergraduate respondents consider telecommuting as a viable alternative to travel to campus.

Table 12. Telecommuting option

Status	Not at all	1-2 days/week	3 or more days/week	Supervisor approve	Supervisor disapprove	Don't know
Faculty	31	41	8	44	10	15
Staff	155	136	31	74	76	151
Grads/postdocs	102	91	35	92	37	80
Undergrads	955	194	196	93	553	590
Total	1243	462	270	303	676	836

14. My usual modes of transportation for travel other than to UCSB are (check all that apply)

❑ Drive alone ❑ Drive with family ❑ Carpool/rideshare with non-family ❑ Bus ❑ Bike
❑ Walk ❑ Other ___________________

Purpose: To draw out the contrast (if any) between habitual non-work travel and work travel.

Sources of bias/error: Minimal.

Principal findings: A large majority of drivers choose to drive when traveling to destinations other than UCSB. The majority of carpoolers drive and bus riders also drive. Few respondents who drive or carpool take the bus for other trips, while not insignificant proportions bike or walk. For those respondents who bike or walk to campus, many drive for trips not to UCSB, although most bike or walk for those trips.

Table 13. Comparison of mode: non-UCSB travel (columns) and UCSB travel (rows).

	Drive alone/family elsewhere	Carpool elsewhere	Bus elsewhere	Bike elsewhere	Walk elsewhere
Drive alone to UCSB	725	168	54	123	177
Carpool to UCSB	113	44	23	33	34
Bus to UCSB	153	70	121	75	109
Bike to UCSB	749	440	249	758	580
Walk to UCSB	130	98	66	70	176

15. My usual mode(s) of transportation to UCSB are (enter a rough estimate of the percentage of trips in each mode)

Drive alone	________% of trips (Part E) ❑ Ride*	Bike	________% of trips (Part D)
Carpool	________% of trips (Part C) ❑ Off-campus**	Walk	________% of trips (Part D)
Bus	________% of trips (Part B)	Other	________% of trips (Part D)

If you usually get a ride to UCSB: ***If someone makes a dedicated trip from home to drop you off, enter this as Drive Alone and check the Ride box. ** If someone drops you off on the way to a place **other than UCSB, enter this as Carpool and check the Off-campus box.

Purpose: This is the principal mode-choice question in the survey. We deliberately avoid characterizing respondents as exclusive users of one mode or another; rather, each respondent splits his/her trips by mode. The purpose of the question is primarily to direct respondents to appropriate sub-parts of the survey. It also documents the degree to which those who drive (and presumably have parking permits) use other modes, indicating the need for flexible policy and pricing.

Sources of error/bias: To recap a point made above, because the survey sampling is not controlled, it is likely that those who opted to respond to the survey have a greater awareness of alternative transportation than average; therefore, the findings on this question do not necessarily represent the true modal split.

Principal findings: The table of dominant mode (absolute) indicates the magnitude of modal demand. Given that the response rate is generally 5–10%, total demand size is 15–20 times these numbers.

Table 14. Dominant mode (absolute)

	Drive alone	Carpool	Bus	Bike	Walk
Faculty	53	7	7	21	0
Staff	185	58	34	42	2
Grads/postdocs	53	15	55	101	7
Undergrads	322	39	113	852	208
All	613	119	209	1016	217

The table for dominant mode (proportion) generally mirrors findings in a 1996 UCSB study of faculty and staff, which showed that (a) driving is a predominant mode among both groups, (b) in terms of alternative modes, faculty, who can afford to live in the Santa Barbara area, tend to bike, whereas staff, who live in satellite communities, tend to carpool more. This table also shows that many undergrad students live close enough to walk, which bears out our common knowledge of the community. The 1996 study showed 80% of faculty and staff driving; here the numbers are closer to 60%, which may reflect greater awareness of alternative transportation, but it is also probably the result of sampling bias.

Table 15. Dominant mode (proportion for each status group)

	Drive alone	Carpool	Bus	Bike	Walk
Faculty (n=88)	60%	8%	8%	24%	0%
Staff (321)	58%	18%	11%	13%	1%
Grads/postdocs (231)	23%	6%	24%	44%	3%
Undergrads (1534)	21%	3%	7%	56%	14%
All (2174)	28%	5%	10%	47%	10%

2.4.2 Part B—Bus Riders

The bus section of the questionnaire seeks information on reasons for mode choice, quality of service, and "first mile" mode. Respondents provide detailed information on the bus routes and stops used, and transfers. Note that bus is the dominant mode among only 10% of respondents.

B1. I don't drive to UCSB because (check all that apply)

❏ I don't have a car ❏ It costs too much to operate a car ❏ It's not good for the environment
❏ UCSB parking costs too much ❏ UCSB parking is hard to find ❏ Trip (including parking) takes too long

Purpose: Stated reasons for not driving, and motivation for riding the bus

Sources of bias/error: Minimal.

Principal findings: In all but one category (faculty walkers/bikers), the most often given reason for not driving is the cost of parking. Undergraduates are more concerned about car costs than the environment while faculty, staff, graduate students, and post docs more often consider the environment. However, overall costs of car and parking outweigh all other concerns. The parking issue is not cited by many bus riders as a reason for not driving; among bikers and walkers, the problem of finding parking is exceeded only by parking costs, as a reason not to drive.

Table 16. Bus riders' reasons for not driving

	No car	Car costs	Environment	Parking cost	Find parking	Too long
Faculty	2	4	8	4	1	0
Staff	13	27	28	32	22	5
Grads/postdocs	11	35	38	57	32	8
Undergrads	113	107	63	153	85	41
All	139	173	137	246	130	54

The same question was asked of walkers/bikers. The table of those results is presented here rather than in the walk/bike section, for ease of comparison:

Table 17. Walkers'/bikers' reasons for not driving

	No car	Car costs	Environment	Parking cost	Find parking	Too long
Faculty	1	8	15	7	6	2
Staff	6	22	36	37	27	8
Grads/postdocs	15	44	71	84	48	30
Undergrads	354	362	258	756	571	375
All	376	436	380	884	652	415

B2. I ride the bus to UCSB because it is (check all that apply)

❏ convenient ❏ inexpensive ❏ better for the environment ❏ the only transportation available to me

Principal findings: In general, convenience and cost are the two principal reasons offered for riding the bus. A large number of respondents cite environmental considerations—among faculty, this is the principal reason for choosing the bus. Relatively few (84), mostly undergrads, state that it is the only available option.

Table 18. Bus riders' reasons for riding the bus

	Convenient	Inexpensive	Environment	Only option
Faculty	5	7	10	1
Staff	30	35	33	10
Grads/postdocs	51	65	44	8
Undergrads	116	160	79	65
All	204	267	166	84

B3. Please rate the bus service in Santa Barbara by checking one box in each line

	Disagree	Neutral	Agree
The bus works well with my schedule	❑	❑	❑
The distance from my home to the bus stop is reasonable	❑	❑	❑
The bus is usually punctual	❑	❑	❑
The bus is comfortable	❑	❑	❑
Overall, the time taken by bus to UCSB is reasonable	❑	❑	❑

Purpose: The same question was asked of other mode users, for comparison. We hypothesize that bus riders have a more favorable view of the utility of the bus, particularly in areas of comfort and punctuality.

Sources of bias/error: Minimal.

Principal findings: Scoring "Agree" as 1, "Neutral" as 0 and "Disagree" as -1, the following results compare responses across modes:

Table 19. Impressions of bus service, average score by mode user group

	Bus (n=344)	Carpool (n=150)	Bike/Walk (n=1378)	Drive (n=710)
The bus works well with my schedule	0.52	0.19	0.00	-0.06
Distance from home to stop is reasonable	0.80	0.48	0.68	0.78
The bus is usually punctual	0.50	0.43	0.34	0.28
The bus is comfortable	0.52	0.57	0.40	0.22
Time taken by bus to UCSB is reasonable	0.59	0.45	0.46	0.44

In general, only bus riders agree that the bus works well with their schedule, and drivers generally disagree. The responses show evidence of attitudinal bias. Carpoolers appear to live furthest from bus routes, making them the best candidates to drive alone, and they rate the comfort factor on buses twice as high as solo drivers do. Drivers have a surprisingly positive impression of the distance to the nearest bus stop, but time appears to be the most important issue in their mode choice, yet their low rating of bus comfort suggests that the convenience of the car is important. This question repeats some of the themes in Question 10 (Things I consider in my choice of transportation), and consistencies/inconsistencies between the responses may be further investigated in terms of stated and revealed choices.

B4. How do you reach the bus stop near your home?

❑ Walk to bus stop
❑ Bike to bus stop
❑ Drive to bus stop: do you then park: ❑ on the street ❑ in a parking area

Purpose: To gauge the validity of estimating travel time by modeling trip from home/origin to bus stop as a walk (accessibility model, Chapter 3)

Sources of bias/error: Minimal.

Principal findings: The vast majority of bus riders walk to the bus stop, while only few ride a bike and even fewer drive. Access to parking near bus stops and minimal space for bicycles on the bus may be limiting factors.

Table 20. How bus riders reach the bus stop

Mode	Number of responses
Walk	302
Bike	39
Drive	17

B5. Using this means, how long does it take to get to the bus stop near your home?

❏ < 3 minutes ❏ 3-8 minutes ❏ 8-12 minutes ❏ >12 minutes ❏ I don't know

Purpose: Comparison with modeled travel time to bus stop.

Sources of bias/error: For the few who take different bus routes on different days (e.g. to arrive at different times), the question fails to capture the subtlety.

Principal findings: Average walking time is 4 minutes and 45 seconds; the average biking time is 5 minutes and 50 seconds; and, the average driving time is 6 minutes and 36 seconds.

Table 21. Time taken to reach bus stop

Mode	< 3 min	3-8 min	8-12 min	> 12 min	Don't know
Walk	135	103	40	21	3
Bike	9	19	8	2	1
Drive	3	7	2	3	0

B6. My bus routes to campus are (fill out all that apply)

At _____:____ (am/pm) I leave from (stop/street) ______________________on (MTD Route #) __________

I transfer at (stop/street) ____ to (MTD Route #) __________

I transfer at (stop/street) ____ to (MTD Route #) __________

Purpose: Comparison with modeled route choice.

Sources of bias/error: Errors possible in entering stop/street and correlating them with stop/street as described in transit time table. Error is minimized by identifying the route number.

Principal findings: This is an error estimation component. Analysis would require that a sample of responses be compared with algorithmic route choices. This is laborious and could not be pursued given the other focus areas of the study.

B7. If you transfer, consider this scenario: suppose there was a direct bus that had no transfers but took a longer route. How much longer a ride would you accept, in exchange for the convenience of no transfers?

❏ 2 minutes ok ❏ 3-5 minutes ❏ 6-10 minutes ❏ 11-20 minutes ❏ 21-30 minutes ❏ 31+ minutes

Scan the list from left to right and pick your decision point → → →

Purpose: To estimate the perceived time value of a transfer. We hypothesize that potential transit users discount the transit option because a transfer is involved, i.e. for non-users, the perceived time value of a transfer is greater than the actual inconvenience value.

Sources of bias/error: This is a value judgment, with inherent estimation problems.

Principal findings: Among 113 riders who do transfer, the average (calculated by weighted-averaging the mid-point of the ranges presented) is 6.1 minutes.

B8. How long does it take to get from the campus bus stop to your office/class?
❑ < 3 minutes ❑ 3-8 minutes ❑ 8-12 minutes ❑ >12 minutes ❑ I don't know

Purpose: To calibrate the corresponding walk in the accessibility model.

Sources of bias/error: Answer can vary, particularly among students who may go to different destinations each day, but the question does not allow for multiple responses. Furthermore the survey does not ask where on campus the respondent goes—since this again potentially varies by day.

Principal findings: Very roughly, the average trip from the bus to place of work is 6½ minutes.

Table 22. Time taken from bus stop to place of work

Mode	Number of responses
< 3 minutes	42
3-8 minutes	168
8-12 minutes	78
> 12 minutes	22
Don't know	8

B9. Are you seriously considering a switch to other methods of transportation?
❑ Driving alone ❑ Carpooling ❑ Biking ❑ Walking ❑ Other ___________________________

Purpose: To estimate willingness to change. The same question was asked of other mode users, for comparison.

Sources of bias/error: Minimal.

Principal findings: More people are considering switching from biking or walking to another form of transportation than those using any other mode; however, the majority of those are switches from biking to walking or vice versa. Omitting those 286 respondents, drivers are the group with the most respondents considering switching modes, and many more are interested in a switch from car to carpool/bus than vice versa.

Table 23. Number of respondents interested in switching from current mode (row) to another mode (column)

Current mode ↓	Switch to Bus	Switch to Carpool	Switch to Bike/walk	Switch to Drive
Bus	N/A	30	91	41
Carpool	19	N/A	35	7
Bike/walk	68	60	286	100
Drive	94	93	160	N/A

2.4.3 Part C—Carpool/Rideshare

C1. How many times in the past 6 months have you used the public bus system in Santa Barbara?
❑ More than 10 times ❑ 5-9 times ❑ 1-4 times ❑ I never take the bus

Purpose: To compare responses in C3 among those who use the Santa Barbara transit system and those who have not. Also to gauge whether respondent habitually discounts transit as an option, or whether it is only the UCSB trip that is unsuitable to transit use. The response must be interpreted within the context of other answers, e.g. the respondent may live at an address that is poorly served by transit, or may get a free ride to UCSB. The question was asked to all non-transit users, for comparison.

Sources of bias/error: While responses are confidential and it is not our intention to be judgmental, there is a blunt community-value awareness component inherent in the question, and responses may be doctored in favor of more frequent transit use.

Principal findings: The majority of both drivers and carpoolers have not ridden the bus in the past six months. A majority of bikers and walkers do ride the bus with about 20% of them riding often.

Table 24. Number of times respondents used bus for any travel in Santa Barbara, last 6 months (all non-bus modes)

Mode (to UCSB)	More than 10 times	5-9 times	1-4 times	Never ride bus
Carpool	37	14	27	100
Bike/walk	245	133	333	648
Drive	58	31	117	447

C2. When and where did you last use any public bus system?

❑ Within the last 12 months City/Country:___________________________________
❑ Within the last 5 years City/Country:___________________________________
❑ Never

Purpose: To compare responses in C3 among groups who have varying degrees of experience of other transit systems.

Sources of bias/error: Minimal.

Principal findings: Most respondents have ridden a bus sometime in the past five years although many of them listed a city other than Santa Barbara and more than a few listed a country other than the United States.

Table 25. Last use of transit, anywhere (all non-bus modes)

	Last 12 mos	Last 5 years	Never
Carpool	78	51	37
Bike/walk	740	359	291
Drive	275	197	177

C3. I tend not to use the bus to UCSB because (check all that apply)

❑ Bus service is not available near my home
❑ Bus is not frequent enough
❑ I don't know the bus schedule
❑ I would need to transfer routes ______ times
❑ I carry heavy loads to work
❑ I drop a family member at daycare/school
❑ I don't feel safe at a bus stop
❑ I travel at a different time every day and the bus schedule is too rigid for my needs
❑ Bus arrives at UCSB at an unsuitable time
❑ Nearest bus stop is too far away
❑ I don't like to wait for a bus
❑ Bus trip to UCSB takes too long
❑ Bus stops are not well sheltered in the event of bad weather
❑ I need to leave campus/run errands during the day

Purpose: This question seeks stated reasons for not taking the bus. Some reasons are substantial (service not available) while others are deliberately frivolous (I don't know the bus schedule; I don't like to wait for a bus). Some bear substantiation by GIS analysis (nearest bus stop is too far away; trip takes too long).

Sources of bias/error: Possible confusion between cause and effect: items may be checked *because* respondent does not ride the bus.

Principal findings: Some of the high scoring responses were predictable, e.g. don't like to wait, trip takes too long. A surprising result was the number of respondents who stated that they didn't take the bus because they did not know the schedule—roughly 30% overall. Based on these numbers, bikers and walkers apparently exert considerable physical effort because they don't know the bus schedule. We suspect that some respondents check "Don't know schedule" merely because it is true on its own, not because it is a factor in modal choice. We revisit the issue of schedule ignorance later in the report, and propose remedies.

Table 26. Reasons for not using the bus (all non-bus modes)

	Carpool (n=119)	Bike/walk (n=1233)	Drive alone (n=613)
Not available	38	88	113
Unsuitable time	37	291	176
Not frequent	41	394	231
Too far away	17	147	105
Don't know schedule	35	518	194
Don't like to wait	40	676	236
Need to transfer (# times)	20	30	64
Trip takes too long	52	382	263
Carry heavy loads	21	68	129
No shelter	17	121	95
Drop off family	6	11	72
Errands	21	243	194
Not safe	9	42	42
Schedule rigid	38	426	205

C4. I use carpool/rideshare to UCSB because (check all that apply)

- ❑ It is convenient
- ❑ It costs less
- ❑ I can stop at daycare/school, etc
- ❑ Pick up/drop off is close to my home
- ❑ It is the only type of transportation available to me
- ❑ It is faster than other modes of transportation
- ❑ I can talk to people I know
- ❑ I read/get work done during my trip
- ❑ I get designated carpooler parking space

Purpose: Stated reasons for carpooling.

Sources of bias/error: Minimal. Likely to be less error-prone than "guilt" questions above.

Principal findings: Convenience, in its several forms, is the predominant reason for respondents to carpool. Bear in mind that the principal carpoolers are staff.

Table 27. Reasons for car pooling

Reason	Number of responses (n=119)
It is convenient	116
It is faster than other modes	76
It costs less	78
I can talk to people I know	62
I can stop at daycare/school	14
I read/get work done	16
Pick up/drop off is close to home	58
Designated parking space	4
Only mode available to me	13

C5. How many people share your car pool (including you)? __________

Purpose: To estimate decrease in parking and traffic demand by carpooling.

Sources of bias/error: With ad-hoc carpools, ridership can vary by day.

Principal findings: The average car pool size is 3.6 with a range of 2 to 15.

C6. Did UCSB's Transportation & Parking Services (TPS) put you in touch with your carpool companions?

❑ No, I ride with friends/family ❑ TPS helped a lot ❑ TPS could have done more _______________

Purpose: To gauge the role of facilitation in organizing car pools, and to gather suggestions.

Sources of bias/error: Minimal.

Principal findings: 80% of respondents are self-organizing; only 25% were facilitated by TPS. No specific suggestions for TPS involvement were entered.

C7. How often do you drive alone, using the free daily parking passes that come with the carpool permit?

❑ Don't know about free passes ❑ Know, but never use them ❑ 1-3 times/month ❑ 4 or more times/month

Purpose: To evaluate the utility of occasional-parking permits granted by TPS for users of alternative transportation.

Sources of bias/error: Minimal.

Principal findings: A plurality of carpooling respondents did not know about the free daily parking passes. For other carpooling respondents the average usage was approximately 1.5 times per month.

Table 28. Use of free daily parking pass

Response	Frequency (n=119)
Didn' t know about them	55
Never	33
1-3/mo	45
4+/mo	11

C8. How much later could you leave home if you drove alone in your own car?

❑ No difference ❑ 1-10 minutes ❑ 11-20 minutes ❑ 21-30 minutes ❑ More than 30 minutes
❑ I don't know/I don't have access to a car

Purpose: To evaluate the time value of car pooling versus driving alone

Sources of bias/error: Respondent's estimate error.

Principal findings: The average time saved by driving would be six minutes, although about half would save no time at all.

Table 29. Time-cost of car pooling (compared with solo driving)

Time difference	Number of responses (n=119)
No Difference	69
1-10 min	27
11-20 min	22
21-30 min	13
Don't know/Driving not an option	8

A surprisingly large number report no difference, and the frequency drops over increasing time intervals. This information is encouraging, and it can be used to promote car pooling.

2.4.4 Part D—Walkers, Bikers, Other

D5. I walk/bike to UCSB because (check all that apply)

- ❑ It serves as exercise
- ❑ It allows me flexibility in my schedule
- ❑ It costs less
- ❑ It is faster than other modes of transportation
- ❑ It is environmentally friendly
- ❑ It is the only form of transportation available to me

Purpose: Stated reasons for walking/biking.

Sources of bias/error: Minimal

Principal findings: Few respondents stated that biking or walking was their only mode of transportation to and from UCSB. Other categories were chosen with approximately equal frequency except for environmental friendliness, which was chosen slightly fewer times.

Table 30. Reasons for walking/biking

Reason	Number of responses (n=1233)
Exercise	1066
Faster than other modes	1014
Flexibility in schedule	1141
Environmentally friendly	862
Costs less	1122
Only mode available to me	276

BIKERS ONLY

D6. How long is the walk from the bike stand to your office/class?

❑ < 3 minutes ❑ 3-8 minutes ❑ 8-12 minutes ❑ I don't know

Purpose: To estimate total travel time for bikers.

Sources of bias/error: Judgment error.

Principal findings: The average walk is just over three minutes, half the time reported by bus riders. This is reasonable given that there are numerous bike racks on campus, but there is only one bus stop.

Table 31. Walking time from bus stop to office/class

Walking time	Number of responses
< 3 minutes	851
3-8 minutes	273
8-12 minutes	98
Don't know	59

2.4.5 Part E—Drive Alone

E4. I drive to UCSB because (check all that apply)

- ❑ It is convenient
- ❑ I can listen to my favorite radio station
- ❑ I can stop at daycare/shopping/etc
- ❑ It is the only type of transportation available to me
- ❑ It costs less to drive
- ❑ It is faster than other modes of transportation
- ❑ It allows me flexibility in my schedule

Purpose: Stated reasons for driving alone.

Sources of bias/error: The options contain a mix of significant reasons (e.g. can stop at daycare) and relatively trivial justifications (e.g. convenient, can listen to favorite radio station). In cases were driving is discretionary and poorly justified, some respondents may cite more significant reasons.

Principal findings: Convenience (convenient and faster) and flexibility (stop at daycare/shopping and allows flexible schedule) are far and away the most predominate responses.

Table 32. Reasons for driving alone

Reason for driving alone	Number of responses (n=613)
Convenient	619
Costs less	64
Listen to favorite radio station	199
Faster	506
Stop at daycare/shopping	328
Allows flexible schedule	596
Only mode available	103

E5. I park …

❑ On campus, in Lot # ________ Permit type ❑ A ❑ S ❑ C ❑ Other _________

❑ Off campus and get in by ____

Purpose: To estimate off-campus parking numbers. It is assumed that those without parking permits use alternate transportation, and new express routes are generally designed to serve drivers, assuming their options are limited. This question shows to what degree that assumption is valid. Lot number indicates whether respondent encounters valet/stack parking, which is employed only in some lots. "Get in by …" sheds light on prevalence of unusual mode combinations.

Sources of bias/error: Minimal.

Principal findings: A significant number of undergrads park off-campus, for a number of reasons: (a) cost, (b) the number of parking spaces for undergrads is restricted, (c) those living close to campus are not eligible for parking permits.

Table 33. Parking

	On campus	Off campus
Faculty	45	0
Staff	167	6
Grads/postdocs	52	10
Undergrads	274	64
All	538	80

E6. How long is the walk from the parking lot to your office/class?

❑ < 3 minutes ❑ 3-8 minutes ❑ 8-12 minutes ❑ >12 minutes ❑ I don't know

Purpose: To estimate total travel time for drivers.

Sources of bias/error: Judgment error.

Principal findings: The average walking time is five minutes and 15 seconds, much more than for bikers and slightly less than from the bus stop.

Table 34. Drivers' walking time from parking lot

Walking time	Number of responses
< 3 minutes	208
3-8 minutes	289
8-12 minutes	150
Don't know	0

E7. How do you feel about valet parking (provided in some lots)?
❑ Not available where I park ❑ I avoid it as far as possible ❑ I don't mind it ❑ I like it

Purpose: Assess attitude toward valet parking

Sources of bias/error: Minimal.

Principal findings: Very few respondents like valet parking.

Table 35. Attitude towards valet/stack parking

Attitude towards valet parking	Number of responses
Avoid it	267
Don't mind it	148
Like it	42
Not available where I park	235

E9. A <u>quarterly</u> parking permit (now $110) could get more expensive. At what point would you switch to other transportation?
❑ $120 ❑ $150 ❑ $180 ❑ $210 ❑ $240 ❑ I would still drive alone with a $240+ fee hike
Scan the list from left to right and pick your decision point → → →

Purpose: While this question can be interpreted as exploring the "breaking point" regarding parking permit pricing, it really is designed to estimate the relative utility of price, relative to time and other utility factors.

Sources of bias/error: Judgment error.

Principal findings: The average "breaking points" are approximately: $210 for faculty, $191 for staff, $180 for graduate students and post docs, and $175 for undergraduates. The proportion of respondents willing to pay more than $240 is high: 40% of faculty, 50% of staff, and 25% of undergraduates.

Table 36. Maximum acceptable parking permit price (quarterly)

	$120	$150	$180	$210	$240	$240+
Faculty	3	7	5	11	6	22
Staff	20	37	34	20	5	56
Grads/postdocs	9	16	10	5	0	7
Undergrads	79	76	41	28	6	74
All	111	136	90	64	17	159

E10. Alternately, suppose the only available parking were off-campus with a shuttle, adding several minutes to travel time. At what level of delay would you switch to another form of transportation?* If the shuttle added …

❑ 1-5 min ❑ 6-10 min ❑ 11-15 min ❑ 16-20 min ❑ 21-30 min ❑ I would still drive at 30+ min delay

Scan the list from left to right and pick your decision point → → →

Purpose: This is intended to estimate the utility of time, in comparison to cost and other utility factors.

Sources of bias/error: Judgment error.

Principal findings: The average decision points are fairly similar from one group to another: 14 minutes for faculty and staff, 13.5 minutes for graduate students and post docs, and 12 minutes for undergrads. For all respondents, the decision point is just over 13 minutes. In general, undergraduates would be slightly less tolerant of delay than the other groups. The proportion of respondents willing to bear more than a 30 minute delay is much lower than the proportions willing to tolerate unbounded increases in parking fees. This does not necessarily mean that time sensitivity is greater than price sensitivity, because these numbers depend on the ranges anticipated when posing the question. It is legitimate to conclude that a price increase to $180–210 and a time delay of 15 minutes are roughly equivalent in terms of their impact on modal choice. One could view this in reverse and consider that a 5–15 minute *improvement* in travel time (say by introduction of an express bus) might be an equivalent incentive for modal switch, and this table might then indicate the response to such an initiative.

Table 37. Maximum acceptable delay in drive time

	1-5 min	6-10 min	11-15 min	16-20 min	21-30 min	30+ min
Faculty	4	15	16	8	4	6
Staff	24	48	48	36	10	24
Grads/postdocs	7	14	25	10	1	6
Undergrads	86	94	71	50	16	35
All	121	171	160	104	31	71

2.5 Conclusions from Survey

The survey documents differences between status groups (faculty, staff, etc) in mode of travel and factors in choice of mode. It provides a number of important parameters for estimating travel time by different modes and for calibrating the accessibility model in the next chapter. For Chapter 5, where we design a new express route, it gives us a realistic expectation of ridership, based on numbers that currently are well served by transit and yet choose other modes.

Each modal part of the survey ends with a free form field for comments. More than 500 comments were received. In order not to inflate the report excessively, they are not reproduced here, but are available at the project web site, *www.ncgia.ucsb.edu/vital/research/path2003/comments.html*

Chapter 3—Accessibility Mapping

Mapping and modeling access to transit and transit service levels is an important aspect of designing efficient transit routes and schedules. It is important to recognize that transit service will remain low except for so called "captive" riders unless the service is competitive in terms of time and cost to other options like the use of a personal automobile. Mapping transit access is one approach that can be used to compare transit services to other modes. Mapping access has been the subject of considerable past research, even associated with large employment centers. Recent references to the literature are provided in the reference section of this report. Service accessibility can be measured in three distinct ways: 1) absolute, 2) level of service, and 3) relative. Absolute access represents whether a service is provided between two distinct areas or points, regardless of the amount of time or cost. For example, absolute access by transit is provided, if one can travel from one location to another, by walking to a nearby bus stop, traveling along a route associated with one or more coordinated bus routes, making associated transfers, and then getting off at a stop that is near to the destination. Level–of-service measures make sense where absolute access is provided. If the time it takes to get to point A from point B is reasonable, as the route is direct and there is little wait time, then the level of service is high. But if it takes considerable time to get from point A to point B, as the route is rather circuitous and requires transfers with considerable waiting time, then the level-of-service is low. One can measure level of service in several different ways (e.g. cost), but the one that has been used the most is the amount of time it takes to make the trip. For example, O'Sullivan et al (2000) has mapped travel times from an area in Glasgow to other areas, using a combination of walking, bus and trains. Shortest travel time routes to numerous points across a region are determined. Lines or isochrones are drawn through points of equal access (i.e. points that can be reached in the same amount of travel time), showing how accessible regions about the city center are with respect to the amount of time it takes to travel to specific locations from the starting location.

Modeling relative access involves comparing access based upon two different modes. For example, we could compare the modes of travel by transit and by personal car. In cities with well-developed mass transit systems transit ridership can be high when the travel times of transit is competitive with respect to other modes. For example, in San Francisco, transit ridership is high when personal vehicle travel takes as long or longer than mass transit. The degree to which people select transit as the preferred mode increases as the ratio of transit time to personal vehicle travel time decreases. Thus, to map competitiveness between transit and the use of personal vehicles, one can map the travel time ratio between transit travel time and personal car travel time. Admittedly, this does miss important aspects like toll costs, parking costs, etc., but it does represent one form of comparing access on a relative basis.

Transit access has been modeled by a number of researchers (see Murray et al (2000) for example), where bus stops and routes are located in order to maximize the amount of population that lives within a specified access distance to a bus stop. This design approach is oriented to maximizing the number of people who are provided absolute access. Absolute access cannot be used to value a service, but only to demonstrate that a service is present. Level-of-service has also been modeled in past research work, except that access is assumed to be constant throughout a given day. Although relative access has been discussed in past research, no one has attempted to map relative access comparing transit and the personal car or make such comparisons throughout time of day. The work in this part of the project is a major departure from past work, in that we have attempted to map access by transit in getting to a destination over time of day. In addition, we have attempted to compare access between transit and the personal car, thereby mapping relative access. The purpose of mapping access and relative access is to help identify those areas that are served competitively by transit. Then marketing programs can be targeted to those individuals in the hopes of converting more to transit ridership.

3.1 Mapping Access for Transit

Beginning with a given starting location, one can identify all points that are reachable from that point in exactly t units of time. If these points that lie at exactly t-units of time away from the starting point or origin are connected together with a line, then that line would represent an isochrone of t-time units. Isochrones can be drawn for a series of travel times, indicating approximate accessibility over a region from a specific point of interest. O'Sullivan et al. (2000) outlined a GIS-based approach to develop isochrone maps of access time. O'Sullivan et al. also developed a test application of this approach and presented a map of access from a place called Easterhouse in the Glasgow area, based upon combined walking, bus, and train travel times. Although they indicated that it would make sense to use bus and train timetables, they used a simplified approach. In this simplified approach they look for the shortest time path to given points by walking to bus routes or train stations, traveling using train or bus or both, and then walking to the final destination. O'Sullivan et al. assumed that the travel speeds along a bus route are constant, so that travel times can be approximated based upon the distance traveled by bus rather than using an explicit timetable. Transfer times were also estimated, between modes like walking and using a bus, as half of the headway time. For example, if busses arrive every 10 minutes at a bus stop, then the estimated waiting time for a bus at that stop is 5 minutes (half of the headway time). Elapsed times for train travel are also used to estimate time to travel between stations. Thus, the shortest time route is not specific to a given time of day or departure time. Using these assumptions allows one to map approximate access as average elapsed travel times, but neglects the fact that travel times vary over the day for transit that is subject to congestion on city streets. In developing an access map, such an assumption is obviously not without problems. For instance, O'Sullivan suggests that people who take the train are quite likely to arrive just before the train leaves the station and therefore minimize the waiting time. This means that the estimate of waiting time as half of the headway time is too high. Further, a train departure may not coincide exactly with a nearby bus arrival, or a specific train or bus departure may be too late to get to a desired destination in time. With the O'Sullivan method, such schedule conflicts are ignored as the wait for the "next" train or bus is always half of the headway time, even when there is not a next train or bus. Thus, when a trip is made based upon a desired arrival time or departure time, accurate modeling of travel time must involve transit route timetables.

Modeling for a specified arrival time, means that the walking and transit riding needs to be coordinated and scheduled so that when the person arrives at the destination, they arrive early or on time. The time to make that trip can be estimated as the time in minutes before the desired arrival time, in which the person must leave in order to arrive at the destination on time. For example, if a bus arrives at a destination at 7:30 a.m. and the next arrival of the bus is at 8:30 a.m., then an individual must arrive a half hour early when using the bus if they are to arrive by 8 a.m. Although arriving a half hour early might not be thought of as a waiting time, it does contribute to the overall time of travel as the individual didn't need to be at the destination at 7:30. To address this type of problem it is necessary to develop a shortest path algorithm that is capable of finding the latest departure time from a given starting point and still get to the destination on time. Elapsed travel times can then be mapped.

When modeling the time it takes to get home, the approach in this research again differs from the work of O'Sullivan et al. in that there is a specified departure time. For example, let's say an individual works from 8a.m.-5p.m. and leaves work at 5 p.m. Taking 5 minutes to walk to the bus stop, that individual must then wait for the bus. One could use half of the headway time to estimate the time to wait, but it would be more accurate to identify the bus departure time based upon the timetable. Further, using a shortest path algorithm geared to looking for the shortest routes using bus and walking networks, where buses can be used only when scheduled allows one to depict accurately when an individual can get to a specific destination. Thus, leaving an employment center at a specified time, one could find the points that one could reach within a combined bus and walk time of *t* minutes. This would allow one to generate isochrones of equal travel time/access from an employment center based upon times of the day.

The task at hand involved 4 major steps:

1) Development of a transit service network in GIS format, involving routes and stops and timetables.

2) Development of a shortest path routing model that finds the shortest time route using transit schedules and stop locations to identify the shortest time route in leaving a given origin and traveling to a fixed destination (in this case the University) and arriving by a desired target arrival time, including walking to bus stops, transfer times, etc. For example, if the desired arrival time is 8 am, the problem involves finding the latest departure time and a feasible route, which allows one to get to the destination by 8 a.m.

3) Development of a modified shortest path routine that involves finding the quickest bus/walking route in order to get home after a desired departure time.

4) A mapping approach so that travel times across a region can be plotted, indicating regional access times as a series of isochrones.

The shortest path routing code was developed in C++ and integrated into ArcMap as a component. This allows the user of the routine to select a desired destination and specified arrival time or an origin and a specified departure time. The rest of the process is relatively automated, producing an access map. A view of the mapping interface is presented in Figure 3.

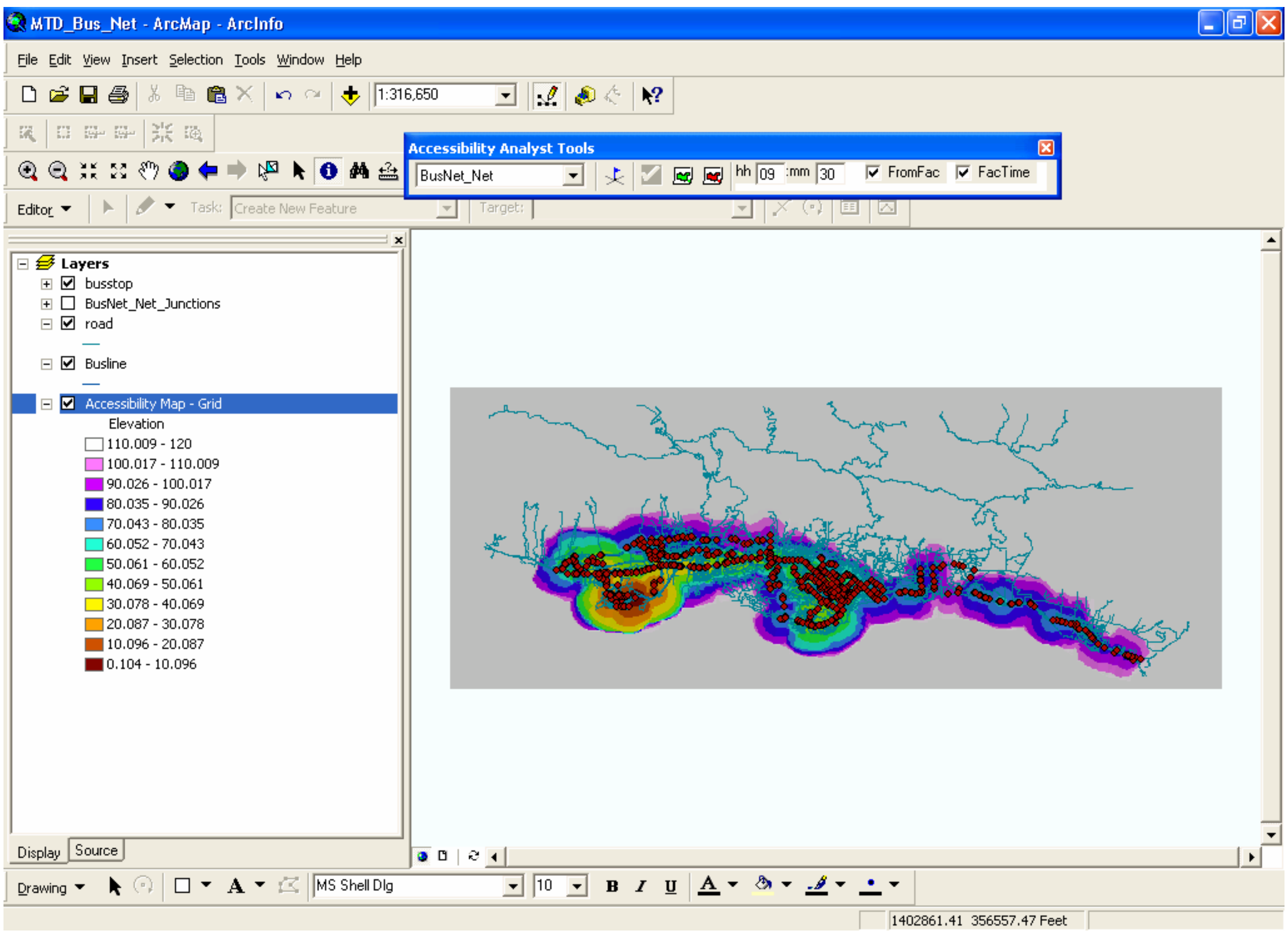


Figure 3. A screen view of the access mapping interface, as a component of ARC/Map product. The embedded tool bar is titled "Accessibility Analyst Tools"

Using the Accessibility Analyst Tool kit, one can generate an access map oriented to a destination and desired arrival time of an origin and a specified departure time. Access intervals are depicted by different colors.

Figure 4 maps access traveling by bus to the University campus, when individuals need to arrive by 8 a.m. Few areas on this map can reach the university without taking more than 30 minutes in time. The map depicts elevation in terms of elapsed travel time to get to or from the University. Dark brown depicts areas where it takes at least 66 minutes to get to the University. The central downtown area of the City of Santa Barbara can reach the university in less than 30 minutes as there is an express bus that departs the transit center in downtown Santa Barbara and goes directly to the University via U.S. Highway 101 after making a limited number of transit stops.

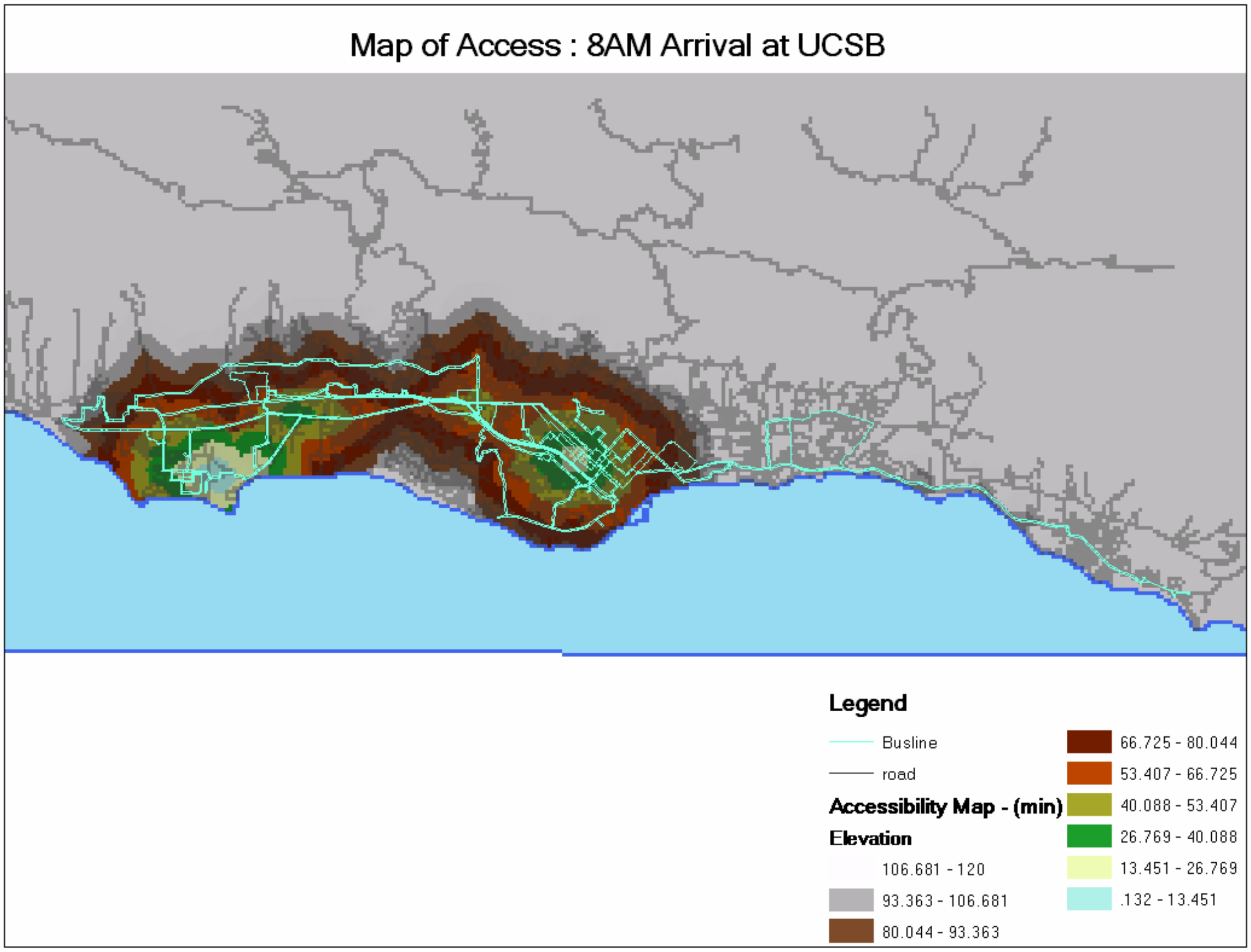


Figure 4. Map of time needed to travel in order to arrive at the University by 8 a.m.

The next two maps depict access to home from the University when leaving at 5 p.m. and when leaving at 5:30 p.m. These two maps also suggest that high levels of service do not exist in traveling to or from the University during periods of high demand for commuting, except for the area surrounding the campus and the area surrounding the transit center in downtown Santa Barbara.

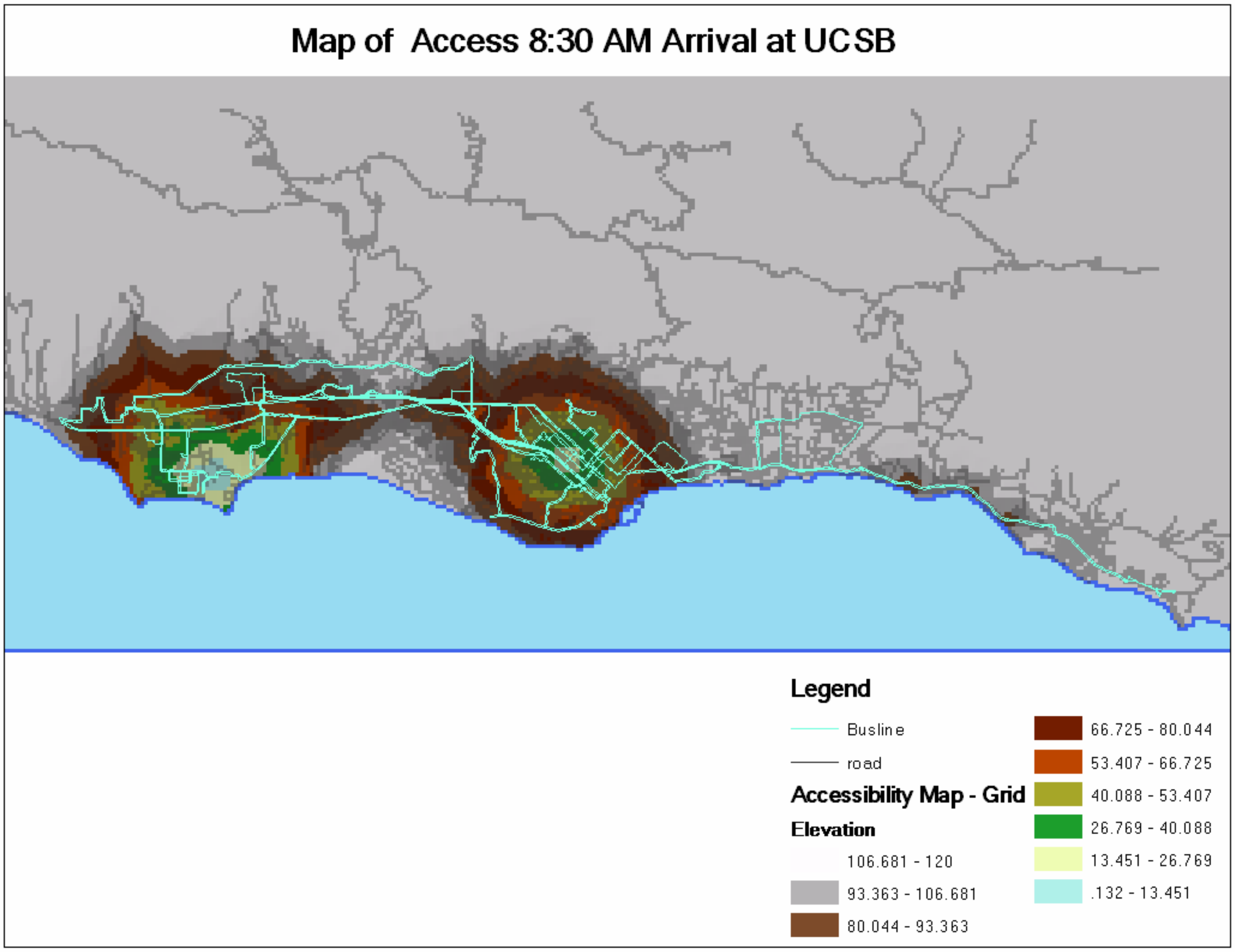


Figure 5. Access to the University by 8:30 a.m. from the Santa Barbara area. Note, major roads are depicted in light green. Note the lack of access for the areas of Montecito, Summerland, Carpenteria, and Hope Ranch.

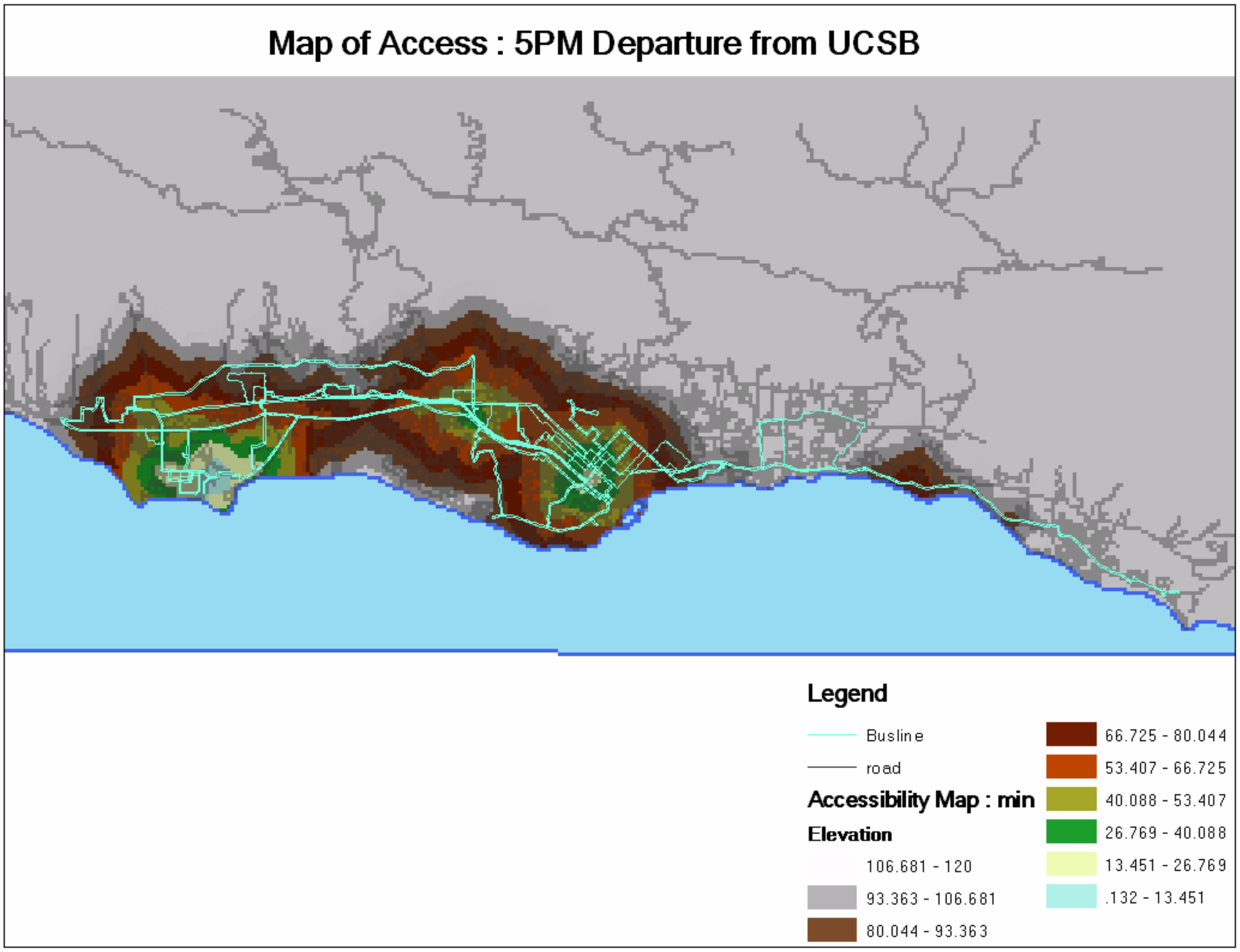


Figure 6. Access to the surrounding area from the University when leaving at 5 p.m. Note, major roads are depicted in light green. Note the lack of access for the areas of Montecito, Summerland, Carpenteria, and Hope Ranch, and the Mesa.

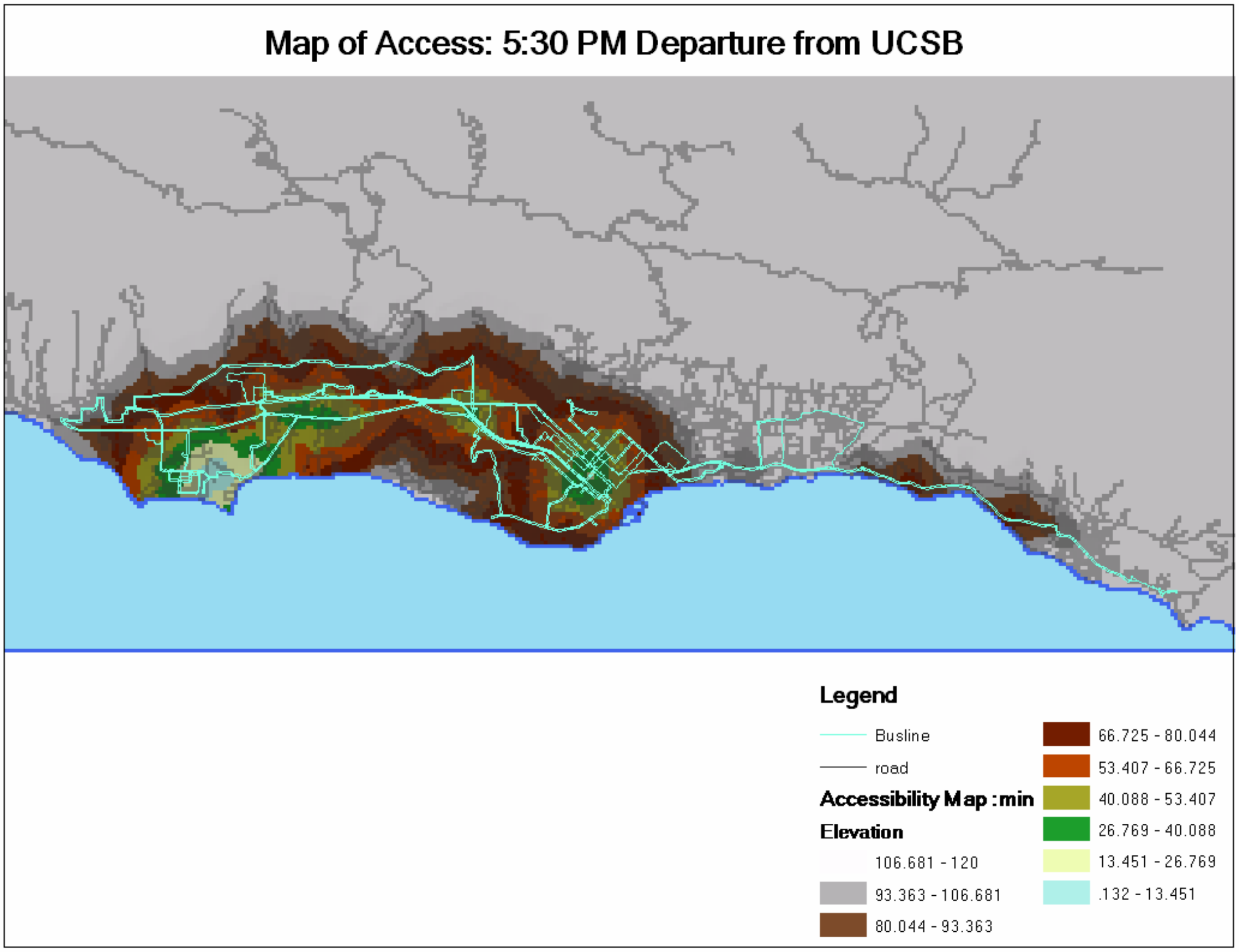


Figure 7. Access to the surrounding area from the University when leaving at 5:30 p.m. Note, major roads are depicted in light green. Note the lack of access for the areas of Montecito, Summerland, Carpenteria, and Hope Ranch, Elwood, El Encanto Heights, the Mesa, and north Goleta.

Chapter 4—Comparison of Modes

One important component of our analysis is to compare the services provided by public transit in terms of using a personal vehicle. Those who completed a survey and drive a personal car were asked how long it took to drive to the University, each day they traveled. This allowed us to compare those travel times with the corresponding time using the bus.

We know in general that if public transit takes considerably longer and parking is inexpensive and unlimited, people will use their car (if they own one). Limited parking or expensive parking can encourage people to use mass transit, even when level of service (average travel speed) is low. Alternatively, when parking is inexpensive and unlimited, mass transit will not be the popular choice unless it is competitive in terms of time. That is, people tend to use their cars when it is faster and the overall costs (of driving and parking) are not exorbitant. When mass transit provides competitive travel times, then the proportion of those who select that mode increases dramatically. The question that we pose here is: Does SBMTD provide any routes to the University in which travel time access is competitive with a personal vehicle? To answer this question, we need to compare travel times using a personal car vs. travel times of mass transit.

Results of the survey were used to map travel times to the University when using a personal car. These times can be compared to the access times generated for the transit system in getting to and from the University. Figure 8 presents a map of self-reported travel times for those who travel to the university. This map represents a composite of a number of survey responses, by approximate home location, as a smoothed surface. For the purposes of this map, driving times were stratified into five categories (intervals are open on the high end): 1) 0-10 minutes; 2) 10-20 minutes, 3) 20-30 minutes, 4) 30-45 minutes, and 5) 45-90 minutes. The map depicts overall accessibility as measured by driving times.

We can compare the access times of bus vs. the personal car by mapping the ratio of travel times by bus as compared to the travel times reported by those who drive. Figure 9 presents a relative access map for travel to the university by 8 a.m. This map depicts relative accessibility in terms of transit vs. personal vehicle when the goal is to arrive at the University by 8AM. Whenever the ratio of travel times is greater than 2.0, transit services are considered to be too slow for most riders who have the opportunity to use their own vehicle. Areas depicted in “burnt orange” and “red” represent those areas in which transit services are poor and not competitive when making trips to the University. Attracting new riders from such areas would be difficult at best, unless services are changed. The areas depicted in “green” are served relatively well by transit (as compared to personal vehicle) and represent areas in which it might be possible to attract new transit riders for those who work at the University. Figure 10 depicts relative access for the return trip to home when departing the University at 5PM. Again, areas depicted in “red” are not served by transit with a level of service that is attractive to those who own a personal vehicle. Areas depicted in “green,” however, are served relatively well. Taking both maps together, i.e. Figures 9 and 10, allows one to see those areas that are served in terms of the journey to work and the journey to home trip. Those areas in which both trips are well-served represented potential markets for increasing ridership. Additionally, increasing ridership outside such areas requires better service provision. It is important to note that the maps depicted in Figures 9 and 10 represent a major achievement for this project as this is the first time that a comprehensive map of relative access has been made, especially for specific arrival and departure times associated with a large employer.

This type of analysis could be similarly applied to any pair of modes, showing for example the advantage of biking over short distances, and the perceived vs. actual time penalty of carpooling. Such analyses would be invaluable in creating informative literature for UCSB’s TPS and TAB when promoting alternative transportation. Now that the concepts, methodology and tools have been developed, it is relatively simple to conduct such analyses widely, at UCSB and elsewhere.

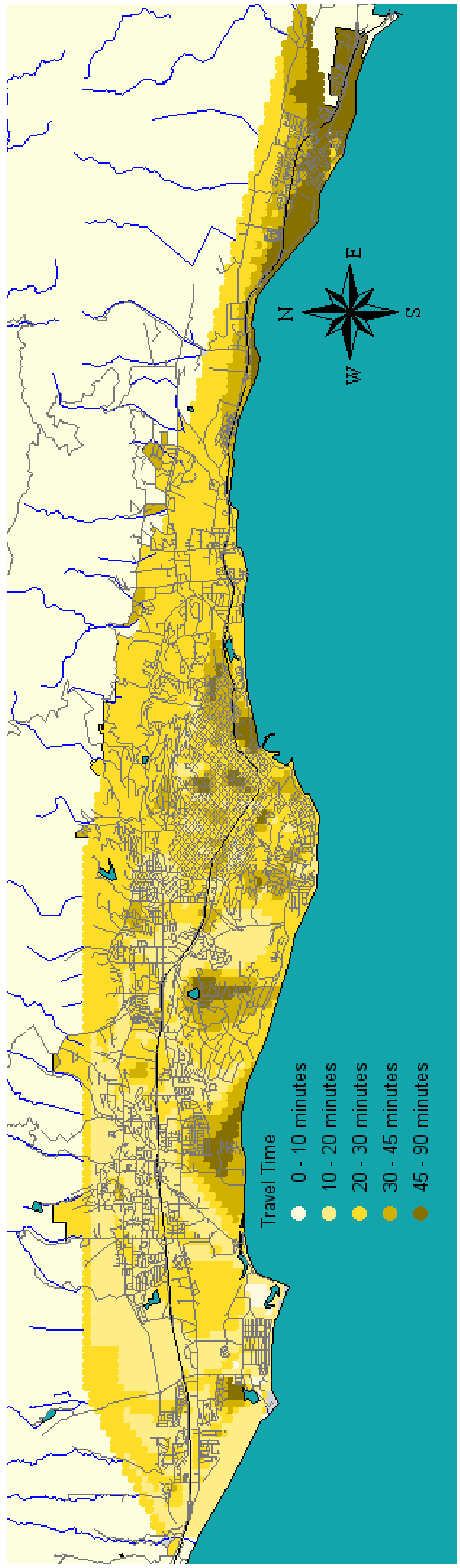


Figure 8. Travel time as reported in survey, all modes.

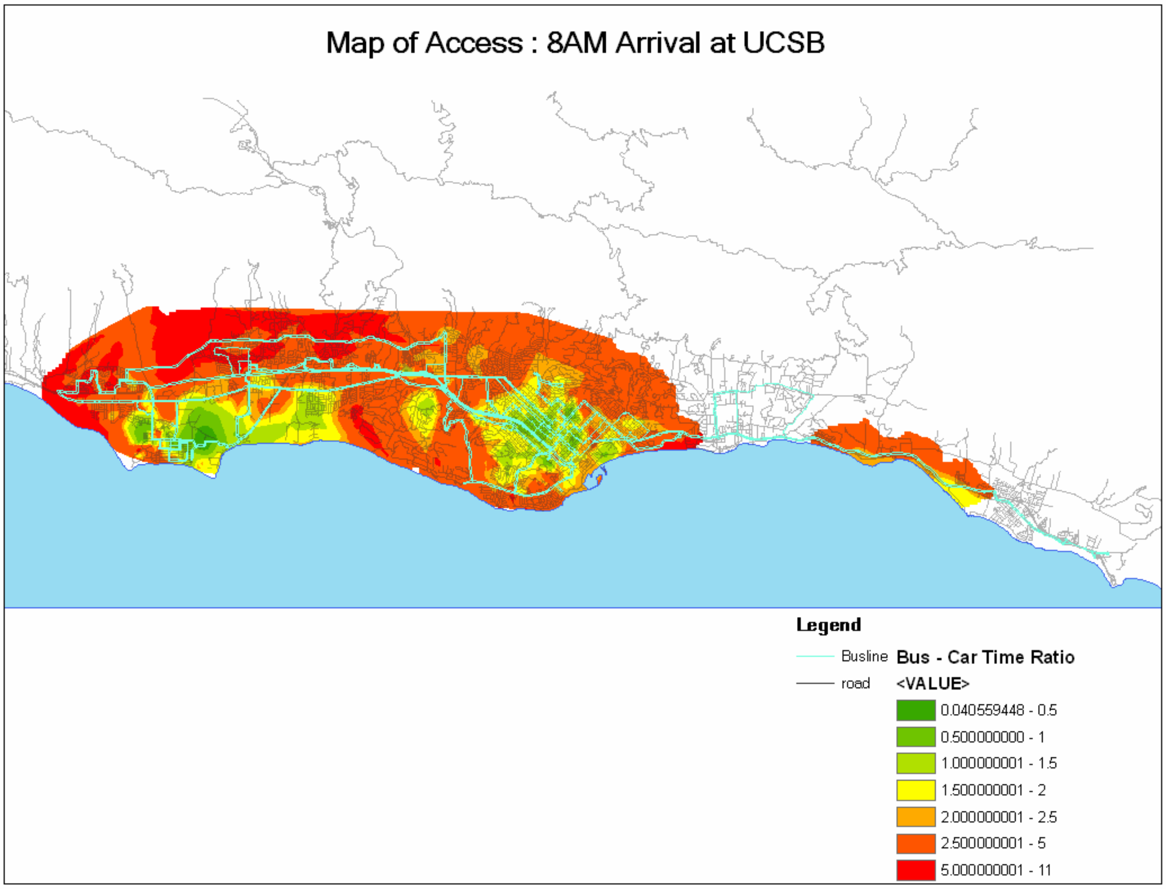


Figure 9. Relative access map, presenting the ratio of bus travel time to car travel times in arriving at the University by 8 a.m. Note, only those areas in very dark green are competitive with the use of a personal car. Also note that areas depicted in green are either close to the University or close to the transit center in downtown Santa Barbara.

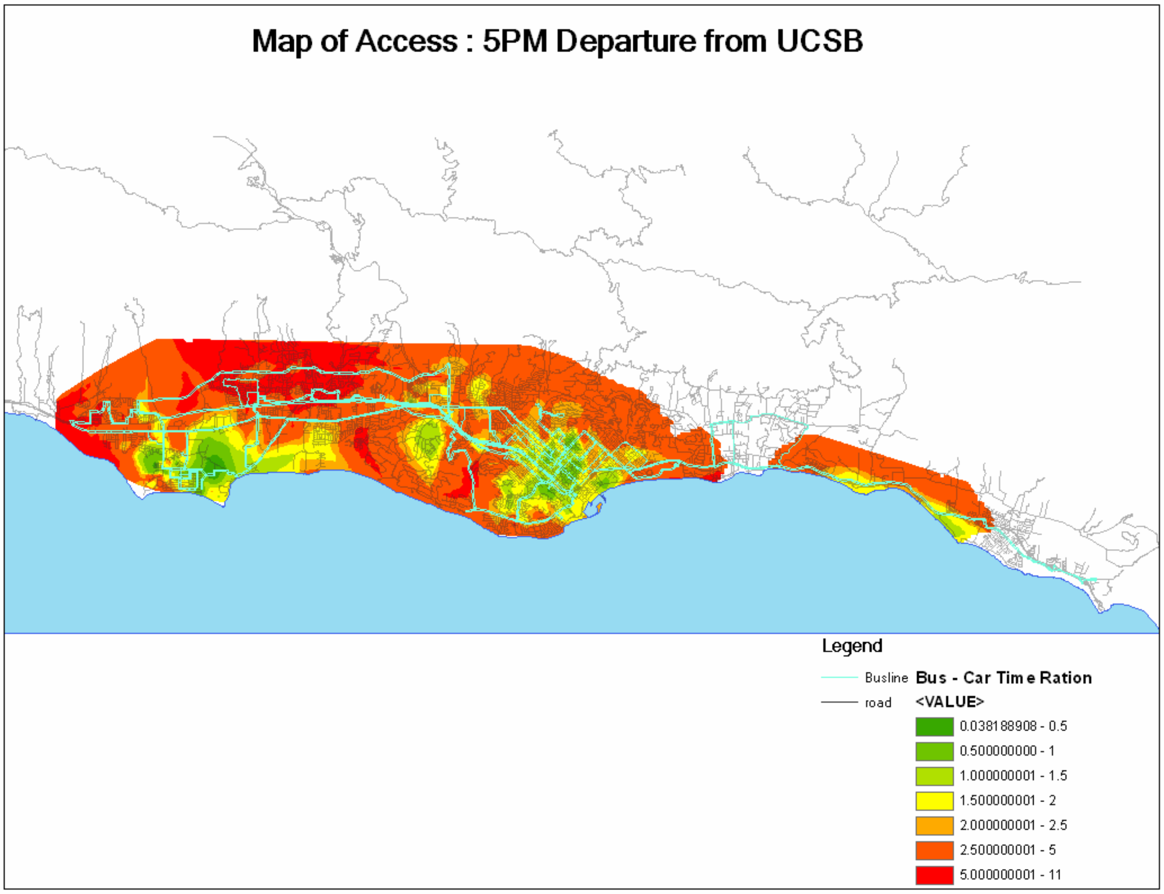


Figure 10. Map of relative access comparing transit travel time to personally reported car travel times, when leaving the University at 5 p.m. Note that much of the region can be reached 5 times faster than by using the bus. This represents a major handicap for the SBMTD to generate greater ridership volumes to and from the University.

Chapter 5—Designing A New Express Route

We recognized from the outset of this project that there might be the possibility to design additional routes that would principally serve the University. As the University is the largest employer in the county, it is appropriate that some of the transit system would be oriented towards serving transit needs on the part of the staff and students. One of the attractive features of the Santa Barbara Metropolitan Transit (SBMTD) system is a direct express route between the University and the downtown transit center. Many of the bus routes in the south coast area either begin or end at the transit center. This means in part that much of the region served by transit is accessible to the University. Unfortunately, some of the services offer poor access, as the route to the University via the transit center may be long and time consuming.

Direct, express bus routes to the University may entice higher levels of ridership. This part of the project focused on identifying such possibilities. During our project, SBMTD had indicated that they planned to serve Santa Ynez valley with bus service to Santa Barbara, for the purposes of serving those traveling to work, and then home again. Our survey identified a number of people who live in the Santa Ynez valley and work at the University. By identifying the times at which they travel and arrive at the University, we were able to give SBMTD personnel data to better understand the needs of those traveling to work at the University, so that schedules for leaving the Santa Ynez area and arriving at the University (one of several stops) could be designed so that the new service will be attractive to University employees living in the Santa Ynez valley. This service will begin in February 2005.

Our second major element of express route design was oriented towards the development of a location model that can be used to search for possible express route alignments that are efficient in terms of travel time to the University as well as provide high levels of access to University employees. An express route must have a limited number of stops, be relatively fast, and at the same time be designed so that stops are located in areas of high demand. That is, a route must be efficient and have high demand coverage around located stops. This type of design problem in transit routing has recently become a problem of interest in the transit routing literature. Express route alignments are considered to be a form of the shortest path/covering problem (Current, et al.).

5.1 Algorithm Specification

The shortest path/covering problem was defined as a problem involving the search for a route between a designated origin and a designated destination. There are two objectives of this problem: 1) to make the route as short as possible, and 2) to align the route so that as many people as possible are within a short distance of the route. This particular problem assumes that stops are distributed along the route where necessary. A modified version of this routing problem has been defined by Boffey and Narula (1998) where limited stops are located along the route. Coverage is provided for only those people that are within a short distance of the located stops. This problem captures the major essence of the express route design problem. It can be formulated as the following discrete optimization problem:

Max covering shortest route problem with limited numbers of bus stop locations

$$Min \quad z_l = \sum_i \sum_j d_{ij} x_{ij}$$ Minimize the length of the route

$$Max \quad z_c = \sum_i a_i y_i$$ Maximize the population that falls within a short distance of the stops located along the route

subject to:

1) Route begins at the designated origin:

$$\sum_{j \neq o} x_{oj} = 1$$

2) Route ends at designated destination:

$$\sum_{k \neq d} x_{kd} = 1$$

3) Route must continue through any intermediate nodes:

$$\sum_{k \neq i} x_{ki} - \sum_{k \neq i} x_{ik} = 0 \quad \text{for all nodes } i \neq o, d$$

4) Locate at most p-stops:

$$\sum_{k} z_k = p$$

5) Stops must be located along route:

$$x_{ik} \geq \mathrm{z}_k \qquad \text{for each arc } i, k$$

6) Define which demands are covered by located stops:

$$\sum_{k \in N_i} z_k \geq y_i \qquad \text{for each demand area } i$$

7) No independent loops must appear in the solution:

There are several forms in which a set of constraints can be formulated for this purpose, where loops/cycles are prevented by simple clique constraints

8) Integer requirements on decision variables:

$$y_i = 0,1 \quad \text{for all } i$$
$$z_k = 0,1 \quad \text{for all } k$$
$$x_{ij} = 0,1 \quad \text{for all arcs } i, j$$

where:

i, j, k = indices of nodes of the network

a_i = the number of people at node i

p = the number of stops to be located along the route

$$y_i = \begin{cases} 1, & \text{if node } i \text{ is covered/ served by a nearby bus stop} \\ 0, & \text{otherwise} \end{cases}$$

$$z_k = \begin{cases} 1, & \text{if node } k \text{ is selected for a bus stop} \\ 0, & \text{otherwise} \end{cases}$$

$$x_{ij} = \begin{cases} 1, & \text{if arc connecting nodes } i, j \text{ is selected to be the route} \\ 0, & \text{otherwise} \end{cases}$$

The above model is a discrete optimization model and classified as an integer-linear programming problem. It is related to the maximal covering/shortest path problem of Current et al, except that it maintains a limited number of stops along the route. Several researchers have investigated this type of model and have solved it for limited route lengths (see for example, Current et al. and Matisziw et al.). The work of Matisziw, et al. is most relevant as they attempted to extend actual transit lines in a growing region. Both Matisziw, et al. and Current et al, solved the problem where the size of the problem was constrained. They solved the above type of problem in an iterative fashion, where each problem included another loop restriction constraint. Specifically, the above type of problem is solved without any loop prevention constraints. If an independent loop is detected, then a constraint is added to prevent that loop from occurring in the solution and then the problem is resolved. Each time the problem is solved, independent loops are detected and constraints are added and the problem is resolved, until no more independent loops are detected. This approach is far more efficient than attempting to generate and add all loop prevention constraints in the model before first solving it. The basic reason for this is that the number of constraints needed to prevent all independent loops grows exponentially with the size of the problem in terms of the number of arcs. Unfortunately, this approach only works for modest sized networks. Beyond small networks, it is necessary to employ a heuristic.

We chose to develop a heuristic for this problem, which has been integrated as a component in the ArcGIS system. The heuristic was designed based upon an insertion/deletion process that represents an efficient node swapping process. The heuristic starts with a known origin and destination. It then finds the shortest path between the origin and destination. This is the beginning route alignment. It then locates stops along the route in a greedy fashion until p stops have been located. Next, it starts an improvement phase, whereby all nearby nodes are tested as possible stop locations. Specifically, the process drops a stop, and then attempts to add the best stop, the one that improves a composite function of demand coverage and route distance. The added stop represents an improvement in the composite function if the stop location is different than the stop location that was deleted. Otherwise, the stop that was dropped is immediately added back. After each stop is tested for replacement, by being deleted, a cycle has been completed. The heuristic continues until a complete cycle has been completed with no change in stops or route.

5.2 Application to UCSB Commuting Demand

The express bus route design heuristic has been applied to a number of target origins in the Santa Barbara area in order to identify potentially good express routes to serve the University. Demand is represented by staff and faculty addresses (approximated by rounding), with the street number rounded to the nearest 100. This means that each block has an assigned level of demand for travel to or from the University. An example of a route designed by the heuristic is given in Figure 11. This route assumes that people would be willing to walk no more than 300 m to a bus stop. The route itself is approximately 7,300 m (about 4 miles) and covers/serves approximately 509 University employees. The heuristic was operated where candidate stops needed to be within 1,500 m of a buffer along the route. This meant that incremental changes in the evolving route could not differ by more about 1½ km. Figure 12 gives an alternate route where less weight more weight is given for bus stop coverage. This second route is approximately 12 km long and could serve more than 1,000 employees.

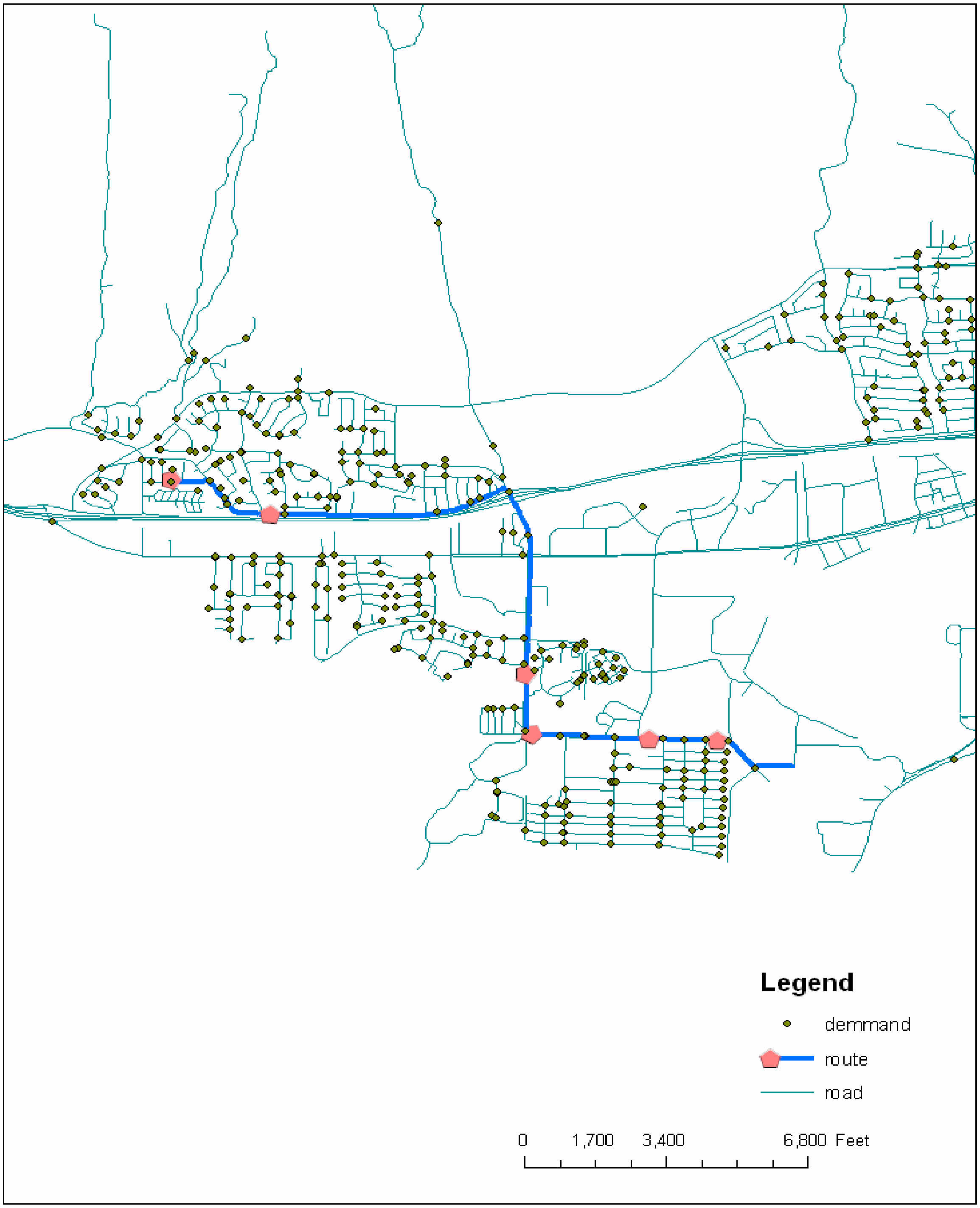


Figure 11. An example route starting at predefined origin and destination (at UCSB). Route covers about 500 people with 7 stops and has a length of approximately 6 km.

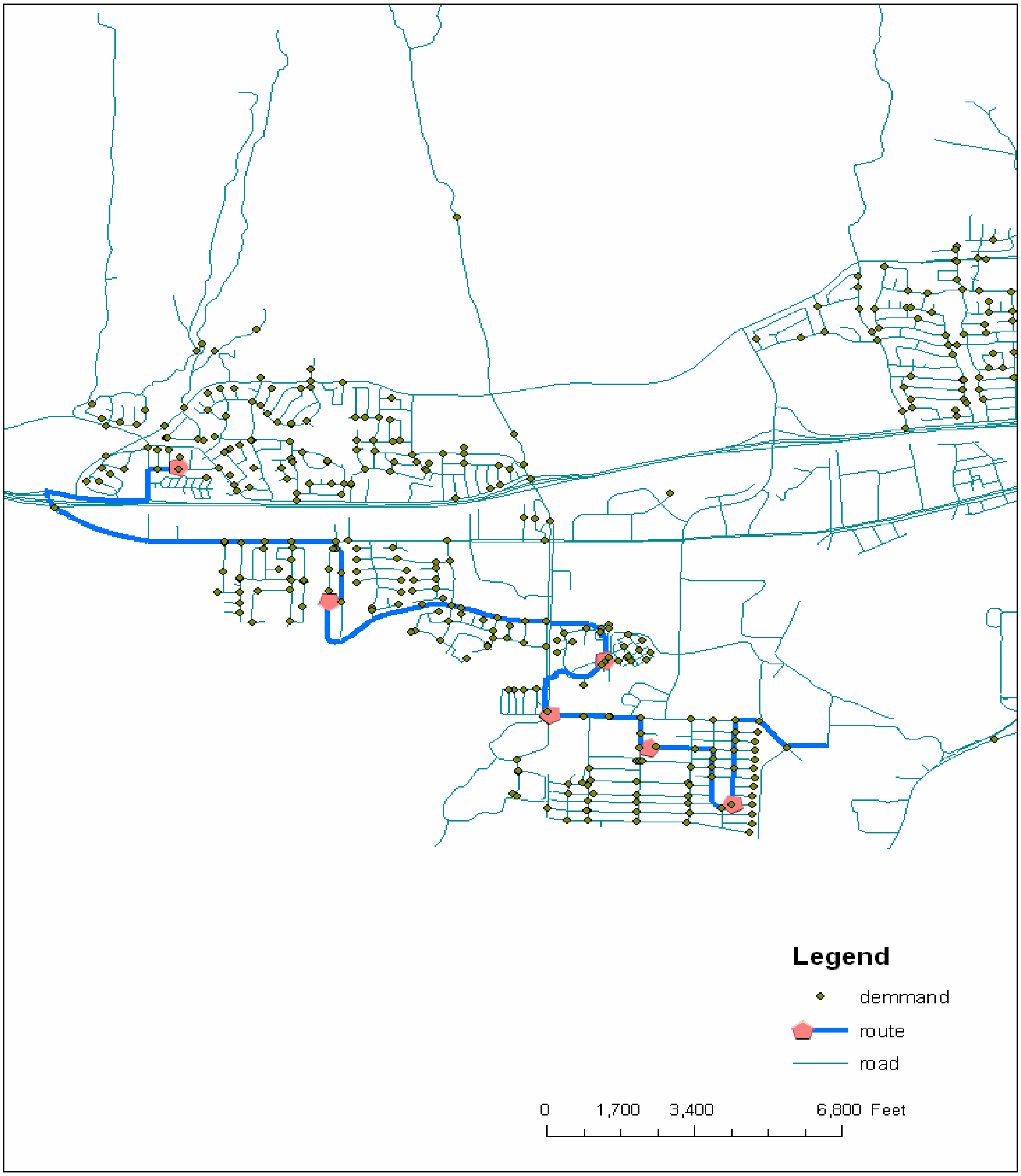


Figure 12. An alternate route with greater weight assigned to route coverage. Route is approximately 12 km long with bus stop coverage of approximately 1,000 employees and students.

It is possible that the model and GIS tool will be useful to the local transit district and to others in route planning. Our process has been used to identify several possible express routes. Further study of these routes and their feasibility for adoption was to have been considered for the second phase of this project. As the second phase has yet to be funded (and quite possibly will not given the current funding circumstances), this study may not have the impact that was originally envisioned.

Chapter 6—Conclusions and Recommendations

This project has made contributions in three principal areas:

1. Methodologically, it has introduced three analytical methods: (a) mapping accessibility based on a published bus schedule and route set, given a specific arrival or departure time requirement; (b) comparison of mode performance by mapping travel times at various and specific times of arrival and departure; and (c) heuristic optimization of bus route design.
2. From the standpoint of transportation services in Santa Barbara County (i.e. MTD and SBCAG), it has generated a wealth of survey data on attitudes, preferences and behavior. The location, time and mode choice data alone are invaluable, and we have already been able to assist MTD with route planning for new services, based on the survey data alone.
3. From UCSB's point of view, the project has made a number of important strides in addressing a pressing parking crisis: (a) it has produced a rich survey data set on travel demand, and variability in demand during the day and during the week, enabling TPS to consider measures such as differential pricing to alleviate the crisis; (b) travel time maps and comparisons will assist TPS and TAB in promoting alternative transportation; (c) new route designs that, if adopted by MTD and SBCAG, will in the longer term provide a viable alternative to driving; (d) not least, the project was aggressively publicized and visible on campus, and that heightened awareness led at least a few survey respondents to reconsider their modal choices.

6.1 Specific Findings

There were few surprises in the survey or analytical findings. For the most part the research confirmed intuitive expectations and quantified patterns that had been previously noted. Some of the significant numerical findings are:

- Travel time to campus is roughly 20–30 minutes on average.
- Roughly 3% of travelers to campus arrive from or return to a place other than home—this means that it is generally acceptable to use residential address as the origin/destination point.
- 27% of solo drivers have never used a bus, anywhere.
- 194 solo drivers don't ride the bus because they "don't know the schedule" (which is available on the Internet and elsewhere).
- Of those living within 1 km of a bus stop, roughly 30% of non-transit-users do not know where the nearest bus stop is.
- The perceived time value of a bus transfer—for those who do transfer—is about 6 minutes.
- Twice as many solo drivers are considering a switch to another mode as vice versa.
- A 14 minute increase in travel time may make the average driver switch to a different mode.
- A parking fee increase from $110/quarter to about $200/quarter may make the average driver switch to a different mode.

6.2 Omissions and Future Needs

Bearing in mind that the research plan was originally conceived as an 18-month project, we were fortunate to be able to condense the important contributions into a 9-month performance period. Inevitably this meant that some aspects of the planned study had to be abbreviated or abandoned. Specifically, survey findings were investigated only to the extent that they impacted accessibility and route design, there were validation steps that had to be omitted, and a number of implementation aspects remain to be pursued. Should follow-up funding be made available by PATH or some other source, it will be beneficial to a number of parties for us to continue to study these aspects.

There were three notable omissions that warrant further study:

1. Train commuting. Soon after the survey was launched, we became aware of efforts by the Coalition for Sustainable Transportation (COAST) and Coastal Rail Now in Santa Barbara to promote the development of commuter rail service using existing tracks. As a result of these efforts, what had earlier been a remote option is now being considered seriously, and late in 2004 Caltrans offered to fund a study of commuter rail in the region (the offer was subsequently qualified in early 2005, and the study is no longer considered imminent). There are currently significant institutional barriers to rail, notably that Southern Pacific, which owns the single line tracks through the area, must place a high priority on goods movement due to its dominant revenue stream; because large sections of the track have no sidings, other services are difficult to accommodate. At the policy level, TPS has declared that it will introduce last-mile bus or mini-bus services to the Goleta train station should commuter rail be introduced. A small number of commuters from northern Santa Barbara County do use rail, and this could be a growing mode of transport for northern and southern travelers in the future.
2. GPS tracking. Early research plans called for GPS tracking of a selection of survey respondents. This would have validated the stated drive time estimates in the survey, and it would also have produced rich data on route choice, time spent searching for parking, and trip chaining. In the case of carpools, GPS data would have provided firm figures for calculating the time and distance overhead. Human Subjects concerns and the time consuming administrative demands of this component kept it from being pursued.
3. Proposed for the second phase, but not funded, would have been an effort to pursue inter-agency economics. We believe it is essential to temper any recommended new express route designs with realistic utilization forecasts. Any long-term shortfall in revenue on new routes would have to be compensated by surpluses on other MTD routes, or by subsidies from other agencies with a broader interest in promoting sustainable transportation, either for their own purposes or for those of the community—such as UCSB and SBCAG. This would require reliable estimates of utilization and revenue and also estimates of utility of the new routes to UCSB and SBCAG.

We will of course continue to develop the relationships with local agencies that have been built and strengthened in the course of this project.

6.3 Recommendations

In general, because the study focused strongly on methodological contributions, it did not reach the point of maturity in implementation for the major components (accessibility mapping, express route planning) to generate policy recommendations.

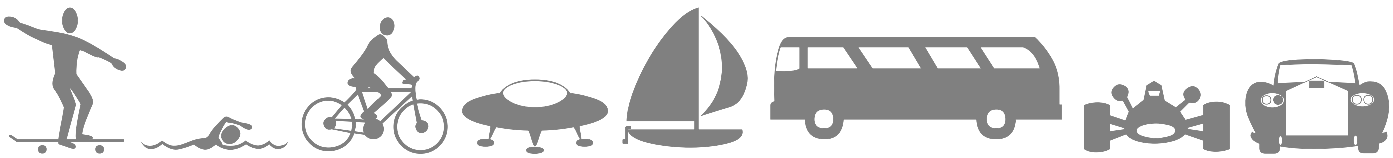
However, experience with the survey and data did suggest one possible course of action in transit promotion applicable not just to UCSB and Santa Barbara, but throughout North America. As we have repeatedly stressed, the availability of the automobile as a fast travel option means that transit managers face an uphill challenge promoting the bus among drivers. The statistics quoted above—that 30% of non-transit-users don't know their nearest bus stop, 27% of drivers have never traveled by bus, and slightly more don't know where to find the bus schedule—combined with the positive attitudes from transit users, suggests that there is a considerable perceptional barrier that must be overcome to attract non-riders to transit. We argue that if these travelers can be persuaded to investigate the schedules and ride the bus *even once*, it would go a long way towards eroding their resistance. An incentive program could therefore be designed, say with a limited number of high value prizes awarded during a designated "Transit Week," to attract drivers as first-time bus passengers, with additional rewards for those who sustain their use of the mode. Given the cost of UCSB's parking alternatives, encouraging more use of existing transit could prove to be a relatively inexpensive, if only partial, solution.

A second alternative is the development of one or more specialized express routes that could serve the University with relative direct journey to work and journey to home trips. We have identified in this project that several routes exist that can potentially serve a large number of employees of the University (staff and faculty). Such options could be used to mitigate traffic on Highway 101 during peak periods.

Finally, we have studied the use of bicycles in the journey to work trip by faculty and staff at the University. We have found that some trips are quite long and that there is a sizable group of people who use bikes in their transportation mix. We believe that this is in part due to the existence of Class 1 bike trails. We have failed to identify statistically significant patterns of use, although bike use appears to be non-existent or very low in nearby areas, when a "safe" route across Highway 101 doesn't appear to exist. We expect that a project directed specifically at collecting a more comprehensive data set on bikers and their patterns of riding might indicate the true value of Class 1 bike trails. This is a unique opportunity as UCSB is served by several Class 1 trails of considerable distance.

Appendix A—Survey Questionnaire

Please respond by
June 4



HOW DO YOU GET TO UCSB?

We need to know

Survey on Transportation, Parking and Transit

Hello! We're conducting a study aimed at easing the parking situation at UCSB and promoting alternative transportation. This could inform a wide range of policy, including parking facilities, bike parking, transit arrangements, etc.* Our study is funded by the California Partners for Advanced Transit and Highways (PATH). For further information on the study: background, research plan, etc, please visit our web site at

www.ncgia.ucsb.edu/vital/research/path2003

Respond on-line
and save this form
for someone else

Please drop the completed form in campus mail (free) using the envelope if provided, or address to:
PATH 2003 Survey, Department of Geography, 3611 Ellison Hall, 93106-4060
A response by **Friday, June 4** would be appreciated

Sign up for GPS Tracking We'd like to track a few travelers using GPS, to document travel time and route to campus. No personal information is attached to the data, but obviously we'll have to communicate with you and equip your car, so we'll need a name, address and phone number. Please visit the web site to sign up.

*UCSB Transportation and Parking Services (TPS) support and are facilitating the study, and will be apprised of its findings and recommendations; however the investigators in the study are not directly responsible for formulating or enforcing UCSB transportation policy. If you have concerns about the study, or suggestions to improve its effectiveness, please e-mail vital@ncgia.ucsb.edu

If you are under 18 you may not fill out this survey. Thank you for your time.

Part A: Everyone starts here and answers the first 2 pages

1. My status at UCSB is
❑ Undergraduate Student ❑ Graduate Student ❑ Staff ❑ Faculty ❑ Other ______________

2. Please enter your street address, rounded to 100. For example, instead of 116 Pine Lane, write 100 Pine Lane (no suite numbers required). This is to protect your privacy. If you do not feel comfortable providing even this information, please skip this question.

Street Address: ________________________________

City: ________________________________

If your trip to UCSB regularly originates at or returns to a **place other than home** (e.g. work), please enter that address here. Treat this place as "home" except for questions 4 and 5 below. Note: this does not refer to intermediate stops on the route. If you have 2 or more other addresses, check here ❑ and use the dominant one.

Street Address: ______________________________

City: ______________________________

3. I am
❑ Female ❑ Male age … ❑ below 35 ❑ 35-55 ❑ over 55

4. I have a long term impairment or medical condition that affects my choice of transportation
❑ No ❑ Yes → ❑ Visual/Hearing/Speaking ❑ Difficulty/inability to walk ❑ Other __________________
↓

5. My usual schedule for arriving at UCSB is

	I come in from	Leave (out the door) at		Arrive at office/class at	Begin work/class at	I'm not **required** to come in	I **do not** come in
Monday	❑ Home ❑ Other	:	❑ pm	:	:	❑	❑
Tuesday	❑ Home ❑ Other	:	❑ pm	:	:	❑	❑
Wednesday	❑ Home ❑ Other	:	❑ pm	:	:	❑	❑
Thursday	❑ Home ❑ Other	:	❑ pm	:	:	❑	❑
Friday	❑ Home ❑ Other	:	❑ pm	:	:	❑	❑

6. My usual schedule for leaving UCSB is

	Departure time		I go from UCSB to
Monday	:	❑ pm	❑ Home ❑ Other
Tuesday	:	❑ pm	❑ Home ❑ Other
Wednesday	:	❑ pm	❑ Home ❑ Other
Thursday	:	❑ pm	❑ Home ❑ Other
Friday	:	❑ pm	❑ Home ❑ Other

7. In general my timings are
Arrival at UCSB: ❑ Not at all flexible ❑ Somewhat flexible ❑ Very flexible
Departure from UCSB: ❑ Not at all flexible ❑ Somewhat flexible ❑ Very flexible

8. I regularly make these stops on the way to/from UCSB (check all that apply)

❑ I drop off/pick up family/friend **off campus** at daycare/school/work ❑ Shopping ❑ Other ___________

How important are these stops? ❑ Important part of my schedule ❑ I could easily get by without doing this

I make these stops on the way from …	Home to UCSB	UCSB to home
Monday	❑	❑
Tuesday	❑	❑
Wednesday	❑	❑
Thursday	❑	❑
Friday	❑	❑

9. I leave campus during the day for lunch/errands

❑ 5 or more times a week ❑ 1-4 times a week ❑ Rarely ❑ Never

How important are these trips? ❑ Important part of my schedule ❑ I could easily get by without doing this

10. Things I consider in my choice of transportation

	Not a factor	Small factor	Big factor
Low cost	❑	❑	❑
Quick travel time	❑	❑	❑
Flexibility to leave/arrive whenever I choose	❑	❑	❑
Comfort/convenience	❑	❑	❑
Safety	❑	❑	❑

11. The bus stop nearest to my home is

Stop/street ______________________________ on MTD Route #_______ ❑ Check here if you don't know

Walking time to this stop is ❑ <3 minutes ❑ 3-8 minutes ❑ 8-12 minutes ❑ >12 minutes ❑ Don't know

12. I have access to an automobile and can afford to drive myself to UCSB (and pay parking fees)

❑ Not at all ❑ 1-3 days per week ❑ 4 or more days per week

13. In <u>my</u> opinion, because of the nature of my duties, telecommuting/working from home would be a practical option if my supervisor allowed it

❑ Not at all ❑ 1-2 days per week ❑ 3 or more days per week

My supervisor would probably ❑ approve ❑ not approve ❑ I don't know

14. My usual modes of transportation for travel <u>other</u> than to UCSB are (check all that apply)

❑ Drive alone ❑ Drive with family ❑ Carpool/rideshare with non-family ❑ Bus ❑ Bike
❑ Walk ❑ Other __________________

15. My usual mode(s) of transportation to UCSB are (enter a rough estimate of the percentage of trips in each mode)

Drive alone	________% of trips (Part E) ❑ Ride*	Bike	________% of trips (Part D)
Carpool	________% of trips (Part C) ❑ Off-campus**	Walk	________% of trips (Part D)
Bus	________% of trips (Part B)	Other	________% of trips (Part D)

If you usually get a ride to UCSB: *If someone makes a dedicated trip from home to drop you off, enter this as Drive Alone and check the Ride box. ** If someone drops you off on the way to a place **other than UCSB**, enter this as Carpool and check the Off-campus box.

Thanks, you've finished Part A. Please go to Part B, C, D or E depending on the mode you use most.
If you regularly use more than one mode, please answer the part for the dominant mode (you may answer the others too).

Part B: Bus Riders (regular/occasional)

B1. I don't drive to UCSB because (check all that apply)

❑ I don't have a car ❑ It costs too much to operate a car ❑ It's not good for the environment
❑ UCSB parking costs too much ❑ UCSB parking is hard to find ❑ Trip (including parking) takes too long

B2. I ride the bus to UCSB because it is (check all that apply)

❑ convenient ❑ inexpensive ❑ better for the environment ❑ the only transportation available to me

B3. Please rate the bus service in Santa Barbara by checking one box in each line

	Disagree	Neutral	Agree
The bus works well with my schedule	❑	❑	❑
The distance from my home to the bus stop is reasonable	❑	❑	❑
The bus is usually punctual	❑	❑	❑
The bus is comfortable	❑	❑	❑
Overall, the time taken by bus to UCSB is reasonable	❑	❑	❑

B4. How do you reach the bus stop near your home?

❑ Walk to bus stop
❑ Bike to bus stop
❑ Drive to bus stop: do you then park: ❑ on the street ❑ in a parking area

B5. Using this means, how long does it take to get to the bus stop near your home?

❑ < 3 minutes ❑ 3-8 minutes ❑ 8-12 minutes ❑ >12 minutes ❑ I don't know

B6. My bus routes to campus are (fill out all that apply)

At ______:_____ (am/pm) I leave from (stop/street) ______________________ on (MTD Route #) __________

I transfer at (stop/street) ____ to (MTD Route #) __________

I transfer at (stop/street) ____ to (MTD Route #) __________

B7. If you transfer, consider this scenario: suppose there was a direct bus that had no transfers but took a longer route. How much longer a ride would you accept, in exchange for the convenience of no transfers?

❑ 2 minutes ok ❑ 3-5 minutes ❑ 6-10 minutes ❑ 11-20 minutes ❑ 21-30 minutes ❑ 31+ minutes

Scan the list from left to right and pick your decision point → → →

B8. How long does it take to get from the campus bus stop to your office/class?

❑ < 3 minutes ❑ 3-8 minutes ❑ 8-12 minutes ❑ >12 minutes ❑ I don't know

B9. Are you seriously considering a switch to other methods of transportation?

❑ Driving alone ❑ Carpooling ❑ Biking ❑ Walking ❑ Other ____________________________

B10. Comments on any question? What might UCSB do to improve transportation to campus?

____

____

Part C: Carpool/Rideshare Users (regular/occasional)

C1. How many times in the past 6 months have you used the public bus system in Santa Barbara?

❑ More than 10 times ❑ 5-9 times ❑ 1-4 times ❑ I never take the bus

C2. When and where did you last use any public bus system?

❑ Within the last 12 months City/Country:________________________________
❑ Within the last 5 years City/Country:________________________________
❑ Never

C3. I tend not to use the bus to UCSB because (check all that apply)

❑ Bus service is not available near my home
❑ Bus is not frequent enough
❑ I don't know the bus schedule
❑ I would need to transfer routes ______ times
❑ I carry heavy loads to work
❑ I drop a family member at daycare/school
❑ I don't feel safe at a bus stop
❑ I travel at a different time every day and the bus schedule is too rigid for my needs
❑ Bus arrives at UCSB at an unsuitable time
❑ Nearest bus stop is too far away
❑ I don't like to wait for a bus
❑ Bus trip to UCSB takes too long
❑ Bus stops are not well sheltered in the event of bad weather
❑ I need to leave campus/run errands during the day

C4. I use carpool/rideshare to UCSB because (check all that apply)

❑ It is convenient
❑ It costs less
❑ I can stop at daycare/school, etc
❑ Pick up/drop off is close to my home
❑ It is the only type of transportation available to me
❑ It is faster than other modes of transportation
❑ I can talk to people I know
❑ I read/get work done during my trip
❑ I get designated carpooler parking space

C5. How many people share your car pool (including you)? __________

C6. Did UCSB's Transportation & Parking Services (TPS) put you in touch with your carpool companions?

❑ No, I ride with friends/family ❑ TPS helped a lot ❑ TPS could have done more _________________

C7. How often do you drive alone, using the free daily parking passes that come with the carpool permit?

❑ Don't know about free passes ❑ Know, but never use them ❑ 1-3 times/month ❑ 4 or more times/month

C8. How much later could you leave home if you drove alone in your own car?

❑ No difference ❑ 1-10 minutes ❑ 11-20 minutes ❑ 21-30 minutes ❑ More than 30 minutes
❑ I don't know/I don't have access to a car

C9. Are you seriously considering a switch to other methods of transportation?

❑ Driving alone ❑ Bus ❑ Biking ❑ Walking ❑ Other ____________________________

C10. Comments on any question? What might UCSB do to improve transportation to campus?

____

____

____

Part D: Walkers, Bikers and Other (regular/occasional)

If you just answered Part C (Carpool/Rideshare), skip to here

D1. How many times in the past 6 months have you used the public bus system in Santa Barbara?

❑ More than 10 times ❑ 5-9 times ❑ 1-4 times ❑ I never take the bus

D2. When and where did you last use any public bus system?

❑ Within the last 12 months City/Country:______________________

❑ Within the last 5 years City/Country:______________________

❑ Never

D3. I tend not to use the bus to UCSB because (check all that apply)

❑ Bus service is not available near my home

❑ The bus is not frequent enough

❑ I don't know the bus schedule

❑ I would need to transfer routes _______ times

❑ I carry heavy loads to work

❑ I drop a family member at daycare/school

❑ I don't feel safe at a bus stop

❑ The bus arrives at UCSB at an unsuitable time

❑ The nearest bus stop is too far away

❑ I don't like to wait for a bus

❑ The bus trip to UCSB takes too long

❑ Bus stops are not well sheltered in the event of bad weather

❑ Need to leave campus/run errands during the day

❑ I travel at a different time every day and the bus schedule is too rigid for my needs

D4. I don't drive alone to UCSB because (check all that apply)

❑ I don't have a car ❑ It costs too much to operate a car ❑ It's not good for the environment

❑ UCSB parking costs too much ❑ UCSB parking is hard to find ❑ Trip (including parking) takes too long

D5. I walk/bike to UCSB because (check all that apply)

❑ It serves as exercise

❑ It allows me flexibility in my schedule

❑ It costs less

❑ It is faster than other modes of transportation

❑ It is environmentally friendly

❑ It is the only form of transportation available to me

BIKERS ONLY

D6. How long is the walk from the bike stand to your office/class?

❑ < 3 minutes ❑ 3-8 minutes ❑ 8-12 minutes ❑ I don't know

D7. Are you seriously considering a switch to other methods of transportation?

❑ Driving alone ❑ Carpooling ❑ Bus ❑ Biking ❑ Walking ❑ Other ________________

D8. Comments on any question? What might UCSB do to improve transportation to campus?

____

____

____

D9. If you answered "Other" please provide details on your mode of transportation

____

Part E: Drive Alone (regular/occasional)

If you just answered Part C (Carpool/Rideshare) or Part D (Walk/Bike), skip to here

E1. How many times in the past 6 months have you used the public bus system in Santa Barbara?

❑ More than 10 times ❑ 5-9 times ❑ 1-4 times ❑ I never take the bus

E2. When and where did you last use any public bus system?

❑ Within the last 12 months City/Country:________________________________
❑ Within the last 5 years City/Country:________________________________
❑ Never

E3. I tend not to use the bus to UCSB because (check all that apply)

❑ Bus service is not available near my home
❑ The bus is not frequent enough
❑ I don't know the bus schedule
❑ I would need to transfer routes ______ times
❑ I carry heavy loads to work
❑ I drop a family member at daycare/school
❑ I don't feel safe at a bus stop
❑ I travel at a different time every day and the bus schedule is too rigid for my needs
❑ The bus arrives at UCSB at an unsuitable time
❑ The nearest bus stop is too far away
❑ I don't like to wait for a bus
❑ The bus trip to UCSB takes too long
❑ Bus stops are not well sheltered in the event of bad weather
❑ Need to leave campus/run errands during the day

E4. I drive to UCSB because (check all that apply)

❑ It is convenient
❑ I can listen to my favorite radio station
❑ I can stop at daycare/shopping/etc
❑ It is the only type of transportation available to me
❑ It costs less to drive
❑ It is faster than other modes of transportation
❑ It allows me flexibility in my schedule

E5. I park …

❑ On campus, in Lot # ________ Permit type ❑ A ❑ S ❑ C ❑ Other _________

❑ Off campus and get in by ____

E6. How long is the walk from the parking lot to your office/class?

❑ < 3 minutes ❑ 3-8 minutes ❑ 8-12 minutes ❑ >12 minutes ❑ I don't know

E7. How do you feel about valet parking (provided in some lots)?

❑ Not available where I park ❑ I avoid it as far as possible ❑ I don't mind it ❑ I like it

E8. Are you seriously considering other methods of transportation?

❑ Carpooling ❑ Bus ❑ Biking ❑ Walking ❑ Other __________________

E9. A <u>quarterly</u> parking permit (now $110) could get more expensive. At what point would you switch to other transportation?*

❑ $120 ❑ $150 ❑ $180 ❑ $210 ❑ $240 ❑ I would still drive alone with a $240+ fee hike

Scan the list from left to right and pick your decision point → → →

E10. Alternately, suppose the only available parking were off-campus with a shuttle, adding several minutes to travel time. At what level of delay would you switch to another form of transportation?* If the shuttle added …

❑ 1-5 min ❑ 6-10 min ❑ 11-15 min ❑ 16-20 min ❑ 21-30 min ❑ I would still drive at 30+ min delay

Scan the list from left to right and pick your decision point → → →

E11. Comments on any question? What might UCSB do to improve transportation to campus?

____

____

* Note: These are not policy proposals. They are hypothetical questions designed to measure perception of cost and time.

References

General References

Hanson, S. ed. (1995) The Geography of Urban Transportation, 2nd Edition, Guilford Press,New York, N.Y.

Transit Route Design Literature

Boffey, B., and S. Narula (1998). "Models for multi-path covering-routing problems," Annals of Operations Research 82; 331-342.

Bruno, G., G. Ghiani, and G. Improta (1998) "A multi-modal approach to the location of a rapid transit line," *European Journal of Operational Research* 104; 321-332.

Bruno, G., M. Gendreau, and G. Laporte (2002). "A heuristic for the location of a rapid transit line," Computers and Operations Research 29; 1-12.

Current, J.R., and D.A. Schilling (1989). "The covering salesman problem," Transportation Science 23; 208-213.

Current, J.R., and D.A. Schilling (1994). "The median tour and maximal covering tour problems," Formulations and Heuristics," European Journal of Operations Research 73; 114-126.

Current, J.R., C.S. ReVelle, and J.L. Cohon (1985). "The maximal covering/shortest path problem: a multiobjective network design and routing formulation," European Journal of Operational Research 21; 189-199.

Dufourd, H., M. Gendreau, and G. LaPorte (1996). "Locating a transit line using Tabu search," Location Science 4;1-19.

Gendreau, M. A. Hertz, and G. Laporte (1992). "New insertion heuristic and post optimization procedures for the trabelling salesman problem," Operations Research 40; 1086-1094.

Gendreau, M., G. Laporte, C. Musaraganyi, and E.D. Taillard (1999). "A tabu search heuristic for the heterogeneous fleet vehicle routing problem," Computers and Opeartions Research 26; 1153-1173.

Laporte, G., J.A. Mesa, and F.A. Ortega (2000). "Optimization methods for the planning of rapid transit systems," European Journal of Operational Research 122; 1-10.

Matisziw, T.C., A. Murray, and C. Kim (2005). "Strategic route extension in transit networks," European Journal of Operational Research; in press.

Ngamchai, S. and D.J. Lovell (2003). "Optimal time transfer in bus transit route network design using a genetic algorithm," Jounral Transportation Engineering; 510-521.

Sancho, N.G.F. (1996). "The hierarchical network design problem with multiple primary paths," European Journal of Operational Research 96; 323-328.

Wu, C., and A.T. Murray (2005) "Optimizing public transit quality and system access: the multiple route maximal covering/shortest path problem," under review.

Relevant Transit Accessibility Mapping and Modeling Literature

Azar, K.T., J.Ferreira, Jr., and L. Wiggins (1994). "Using GIS tools to improve transit ridership on routes serving large employment centers: the Boston South end medical area case study," Computers, Environment, and Urban Systems 18; 205-231.

De Jong, T. and J. Ritsema van Eck (1996). "Location profile-based measures as an improvement on accessibility modeling in GIS," Computers, Environment, and Urban Systems 20; 181-190.

Handy, S.L. and D.A. Niemeier(1997). "Measuring accessibility: an exploration of issues and alternatives," Environment and Planning A 29; 1175-1194.

Hillman, R., and G. Pool (1997) "GIS-based innovations for modeling public transport accessibility," Traffic Engineering & Control 38; 554-559.

Kim, D._S., K. Mizuno, and S. Kobayashi (2003). "Modeling urbanization by accessibility in rapid-growth areas," J. Urban Planning & Development 129; 45-63.

Kim, H.-M. and M.-P. Kwan (2003). "Space-time accessibility measures: a geocomputational algorithm with a focus on the feasible opportunity set and possible activity duration," J. Geographical Systems 5; 71-91.

Kwan, M.-P., A.T. Murray, M.E. O'Kelly, and M. Tiefelsdorf (2003). "Recent advances in accessibility research: representation, methodology, and applications," J. Geographical Systems 5; 129-138.

Murray, A.T. (2001). "Strategic analysis of public transport coverage," Socio-Economic Planning Sciences 35; 175-188.

Murray, A.T., R. Davis, R.J. Stimson, and L. Ferreira (1998). "Public Transportation Access," Transportation Research 3; 319-328.

Murray, A.T. and Xiaolan Wu (2003). "Accessibility tradeoffs in public transit planning," J. Geographical Systems 5; 93-107.

Peng, Z.-R. (1997). "A methodology for design of a GIS-based automatic transit traveler information system," Computers, Environment, and Urban Systems 21; 359-372.

Pirie, G.H. (1981). "The possibility and potential of public policy on accessibility," Transportation Research 15A; 377-381.

Ritsema van Eck, J.R. and T. de Jong (1999). "Accessibility analysis and spatial competition effects in the context of GIS-supported service location planning," Computers, Environment and Urban Systems 23; 75-89.