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Expanding Usage Of Cellular Phones: User Profile And Transportation Issues

Authors
Yim, Youngbin
Kanafani, Adib
Ygnace, Jean-luc

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CALIFORNIA'PATH PROGRAM
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UNIVERSITY OF CALIFORNIA AT BERKELEY

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Youngbin Yim
Adib Kanafani
Jean-Luc Ygnace

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EXPANDING USAGE OF CELLULAR PHONES: USER PROFILE AND TRANSPORTATION ISSUES

Final Report

Youngbin Yim
Adib Kanafani
Jean-Luc Ygnace

Prepared by:
Institute of Transportation Studies - PATH
University of California, Berkeley

December 199 1

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Foreword

This research was undertaken as a collaborative effort between the Institute of Transportation Studies - PATH and INRETS. Dr. Jean-Luc Ygnace of INRETS initiated this research and was one of three key researchers in this project. In France, Dr. Ygnace is currently conducting a similar research survey sponsored by the French Government Department of Transportation. This study is an initial step toward an understanding of consumer responses to advanced traveler information systems.

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This is an empirical study of cellular phone users in the San Francisco Bay Area. Several studies have explored the potential application of cellular telephones for traffic control and management, yet little is known about the effects of telecommunications on urban travel behavior. In an IVHS environment, two-way vehicle communication capability is essential to traffic management and highway surveillance. Cellular networks can provide this capability. Therefore, this research is aimed at understanding the role that cellular telephones can play in the management of urban traffic systems. The conjecture is that communications technology, such as cellular phones, would have some relation to the temporal and spatial pattern of activities, and therefore some impact on trip making. If the experience with domestic telephones is extended to the cellular mobile telephone, then one might expect similar effects. Some trips will likely be replaced by cellular communications and others will be generated because of them. Cellular communications may also encourage drivers to alter trip patterns such as routing, mode choice or chaining.

The objectives of this research are: 1) to assess the impact of cellular communication on driver behavior, 2) to determine the population segment likely to use the advanced traveler information systems, and 3) to identify the role that cellular technology can play in urban traffic management. The study was undertaken in the form of an extensive user survey. In March, 1991, a mail survey was conducted among 35,000 randomly selected GTE Mobilnet customers in the eleven counties of the Bay Area and in the surrounding regions. The eleven counties of the GTE service area included Sonoma, Napa, Solano, Mat-in, Contra Costa, Alameda, San Mateo, Santa Clara, San Francisco, Santa Cruz, and Monterey.' The response rate was 20%.

An important finding of the survey is that the primary transportation effect of cellular technology is on trip scheduling and, to a lesser extent, on trip frequencies. While only 25% of the respondents claimed that the primary purpose of having a cellular phone was for trip scheduling, over 60% admitted that cellular telephones affected their trip behavior.

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[1] The San Francisco Bay Area consists of nine counties: Sonoma, Napa, Solano, Mat-in, Contra Costa, Alameda, San Mateo, Santa Clara, and San Francisco. Santa Cruz and Monterey Counties are outside of the Bay Area political jurisdiction.

In the Bay Area, real-time traffic information is not available. Fifteen percent of the respondents obtained traffic information only when they expected traffic congestion. Evidence from the survey also suggests that, while cellular phones might not have a significant net effect on the frequency of trip generation, they will alter trip patterns as people use them to adapt their activity patterns. Only with substantial use of cellular phones for route guidance might there be a measurable net effect on trip frequency. Because of the absence of real-time traffic information in the Bay Area, it was not possible to measure the direct impact of en-route traffic information on driving behavior. Once an up-to-the minute traffic information service becomes available, a substantial increase in the usage of en-route traffic information may result in a consequent increase in route shifts.

Within the context of an IVHS environment, cellular systems can be utilized in many ways. These include: vehicle detection and incident verification; dynamic route guidance and driver information services; incident reporting; transit management and schedule reporting; multimodal (or intermodal) transportation services; fleet vehicle location reporting and management; and off-street parking availability information services. As cellular technology offers a wide range of potential applications for automated traffic management and traveler information systems, research is needed to fully explore its capability in an IVHS environment and to shed some light on the role that it can play in the larger context of IVHS.

In light of the current and emerging needs of cellular technology assessment, immediate and long-term actions are warranted. The immediate actions should include testing the capability of cellular technology for vehicle detection and experimenting with the concept of smart travelers and smart buses. The long-term actions should be directed toward (1) developing a comprehensive multimodal database, (2) refining implementation strategies for the advanced traveler information systems, (3) evaluating the ATIS system utilities in the Bay Area, and (4) encouraging a partnership between the public and private sectors for system implementation. In addition, institutional issues relating to deployment of cellular technology should be explored and examined to identify potential barriers that may be a hindrance to technology application. Implementation policy issues should also be investigated. These include: financing and management strategies of the automated traffic information systems, and the development of equitable fee schedules for access to traveler information.

PREFACE

This is the final report of a research survey on cellular phone users in the San Franciscd Bay Area. The purpose of the survey was to assess the interrelationships between cellular communication and driver behavior. This report documents the results of a mail survey of GTE Mobilnet customers conducted in March 1991.

1. INTRODUCTION

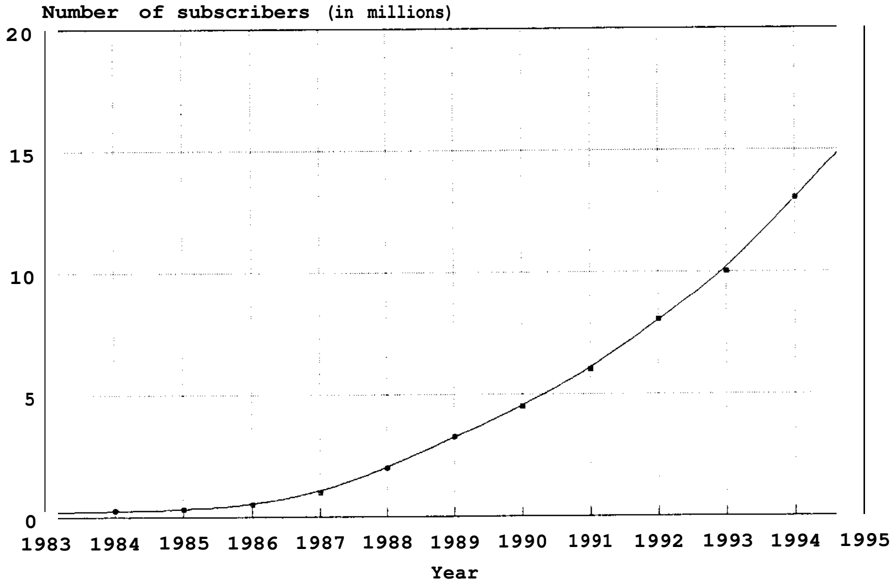
With the advancement of electronic and telecommunications technology, there is widespread optimism that the advanced traveler information systems (ATIS) will improve the performance of urban transportation systems. Possible improvements include relieving congestion, improving safety, and increasing productivity. Several studies have suggested that travelers equipped with up-to-date traffic information will modify their travel behavior in such a way as to improve their utilization of available system capacity (Huchingson, 1977; Wootton and Ness, 1989; Spyridakis, et al., 1990). Most studies to date have dealt primarily with driver responses to, and utilization of, broadcast traffic information. More recent work within the framework of IVHS research deals with route guidance systems in which user specific information is transmitted directly to individual motorists. One technology that would make this possible is cellular phone technology. The recent increase in the use of this technology in automobiles makes it possible to investigate the utilization patterns of this technology and the extent to which these patterns relate to travel behavior. This section reports on an empirical study of cellular phone users in the San Francisco Bay Area in the form of an extensive user survey.

With the advancing state of cellular phone technology, demand for cellular phones has been increasing (Figure 1). At the same time, the services offered to subscribers, including traffic and route guidance, increased. National data in the U.S., particularly in California and in East Coast urban areas, show a sharp increase in cellular phone demand during the past three years. Similar trends can be observed in other countries, such as Sweden, France, and England. Market analysts forecast that eight percent of all new automobiles will be equipped with cellular phones by the year 2000 (Appendix 1).

1.1. State of the Cellular Technology

Cellular technology has undergone rapid development over the past decade. One result has been a lowering of the cost of cellular phones, making them affordable to an expanding segment of the population. In the three years between 1987 and 1990 the typical price of a cellular phone dropped from over $2,000 to under $500. Technology is also producing smaller, lighter and cordless units that are portable, and “transportable”.

Figure 1. Market Trend of Cellular Phones



Data source: Shaw, 1990

Digital formats are being introduced which can handle higher volumes of telephone traffic more efficiently than the analog formats that predominate in the current market (Appendix 2).

Perhaps the most significant trend in the cellular industry has been the move toward the household market. Until recently, cellular phones were used primarily for business purposes. The predominant sectors have typically been in the categories of 1) construction, 2) finance, insurance and real estate, 3) services, and 4) transportation, communications, and utilities. But recent surveys showed an increase in household cellular phone use (Roscoe and Lee, 1990). The usage of cellular phones has also diversified. Prior to 1988, the primary use of cellular phones was for business. In the second quarter of 1990, surveys showed that only 45% of the subscribers used cellular phones for business. Thirty-one percent used their phones for both business and personal reasons, and as many as 25% of the subscribers used their cellular phones for personal reasons only.

The demographic profile of cellular phone users has diversified since 1988. By 1990, the mean household income of cellular phone users dropped from $90,000 to $44,000 and the average age of the subscribers decreased from 55 years to 39 years. In 1990, 15-20% of the subscribers were women, compared to the 1988 figure of less than 10%.

The industry has aggressively promoted cellular technology and has successfully penetrated the household market. The industry is also promoting the concept of highly productive mobile workstations. AT&T is currently conducting a series of experiments with mobile offices. These are automobile cellular workstations where the work schedules are largely dictated by customers' needs.

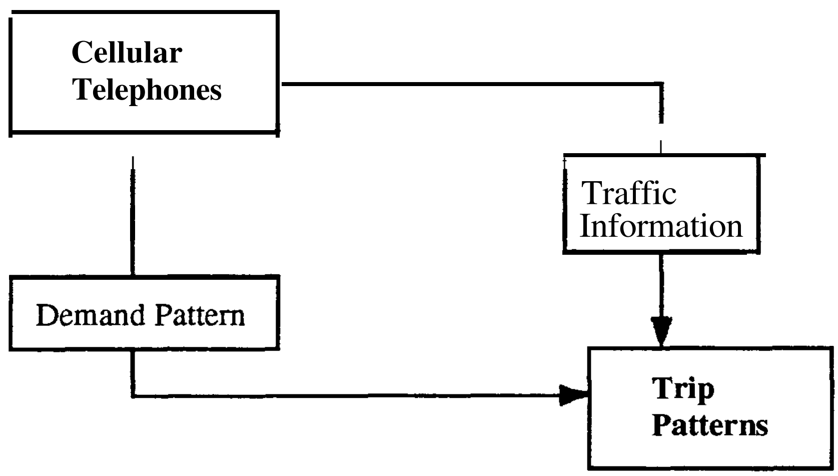
With the recent interest in Advanced Traveler Information Systems (ATIS), efforts are underway to explore the role that can be played by cellular telephone systems. In Europe the system of Cellular Radio for Traffic Efficiency and Safety (SOCRATES) deals with dynamic in-vehicle route guidance (Appendix 3). The technology is being tested with promising results and efforts are underway to explore how cellular traffic information can be conveyed via the forthcoming pan-European digital cellular mobile radio system, commonly known as GSM (Welling, 1990).

1.2. Conceptual Framework

Our interest in cellar phones has to do with the role they could play in the management of urban traffic systems and with their potential impacts on urban travel and traffic patterns. One would expect a technology that facilitates communications, such as cellular phones, to have some relation to the temporal and spatial pattern of activities, and therefore some impact on trip making. If the experience with domestic telephones is extended to the cellular mobile telephone, then one might expect similar effects. Some trips will likely be replaced by cellular communications and others will be generated because of them (Garrison & Deakin, 1988). It is also reasonable to expect some rescheduling of trips and some adjustment in the trip-chaining behavior of cellular-phone-equipped motorists.

In looking at the impact of cellular phones on traffic patterns, we distinguish between two separate effects, illustrated schematically in Figure 2. The first effect is that cellular phones directly influence travel demand by altering the organization of urban activities and the relationship between activity patterns and their temporal and spatial realizations. The replacement of some trips by communication and the generation of new trips because of it both fall under this category. The second effect is that cellular communications, by providing up-to-date information on the condition of the traffic system, permit their users to alter trip attributes, such as routing, mode choice, or chaining. Of course, these two effects are not unrelated.

Figure 2. Conceptual Framework



1.3. Previous Studies

While there is an abundance of studies on the travel behavior of motorists, little has been done to explore the behavior of motorists with cellular phones. Studies of the relationship between communications and trip making come close, but they do not deal explicitly with mobile communication systems. Some of the recent work on the Advanced Traveler Information System does explore the effects on trip behavior when information is acquired while in transit, particularly in the area of route choice.

The response of motorists to traffic information was studied in a survey of motorists in Seattle (Spyridakis et al., 1990). Using traffic information conveyed via radio broadcasts and variable message signs, motorists were more likely to shift routes and departure time than other attributes of their trips. Motorists were found to prefer receiving information before entering the freeway and expressed a desire for a telephone hot-line or a cable TV station dedieated to real-time traffic information. Khattak, et al. (1991) also found that route choice was influenced by real-time traffic information. Motorists were more likely to shift paths if traffic information was given in advance through radio or other means than when delays were observed by the motorists themselves.

The direct relation between trip making and telephone communications was studied by Claisse and Rowe (1990). This survey of 663 people in Lyons, France found that two-thirds of the telephone traffic had some connection and possible substitution effect with daily trips. Over 80% of the calls made by the sample population were local calls, and the other 20% were regional or long-distance calls. Twenty-one percent of the domestic telephone calls made during weekdays were reported to have substituted mainly for automobile business trips. Only 3.26% of the calls were reported to have generated unplanned trips. Claisse and Rowe's survey dealt with domestic (home) telephones and not mobile communications.

2. CELLULAR PHONE USER SURVEY

When the Federal Communication Commission (FCC) began accepting cellular radio license applications in 1982, the FCC regulated regional competition by granting permits to two operators for each market. According to the FCC, the markets are classified into urban and rural. The FCC's urban markets are defined as the Standard Metropolitan Statistical Area (SMSA), while the rural markets are defined as the designated Rural Service Areas (RSA). There are 306 urban markets and 428 rural markets in the U.S.

In the Northern California region, GTE Mobilnet and Cellular One are the two operators permitted to offer services to Bay Area consumers. Although the precise number of subscribers could not be obtained, mainly because of the competition between GTE and Cellular One, the California State Utility Commission estimated that approximately 150,000, or 4%-5%, of the four million Bay Area automobiles were equipped with cellular phones in 1991.

2.1. Methodology

For this survey, the sample population was selected from GTE Mobilnet customers in eleven counties of the Bay Area and in its surrounding regions. The GTE service area covers Sonoma, Napa, Solano, Mar-in, Contra Costa, Alameda, San Mateo, Santa Clara, and San Francisco counties in the Bay Area and extends to Santa Cruz and Monterey counties to the south. Even if the sample population did not truly represent Bay Area cellular phone subscribers, GTE customers were chosen partly because of their receptivity to our study but primarily because of the range of GTE service features offered in traffic and travel information (Appendix 4).

Between February 22 and March 4, 1991, 35,000 questionnaires were mailed to randomly selected GTE customers from its subscriber list. The sample size was determined based on the expected return rate of 15 % to 20%. By the last week of March 1991, approximately 7,500 or 20% of the questionnaires were returned. The data were edited manually, then processed through an optical scanning machine to enter the data. The number of forms processed for this study was 7,347.

The self-administered mail questionnaire consisted of 39 closed-ended, dichotomous and multiple choice questions (Appendix 5). The names and telephone numbers of respondents were solicited with an interest in conducting a follow-up telephone survey. Of the 7,347 subscribers responding, 52.1% expressed an interest in participating in the follow-up telephone survey.

The questionnaire was designed to obtain user attributes that might have influenced their travel behavior. Therefore, questions were specifically addressed to demographic profiles of subscribers, functional and temporal usage of cellular phones for daily activities, and changes in travel patterns based on traffic information and activity patterns. Socioeconomic profiles of cellular users will suggest the potential market segment for Advanced Traveler Information Systems. Information on functional and temporal usage of cellular phones will reveal the extent to which daily activities are directly influenced by cellular communication. The third series of questions will give us answers as to how traffic information through cellular communication permits drivers to alter trip attributes such as routing and scheduling, and how cellular communications influence travel patterns because of consequent changes in activity patterns.

3. SURVEY RESULTS

The survey results are reported in several parts: 1) demographic profile of cellular users, 2) usage of cellular phones, 3) traffic information and travel behavior, 4) travel information needs, 5) route guidance system, and 6) cellular phone usage and travel behavior (Appendix 6).

3.1. Demographic profile of cellular users

Similar to the national trends on cellular phone users, our sample population represented upper middle and upper income households ($50,000 - $150,000) with ages varying between 30 and 55 (Figures 3 and 4). The sample was predominantly male in composition (79.6%). The majority of respondents were employed either full time (56.3 %) or self-employed (37.6%) and they were mostly engaged in professional, managerial, or sales occupations (Figures 5 and 6). All industries were well represented although construction, sales (whole sale, retail trade, and real estate), and service industries showed slightly higher representation than others (Figure 7). Eighty-five percent of the respondents commuted to work and only 15 % worked at home. Many of them also had two or more employed persons (62.8 %) in their households.

3.2. Usage of Cellular Phones

In referring to the conceptual framework of this research, we were concerned with the manner in which cellular communications influenced daily activities with respect to spatial and temporal arrangement of travel patterns. The survey showed that cellular phones were more heavily utilized for business (71.8%) than for personal activities (28.2%). This suggests that business trips are more likely be influenced by cellular communication. The survey also indicated that the primary reason for getting a cellular phone was associated with productivity (36.7%) and convenience (34.0%) -- by being able to conduct business while driving or to have access to a phone at all times. Only 3 % said that the reason had to do with trip planning or rescheduling appointments. However, nearly 25% of the respondents indicated that, in practice, the primary purpose of cellular phones was to schedule or reschedule appointments while driving (Figures 8 and 9).

According to the survey, cellular communication was closely associated with the amount of time spent in a car. The more hours spent in a car, the more calls were made for checking messages, rescheduling appointments, seeking directions, or coordinating tasks.[1] No matter how many hours spent in a car, business calls for coordinating tasks occurred twice as frequently as those made for checking messages or rescheduling appointments.

It appeared that the reason for getting a cellular phone was also associated with the number of hours spent in a car. For those who spent more than two hours a day in a car, the reason for having a telephone in the vehicle was to increase productivity. For those who spent less than two hours a day in a car, the reason was convenience. This suggests that travel behavior of high-mileage drivers is more significantly influenced by cellular communication than the travel behavior of low-mileage drivers.

3.3. Traffic information and travel behavior

In this section, we were concerned with the extent to which traffic information was utilized via cellular communication and the way in which drivers modified their travel patterns based on this traffic information. The survey showed that a small percentage of the respondents used GTE's traffic information service. Only 15.8% of the 7,347 respondents indicated that they sought traffic information via cellular phones (Figure 10). Almost ten percent (9.7%) of the respondents indicated that they sought traffic information when congestion was expected ahead, and 3% said the information was sought before leaving home, work or other activities such as meetings or events (Table 1). Cellular phones were not used very often for seeking route guidance or road directions.

The low demand for traffic information services in the Bay Area is undoubtedly associated with the reliability of such information. The Bay Area, at present, does not have a real-time traffic information service. The information that GTE distributes is based primarily on Metro Traffic service, a private organization providing most of the Bay Area traffic information to commercial radio and television stations. The traffic information is updated every 15 minutes. In addition, GTE charges $1 a call for information similar to what can be obtained from commercial radio stations.

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[1]The cross tabulation showed a linear correlation ($r = .21, p \leq .0001$) between the number of hours spent in a car and the number of business calls made while driving. This correlation was not as significant as when the cellular phones were used primarily for personal calls.

Table 1. Traffic information sought using cellular phones

For en route decisions:	
When expected congestion ahead	9.7%
For pre-trip planning:	
Before leaving home	0.8%
Before leaving work	0.7%
Before leaving any activities	1.5%
Other	3.3%
Never	84.2%

Concerning the driver response to traffic information, our interest was to observe travel behavior after obtaining traffic information. The hypothesis was that the majority of those who sought traffic information would divert if choices were available. The survey indicated that the majority of the 1,162 who sought traffic information took alternate routes. Very few changed destination, rescheduled, or canceled their trips (Figure 11). In addition, no significant difference in behavior was exhibited between men and women.

According to the survey, the frequency of traffic information sought is associated with the number of hours spent in an automobile. The longer the time, the greater the use of traffic information. Similarly those who spent more hours in automobiles diverted their routes more often than those who spent fewer hours in their cars.

3.4. Travel information needs

As trip patterns are influenced by travel information, the interest was to learn about the type of information which would best guide drivers. When asked about the type of travel information most needed while driving, the survey indicated that the fastest alternate route information was most important, followed by real-time traffic and parking availability information. Traffic reports on outside local regions were not viewed as important (Table 2, Figure 12). When the responses were compared between men and women, the most desired service feature in both cases was still the fastest route information. To men, real-time traffic information was more important than off-street parking information. To women, off-street parking information seemed to be more important than real-time traffic information.

Table 2. Travel information needs

	All	Male	Female
Fastest alternate route	33.3%	33.2%	9.5%
Real-time traffic information	26.2%	17.2%	3.4%
Off-street parking availability	10.6%	12.3%	4.3%
Traffic report on other regions	5.5%	2.8%	0.6%
Other	10.5%	14.1%	2.6%
	100.0%	79.6%	20.4%

3.5. Route Guidance Information System

When asked about an in-vehicle route guidance system, only 37.4% of the respondents said they would be interested in having a device which would visually display the shortest route information for their destination (Figure 13). Of those who were interested, the vast majority (61.1%) expected to have to pay less than $500 (Figure 14). Men (39.2%) were slightly more interested in using the system than were women (31.3%).

Of those wishing to have the fastest route information service, 45% wished to obtain that information from a source other than an on-board route guidance device. On the other hand, of those who never sought traffic information via cellular calls, as many as 35.3 % wanted to use a route guidance system.

Demand for in-vehicle route guidance systems was not closely associated with age or household income. However, subscribers engaged in the service industries appeared to be more interested than those in other industries. There was no significant difference between commuters and non-commuters in attitudes toward the on-board navigation system.

As mentioned earlier, the survey also indicated that traffic reports outside the Bay Area were not as important as other traveler information. Nonetheless, traffic information in other regions could be important to those who are not familiar with the conditions of these regions. Surveys of French and American motorists conducted by Ygnace (1990) indicated that 77% of the people who used the DriverGuide device at Roissy Airport in Paris would rent a car with an on-board navigation system for an extra fee when arriving in other cities.

3.6. Cellular phone usage and travel behavior

In assessing the impacts of cellular technology, we considered taking two samples: one with cellular phones and one without, then comparing the two samples in their travel behavior. There were, however, severe technical problems associated with comparing two samples taken from different pools. Therefore, for this survey, we decided to ask about the perceived changes in travel behavior after getting a cellular phone. Nearly 80% of the respondents indicated that they perceived no change in their trip frequency, miles driven, or trip scheduling (Figure 15).

When asked about their perceived changes in trip frequency in an average month, after acquiring a cellular phone, 77.3% thought they drove as frequently as before. As many as 82.7% of the respondents thought there were no significant changes in miles driven, and 71.9% thought their trip schedule remained just about the same as before. However, of the 22.8% of the respondents who reportedly modified their driving behavior, almost twice as many thought they drove "less" than those who thought they drove "more". This "decrease" in trip making is more marked for non-commuters than for commuters.

While the vast majority of the respondents thought the cellular technology had no effect on their travel behavior, a large number of respondents also indicated that their trips were affected by cellular communication. When the ordinal scale was applied in measuring the effects of the technology, such as by asking the number of trips made per day, per week, or per month, different results were obtained. Over 60% of the respondents indicated that their driving behavior was modified one way or another because of cellular communication. For business trips, of the 6,237 subscribers who responded, 41.6% indicated that they made unscheduled trips at least once a week or more because of cellular calls. Scheduled trips were also postponed or canceled because of cellular calls (Figure 16, Table 3). The effects of the cellular calls on trip scheduling appeared to be more significant than trip generation. Personal trips seem to be less affected by information gained from the use of cellular communication than do business trips.

Table 3. Effects of technology on trip scheduling

Trip scheduling	Frequency of change > l/day	< 1/day & > 1 /week	> l/month	Never
Made unscheduled visits				
Business purpose	8.6%	33.0%	24.8%	33.6%
Personal purpose	3.5%	22.1%	34.3%	40.1%
Postponed scheduled visits				
Business purpose	5.5%	30.7%	33.8%	30.1%
Personal purpose	2.2%	16.6%	36.8%	44.3%
Canceled scheduled visits				
Business purpose	4.0%	23.5%	37.1%	35.4%
Personal purpose	1.8%	12.4%	36.4%	49.4%

The cross tabulation showed that there were few behavioral differences between those who commuted and those who did not in the way unscheduled trips were made, or scheduled trips were postponed or canceled. Among those respondents who commuted to work, 39.9% made unscheduled trips at least once a week while 46.5 % of non-commuters made trips without previous arrangements.

As expected, changes in trip frequency were associated with the changes in trip scheduling. The respondents who thought they drove "less often than before" also thought they canceled their trips "more frequently than before." Of those respondents who, at least once a month, made unscheduled visits because of cellular calls, 76.7% said they thought they drove more often than before (Table 4).

Among those respondents who thought cellular phones affected their driving behavior in vehicle miles, twice as many thought they drove less than those who thought they drove more. The survey indicated that changes in trip frequency, the number of trips made, is significantly correlated with changes in trip length ($r_s=.57, p\leq.0001$). Frequent drivers thought they had driven more miles than did infrequent drivers.

Of those who perceived their trip scheduling to have changed, more respondents thought they modified their schedule "more often than before" than those who thought they changed their schedule "less often than before."

Table 4. Perceived changes in travel behavior after getting a cellular phone

Changes in trip frequency:	
Drive as often as before	**77.2%**
Drive more often than before	**8.0%**
Drive less often than before	**14.8%**
Changes in trip length:	
No change	**82.7%**
Drive longer than before	**5.8%**
Drive shorter than before	**11.5%**
Changes in trip scheduling:	
Same as before	**71.9%**
More often than before	**16.6%**
Less often than before	**11.5%**

The survey also suggested that trip frequency and vehicle miles driven are closely related to the way the drivers modified their trip scheduling. Those who thought they changed their schedule “more frequently than before“ also thought they made more frequent unscheduled visits, or that they frequently postponed or canceled scheduled visits.

Self-employed subscribers indicated that they drove more frequently and longer distances than did those who were employed. More of the employed respondents thought their travel schedules changed more frequently than did the self-employed.

3.7. Summary and conclusions

One of the important findings of the survey is that cellular technology seems to have some effect on travel behavior by altering daily activities in trip making. Nearly 25% of the respondents claimed that cellular phones were used primarily for rescheduling trips and over 60% indicated that cellular communication affected their trip behavior. The primary effect was on trip rescheduling and, to a lesser extent, on trip frequencies.

Cellular phones were infrequently used for en-route traffic information and then only if the user expected traffic congestion. Evidence from the survey suggests that, while cellular phones might not have a significant net effect on the frequency of trip generation, they will alter trip patterns as people use them to adapt their activity patterns. Only with substantial use of cellular phones for route guidance might there be a measurable net effect on trip frequency.

There were technical difficulties in assessing the direct impacts of the technology on travel behavior because of the absence of real-time traffic information in the Bay Area. Once the real-time traffic information service becomes available, increased use of cellular phones for route guidance may result. It is highly desirable to test the net effect of cellular technology through technology demonstration projects.

Figure 3
Age

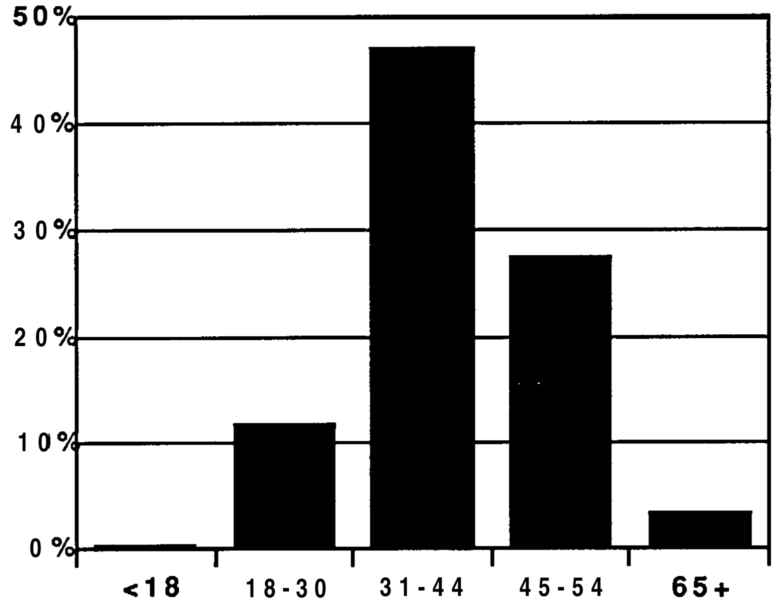


Figure 4
Household Income

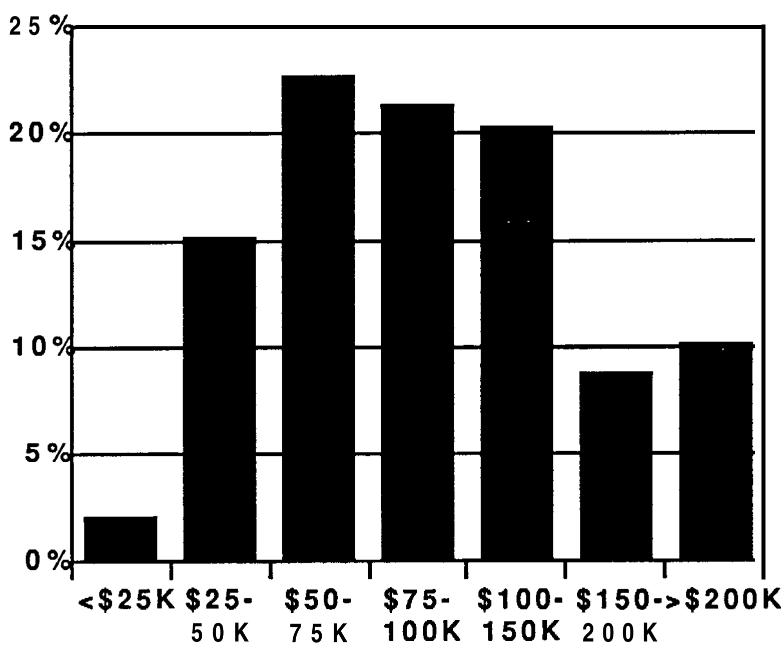


Figure 5
Employment

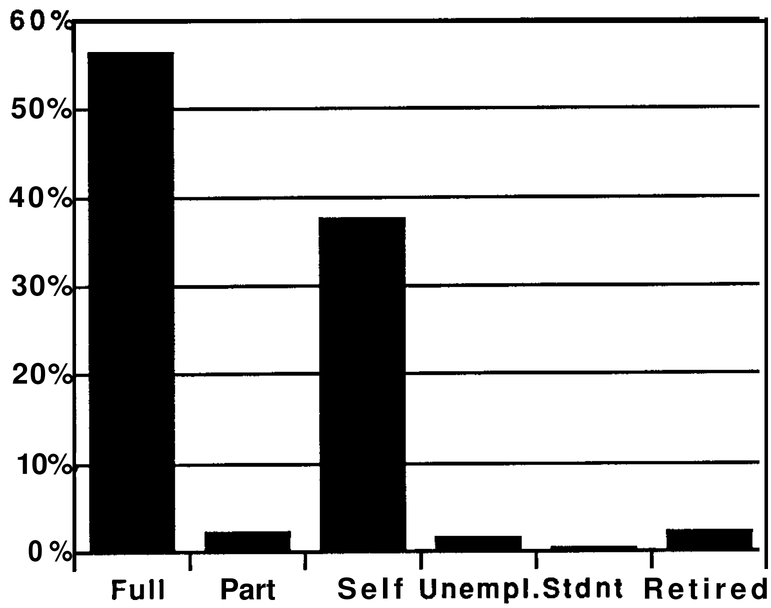


Figure 6
Occupation

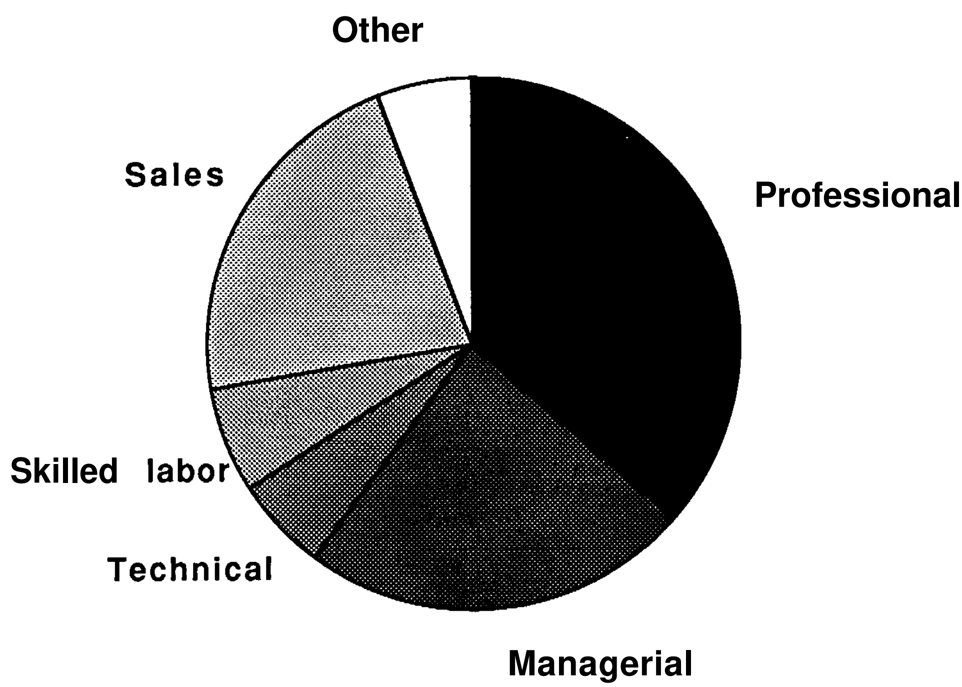


Figure 7
Industry

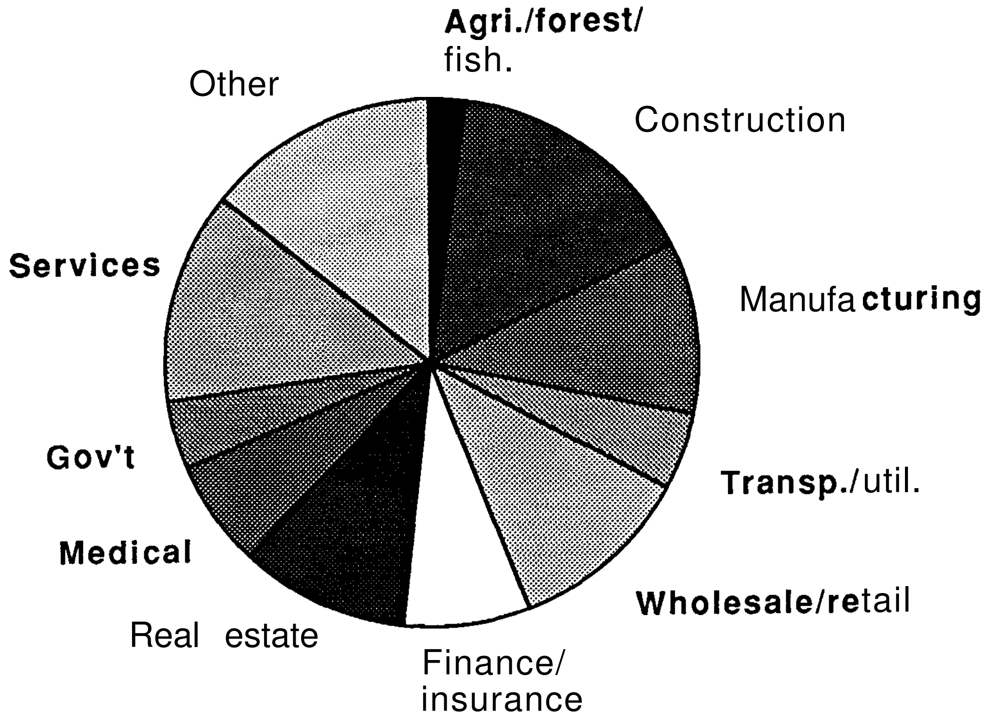


Figure 8
Primary Reason for Getting a Cellular Phone

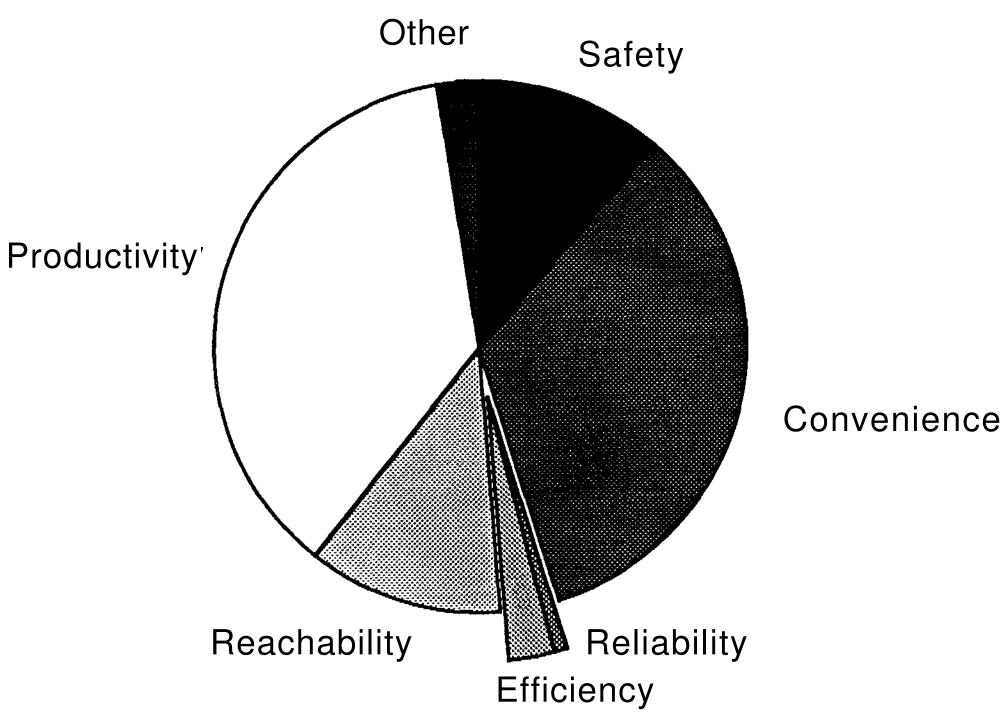


Figure 9
Primary Purpose of Cellular Phones

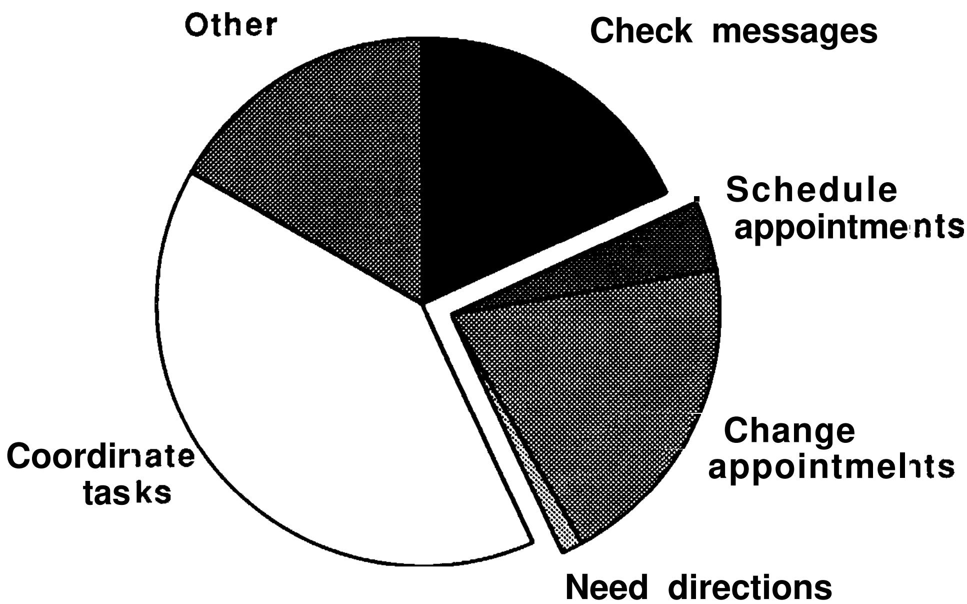


Figure 10
Traffic Information

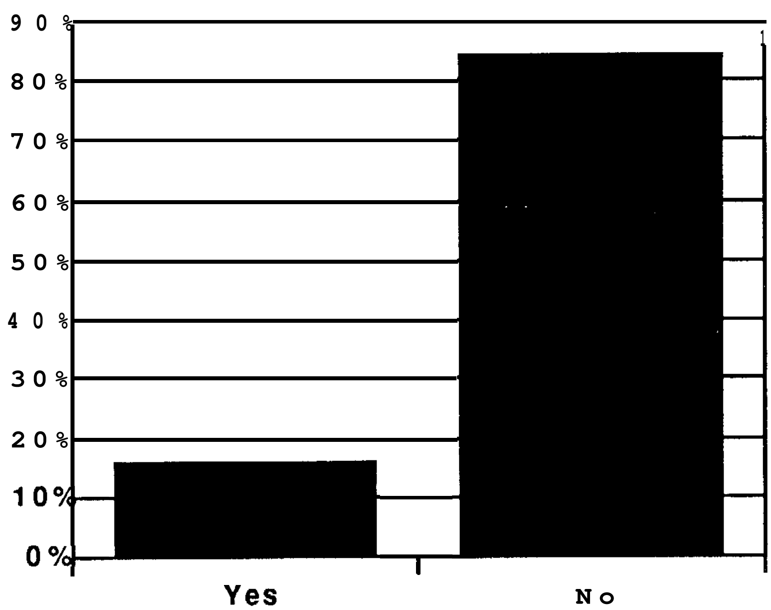


Figure 11
Travel Behavior (Based on Traffic Information)

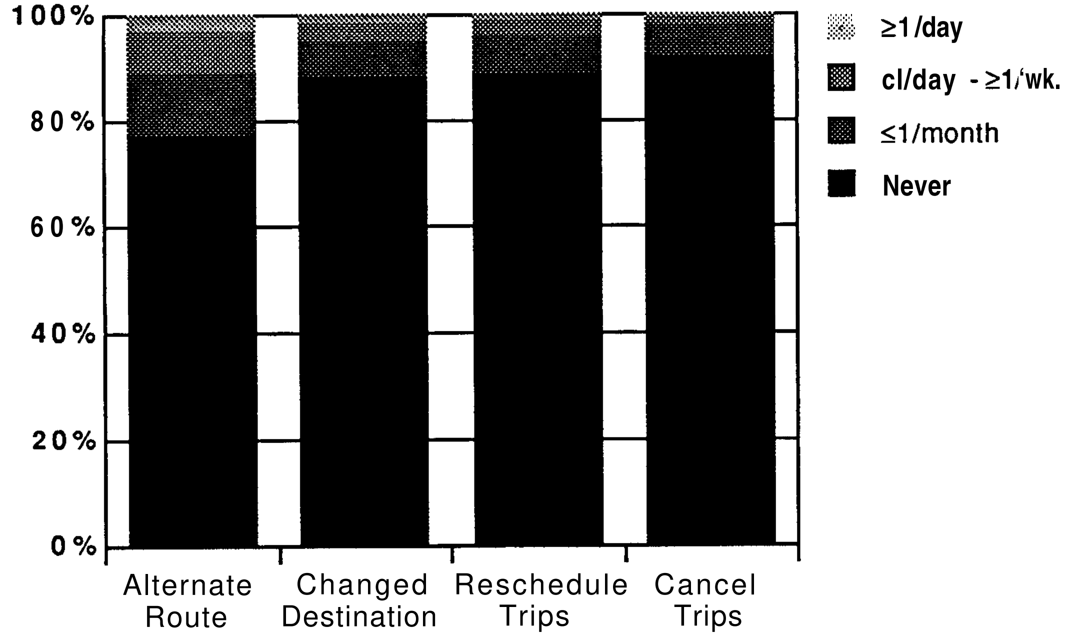


Figure 12
Travel Information Needs

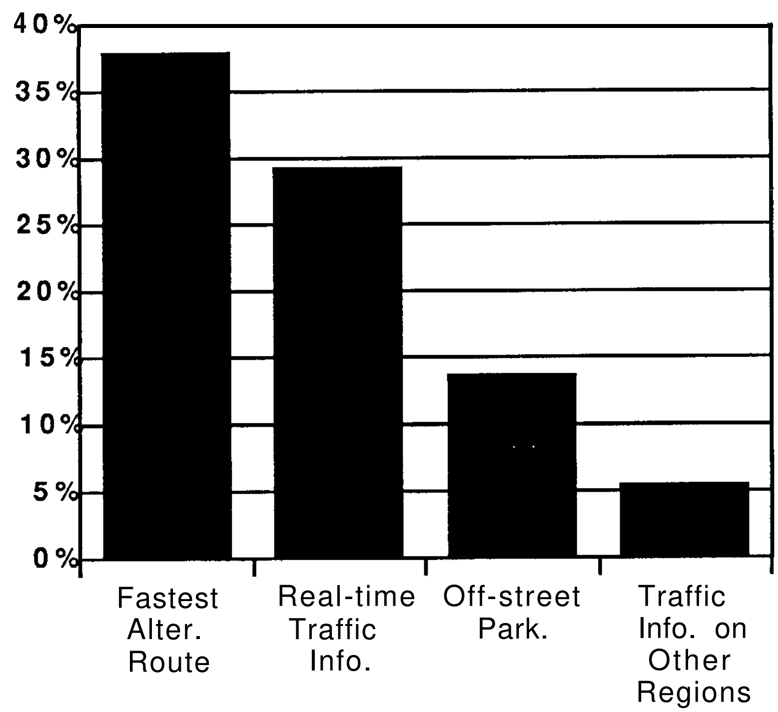


Figure 13
Route Guidance System

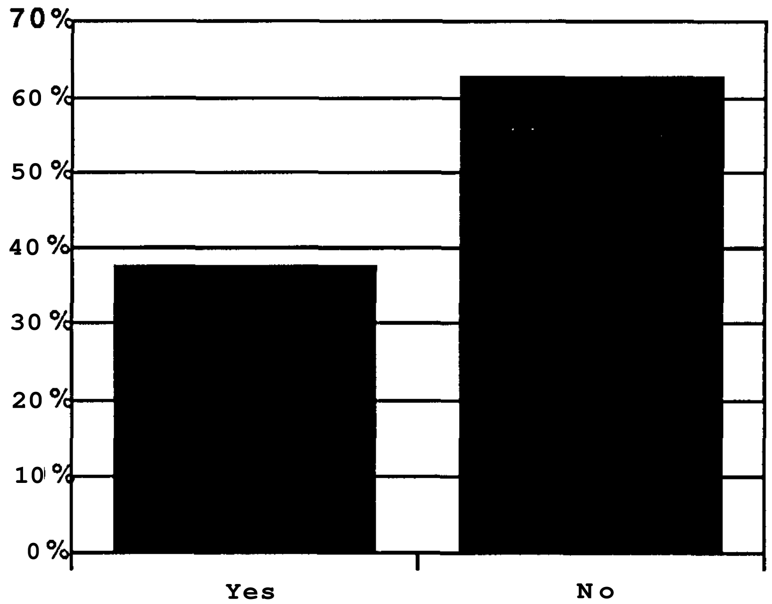


Figure **14**
Willingness to Pay for Route Guidance System

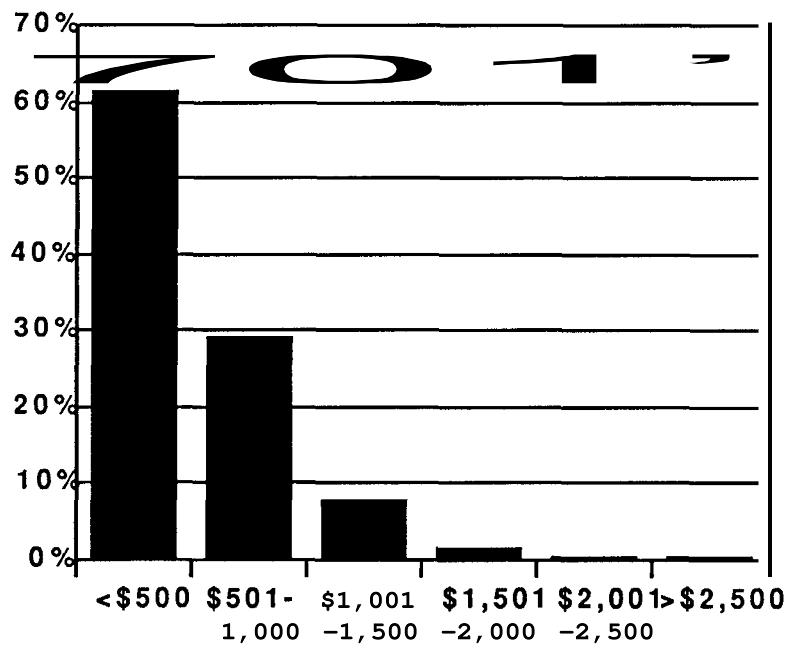


Figure 15
Perceived Changes in Travel Demand

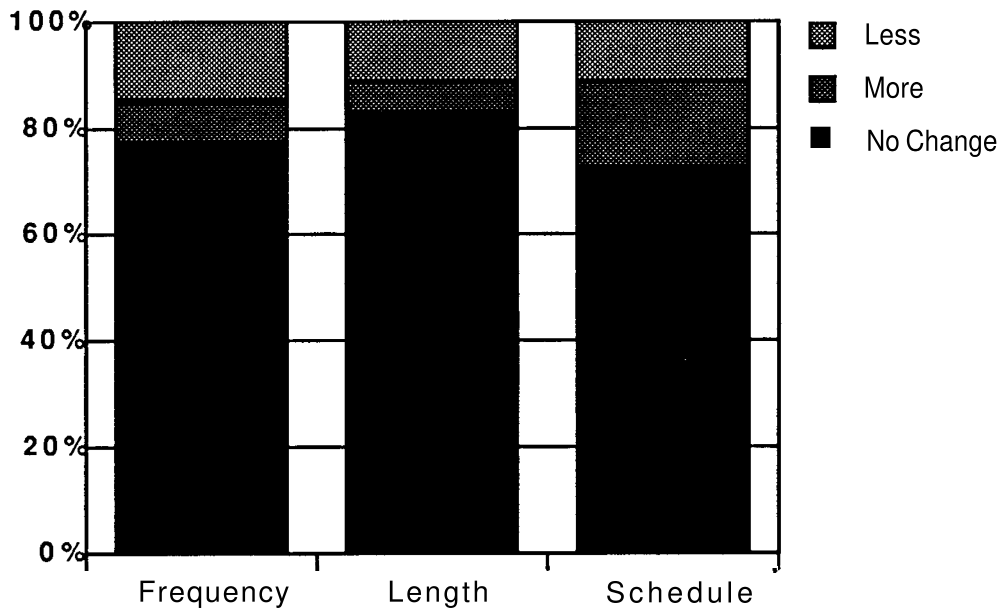
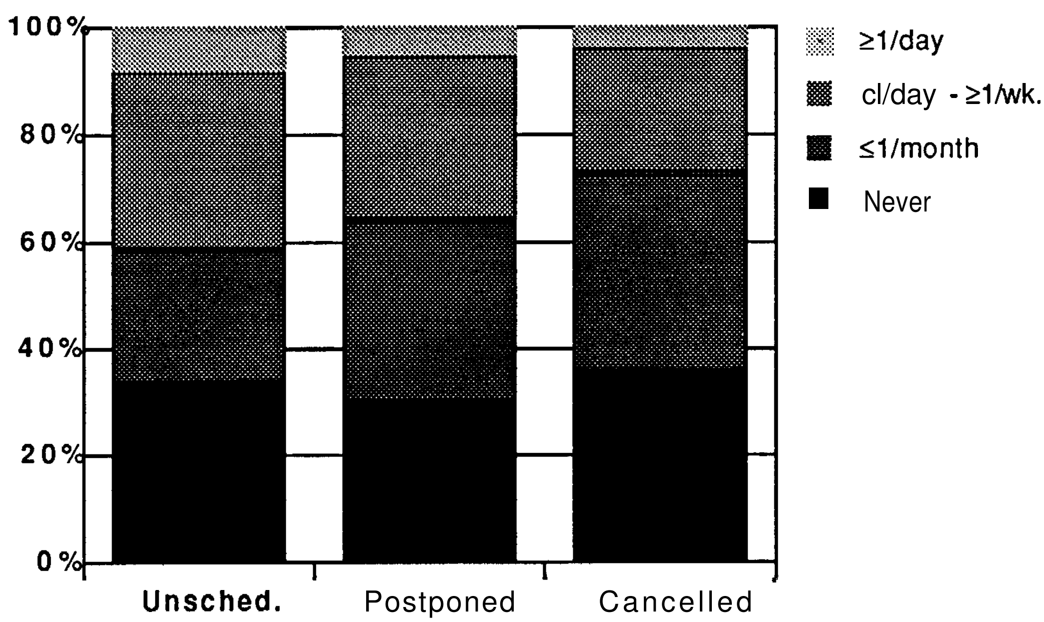


Figure 16
Trip Schedule (Business)



4. FURTHER RESEARCH ON CELLULAR TECHNOLOGY APPLICATIONS

The previous sections examined the travel behavior of cellular phone users. In this section, the potential application of cellular communication for traffic management and the need for research on this subject are discussed.

4.1. Potential Applications of Cellular Technology for Traffic Management

In the past decade, the cellular industry has gained consumer acceptance faster than the television or VCR industries and has quickly penetrated the consumer market. The growth of the industry has demanded a change in the distribution channels offering their products and services to tap larger market. Beginning in 1985, specialized cellular retail outlets were established to provide convenient services to local customers. Then beginning in 1988, the distribution channels reached major retail outlets in neighborhood shopping centers. The near-term prospect of cellular distribution is the availability of cellular phones from automobile manufacturers (Shaw, 1990).

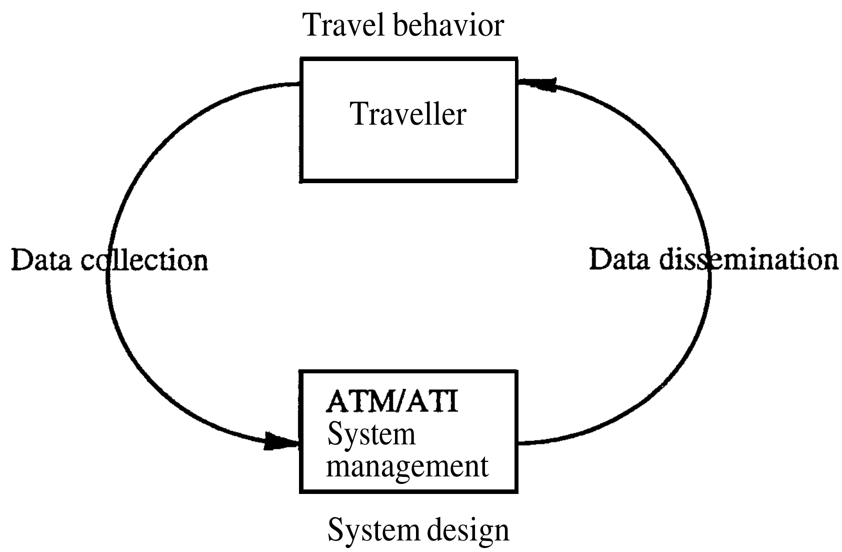
Several studies and research proposals have explored the potential application of cellular technology for travel guidance and traffic control (Frank, 1989; Frank and McCarter, 1990). In traffic surveillance and management, vehicle location monitoring and reporting are key to vehicle detection and incident verification. Two-way vehicle communication ability is essential to the traffic monitoring and reporting system. Cellular networks can provide such a capability.

Within the context of an IVHS environment (Figure 17), potential applications of cellular technology include (Catling, 1991):

1. Vehicle detection and incident verification
2. Dynamic route guidance and driver information service
3. Incident reporting
4. Transit management and schedule reporting
5. Multimodal transportation service
6. Fleet vehicle location reporting and management (Baker, 1990; Scapinakis, 1991)
7. Off-street parking availability information service

As the cellular technology appears to have a wide range of potential applications for automated traffic management and traveler information systems, further research is needed to fully explore its capability in an IVHS environment, and to shed some light on the role that it can play in the larger context of IVHS systems.

Figure 17. Potential Applications of Cellular Technology



4.2. Future Research Topics

Research topics relating to cellular technology include: 1) the study of the effects of cellular calls on trip demand (cellular calls in lieu of driving); 2) the exploration of cellular technology as an element in permitting the use of vehicles as probes; 3) the study of dynamic travel guidance for rideshare and transit information; and 4) real-time traffic information for drivers and fleet operators. The following topics are suggested research subjects in cellular technology relating to Advanced Traffic Management and Travel Information Systems.

A) <u>Trip substitution or trip generation</u>

Evidence from the survey of cellular users indicates that the primary effect of cellular technology was on trip scheduling. Cellular communications might have replaced some trips and, on the other hand, might have generated others. The present study could not measure the net effects of cellular communication on trip substitution and trip generation. Continuing research is needed to quantify the impact on trip demand.

In the present research, cellular call traffic patterns between zones and within zones were analyzed. To measure the net effects of substitution or generation of communication, follow-up telephone surveys of cellular phone users should be conducted.

B) Vehicle as probe

Both theoretical and experimental studies are needed to assess the potential of the cellular technology for vehicle detection and incident verification. Loop detectors and closed-circuit televisions are currently used in detecting incidents and obtaining other traffic information. However, the installation cost is high and the system performance is low. According to Caltrans, the typical lag time between incident detection and data transmission to the California Highway Patrol is approximately seven minutes. Mobile radio systems, on the other hand, have a typical transmission time of less than one minute with fairly high accuracy. Cellular systems have the potential of providing traffic and travel information.

The San Francisco Bay Area has severely limited infrastructure capabilities for collecting traffic information. Loop detectors are placed only on the San Francisco/Oakland Bay Bridge and on a small segment of I-80 at the entrance to the bridge on the East Bay side. Although there are plans to install loop detectors on the entire 500-mile Bay Area freeway network over the next ten years, availability of funds for the project is uncertain. The proposed detectors will have 2 loops on each lane and will be spaced every 1/3 mile.

Given the circumstances of the Bay Area, it seems appropriate to test the feasibility of cellular technology with Bay Area motorists. The present study analyzed the commute traffic patterns of the cellular phone users in the San Francisco Bay Area (Appendix 7). That information would be extremely useful if the technology were to be tested in the region.

In the absence of infrastructure, the question is whether the probe vehicle technology can alone or in combination with already existing detection technique provide the necessary data to support traffic management and control strategies? Considering the interest in AVI/AVL technologies for vehicle probes, remarkably few demonstration projects are currently underway world-wide. Experimental studies of probe vehicles in a large scale urban setting are needed in order to develop proper policies and strategies for AVI/AVL technology adaptation and deployment.

The critical issues concerning the design of AVI/AVL technology experiments for vehicle probe are: (1) the number of probe vehicles (critical mass) required to obtain accurate travel-time information; (2) the frequency of data reporting; (3) the locations and spacing of reporting stations; (4) the types of technologies to be tested; (5) the deployment stages of technologies; and (6) the selection of demonstration sites.

Within the framework of the above issues, the future research needs are: (1) to identify the trade-offs between loop detector techniques and vehicle sensor technologies, such as the cellular network in terms of capital and operating costs with respect to the quality of data; (2) to develop a conceptual model for testing the ability of probe vehicles with single and multiple technology scenarios; and (3) to design an experimental study of probe vehicles for evaluating candidate technologies. Distinct from emerging AVI/AVL technologies, the cellular market has moved toward the rapid deployment of technology. This is an advantage it has over other technologies for testing its ability and immediate application. Research issues could include: (a) what is the role of cellular technology in vehicle detection and incident management assuming that some percentage of Bay Area motorists have cellular phones? (b) what would be the necessary market penetration of cellular phones (percentage of vehicles equipped with cellular phones) in order to establish a reliable reporting system for accurate real-time traffic information? and (c) what is the necessary sampling ratio between general automobile traffic and cellular phone user traffic in order to estimate the percent of cellular phone users who would participate in vehicle probe?

What is needed to determine the extent to which public agencies or any private organizations involved in freeway operations can rely on cellular phones for traffic surveillance and management? It is probable that most cellular users would be willing to report incidents. Quantity and quality of cellular calls for incident verification should be evaluated. Too many 911 calls may oversaturate the data processing system with redundancies. On the other hand, too few calls may not provide required accuracy of information for traffic management. Performance of a cellular network can be evaluated based on the reliability of the data or on the probability of the failure of the technology.

Such an exercise will be useful in selecting sensor technologies for vehicle probe.

C) Advanced Traveler Information Svstems

In the current research, capabilities of various communication technologies have been explored to determine their potential use for Advanced Traveler Information Systems. The cellular technology was one of those being considered for such application, i.e., dynamic route guidance systems and real-time traffic information to drivers.

Research is needed especially in the subject of compatibility of the format and quality of information with the other database. There are other issues relating to Advanced Traveler Information Systems that are a hindrance to technology deployment, such as consumer acceptance of the technology and the level of utilization of traffic information. The follow-up telephone survey could include the questions concerning: (a) the level of interest in obtaining the types of information for pre-trip planning and en-route decisions, i.e., ridesharing options, pre-trip planning itineraries (shortest path), real-time traffic information, and in-vehicle navigation; (b) the level of participation in current traffic incident detection; and (c) the equitable fair dispensation for participation of cellular users and operators in the traffic management system.

D) Transit Svstem Management and Information Service

Investigation is needed in the area of how the emerging communication technologies such as cellular systems could enhance productivity and increase ridership for cat-pooling, vanpooling, and transit systems. Since the Bay Area suburbanization in the 1950s, transit ridership has remained small relative to automobile driving. Evidence indicates that over 80% of the California workforce uses private automobiles for the daily commute to and from work (Transit Facts, 1989). The fraction of commute trips that are made by carpooling and vanpooling is also small despite many incentives for ridesharing. In the past ten years, there has been almost no increase in either vanpooling or carpooling.

The reluctance to use pools or transit systems seems to be associated with perceived "inconvenience" and "unreliability" (Shu and Glazer 1979; Connecticut Department of Transportation, 1980; Christiansen and McCasland, 1988; Bullard, 1989). Nonetheless, several studies have suggested that transit ridership could increase if reliable transit schedule information were made available to potential riders (Municipality of Metropolitan

Seattle, 1987; California Department of Transportation, 1989). Real-time traveler information and thus dynamic rideshare arrangements could encourage mode shift from single occupancy vehicle to mass transit or rideshare. Emerging cellular network and other communications technologies are viable means of achieving this goal.

Potential applications of cellular technology to rideshare activities and transit services are listed 'below :

(a) Transit management and information services

This includes fleet management for small systems and passenger information services providing real-time bus schedule information for arrival and departure activities at every bus station and bus-stop.

(b) Rideshare information services

This includes information on real-time arrival and departure schedules, pool locations, and parking availability at park-and-ride lots for vanpools and cat-pools.

(c) Parking management and traffic information services

For vanpool or carpool drivers, a cellular network could link information among parking facilities to improve parking management and service. This would allow drivers to find the most convenient parking locations at the transfer points, i.e., park and ride lots, and at the destination, as well as to reserve and pre-pay for their space.

(d) Pre-trip planning and information services

Public transit and rideshare information could be linked with other advanced traveler information systems such as dynamic route guidance to allow riders to plan the time and the modes of transportation. This can be viewed as a comprehensive dynamic information system operation capable of providing trip-planning information for users, as well as trip management information for operators. The former includes real-time departure and arrival information, guided information on available modes, parking availability information, and fare structure. The latter includes vehicle location and traffic information.

Research is also needed on the evaluation of cellular communication technology as it compares to other technologies for effective management and operation of public transportation systems. Cost effectiveness of the cellular system should also be included in the future research.

E) Multimodal integrated transportation service

The concept of a multimodal integrated transportation system (MITS) is the integration of Smart Bus and Smart Traveler systems with a system making real-time travel and ridesharing information available to vehicle operators and customers. The Smart Bus concept is an integration of fixed-route transit, dial-a-ride minibus, and paratransit services in order to improve operational efficiency and to increase public transit ridership. The Smart Traveler concept is the making of real-time traffic and rideshare information available to vehicle operators and customers. To determine the applicability of the MITS, the concept needs to be developed, evaluated, and tested in selected regions. Research needs are in (1) assessing the feasibility of cellular technology in supporting Smart Bus and Smart Traveler concepts, 2) developing the comprehensive multimodal database and implementation strategies 3) evaluating the system utility by testing the MITS in the selected regions and 4) assessing the cost-effectiveness of MITS.

The research should include theoretical analysis and computer modeling as well as field experiments. First, the existing and emerging technologies, including cellular technology, being considered for MITS should be evaluated in order to determine their potential to support the Smart Bus and Smart Traveler concepts. Second, the conceptual framework of MITS should be developed and the institutional organization should be identified for both private sector and public agency involvement. Case studies should be performed to test the MITS concept in heavily congested urban areas. Market research should be conducted to assess consumer receptivity to the multimodal integrated transportation services.

F) Institutional and policy issues

In contrast to the on-going efforts in hardware advancement, there have been very few research projects that have addressed institutional issues regarding technology adaption in IVHS research. Implementation of the smart vehicle and highway systems requires a partnership between the public and the private sector. Research should include identification and evaluation of institutional issues relating to adaptation and deployment of promising technologies for automated traffic management and real-time traveler information systems. Of particular interest would be a study of the institutional barriers that may be a hindrance to technology deployment. Institutional and policy issues may include: who should finance and manage these advanced systems; who should operate and distribute real-time information services; and should a fee be charged for access to travel information?

Research should include: (1) investigation of the capability of cellular technology as compared to other existing and emerging communication technologies for effectively gathering traffic data and disseminating traveler information to motorists and transit riders; (2) identification of potential barriers that prevent private sector participation in the process of technology adaption; and (3) evaluation of pricing strategies and institutional responsibilities for disseminating different levels of information.

Appendices

Appendix 1. Cellular Market Trends

When the cellular telephone industry began in 1983, the number of subscribers totalled only 500 in the U.S. In 1987, the number passed 1 million, in 1989, it passed 3.5 million, and today 5.3 million people use cellular phones. This figure is approximately 5% of the total vehicles in the U.S. As the number of subscribers has soared, the cost for the cellular services has markedly decreased. From $200 a month in 1983 for the monthly service charge, the total average cost today for a cellular phone is $103 per month, which includes air time, access, and amortization. The rapid growth of cellular phones has been due mainly to the reduced cost of cell phone hardware and airtime. "Average cell phone hardware prices have dropped by a factor of three, while airtime service costs have declined on an average of 15 to 20%. As the demand for cellular service increases, along with initiating service in the remaining serving areas, cellular service providers will effectively cover 95 % of the geographical area and virtually 100 % of the population of the U.S. with cellular service. It is expected that all major interstate highways within the U.S. will have cellular coverage as early as 1992." (Mason, 199 1)

For the past several years the number of cellular phone companies has been dwindling. Consolidations have become increasingly common. For instance, the Bell regional holiday companies have consolidated and now pursue non-wireless sectors outside their operating regions, their main competition being RHC. Competition has also pitted Southwestern Bell against Ameritech and Bell Atlantic in the wireless market. As the cellular phone industry must make larger investments as more people subscribe, few expect consolidations to halt, though the merger and acquisition phases are expected to slow. More capital is needed in order that new cell sites and other necessities can be built.

Some predicted in 1983 that there would be little demand for cellular telephones, but it is now a $4.55 billion industry with an increasing number of subscribers. Businessmen and women have been among those creating the greatest demand, but a great number of less traditional users have created demand also. Cheaper access, equipment prices, and air time have attracted those less traditional users, as have aggressive advertising and word-of-mouth. Pocket cellular phone users comprise the fastest growing segment; new models are being introduced more frequently, their sizes continue to shrink, and their prices are decreasing.

Throughout the 1990's, the cellular phone industry will continue to grow. Herschel Shosteck Associates has predicted the total number of subscribers will be 16.4 million to 20.6 million by 1995. This continued growth has forced several issues to the forefront which must be handled during this decade. The issues include: the conversion to digital technology, different marketing schemes, reaction to personal communications services and networks,' and increased competition caused by the possible introduction of a third licensee.

Conversion to digital technology poses the biggest challenge for the cellular industry. The CTIS and the manufacturing trade group Telecommunications Industry Association have endorsed Time Diversion Multiple Access technology (TDMA). Narrow Band Advanced Mobile Phone Service (N-AMPS) has been promoted by Motorola as another possibility to bridge analog and digital cellular services.

Dennis Rucker, the director of science and technology for Ameritech Mobile Services, states that a system that is now being internally called Advanced Cellular Services (ACS) will be developed over the next decade. This development will produce smaller handsets and will emphasize the replacement of mobile phones with these phones. Microcell and digital technology will be demanded; digital is being introduced in the fourth quarter of 1991 in Los Angeles.

Digital will be one factor in the cellular industry's need to use spectrum more efficiently while responding to growing demand and developing new wireless services. Demand for spectrum will continue from a wide range of users and the industry must be technologically innovative in order to prosper. Conversion will affect industry revenues and pricing and some analysts believe that incentives will be needed to promote the necessary new digital handsets.

More investments for the conversion to digital will be needed for cellular network equipment, but the additional capacity will insure long-term growth for the markets. The challenge to sell digital will include confronting the industry's marketing system, particularly the high incentives paid to providers and the built-in incentives that cause competitors and their agents to lure customers back and forth with equipment discounts and other incentives. The current commission system has left many dissatisfied.

Of uncertain benefit is the signing on of new, non-traditional, often low-end users. Casual users who use little air time are not necessarily a great asset to the industry, given the steep commissions. often paid to lure them. Also controversial is Congress' consideration of a third licensee. The industry has declared that such a move would be unfair and would slow cellular developments in rural areas.

Personal Communication Services (PCS) could open a new world for the industry, but opinions vary on whether PCS will be a profitable addition to cellular services. (Mason, 1991). PCS has been slow to develop in Great Britain, providing a possible scenario of how U.S. markets might react. Existing cellular carriers with an allocated spectrum are predicted by Probe Research to be the first to implement PCS during the 1992-93 period. By 1993, the services could have 250,000 subscribers and general annual earnings of $105 million.

The government could pose a problem for OCS; if the FCC grants a new spectrum of frequencies and excludes the cellular carriers and local exchange carriers from participating, PCS would be a threat to both. The FCC is studying PCS and the possibility of an additional spectrum. According to agency officials, the FCC is expected to make a formal decision soon.

Personal Communications Services could meld services and technologies offered by the cellular industry. With a tremendous demand for cellular and cellular-like services expected in the future, pocket phones that could be used at home and while walking to work, such as those CT2 and CT3 are offering, will become increasingly common.

An increasing number of small companies are finding that cellular phones can be used instead of two-way land mobile radios. More public safety agencies are using cellular phones in addition to their traditional mobile radio systems. Executives and observers of the industry believe that the perceived and actual values of cellular technology will be improved as current systems are used fully and new systems are created.

Data transmission represents a potentially important new growth area within the industry. Cellular Data, Inc., a Palo Alto, California - based company, is working with several cellular companies in field testing a product it developed which can use spectrum between cellular channels for data. Value-added services for subscribers are additionally enhancing the perceived value of cellular service, according to executives and vendors. Voice mail, for instance, has grown; Octel Communications, based in Milpitas, California, controls 60% of the voice mail market and has benefitted from cellular providers.

Appendix 2. Technology Assessment in Cellular Radio

The technological basis of the cellular system is the mobile radio system. This was commercially available in St. Louis, Missouri as early as 1946. Unlike the conventional wireline telephone technology, the mobile communication system uses radio frequencies (RF) in the 30 to 40 megahertz spectrum. The RF technology encouraged Radio Common Carriers (RCC) to enter the wireless telephone market and to compete with the wireline telephone companies. The Mobile Telephone Service (MTS) in its early stage was operated manually by connecting mobile radio calls to the public switch telephone network. Consequently, service coverage was limited only to the number of radio frequencies allowed in a given region (Shaw, 1990).

For almost two decades between the mid-1940s and the 1960s, no significant technological advances were made in the mobile telephone system. In the late 1960s, Improved Mobile Telephone Service (IMTS) was finally introduced to automatically connect mobile radio calls to the public switch telephone network. The high operating cost of the IMTS and over-saturated radio frequencies made it virtually impossible to expand the mobile telephone service. In spite of the technical limitations, demand for mobile phones steadily increased, with the subscription waiting lists as high as seven times the number of the paying customers in some urban regions, including New York City.

As demand increased, suppliers had to find new ways of increasing the capacity of radio frequency channels. Service areas are, therefore, subdivided into many small cells with each cell being connected to a central office by low power cell transmitters. The central office then controlled the larger service areas via connected network. In theory, the cellular radio system, by cell splitting (large cells into small cells) would provide an unlimited capacity of radio frequency channels.

The providers soon realized that cell splitting and frequency reuse could not satisfy the subscriber demand even if cell size were as small as a half mile in diameter. The cost of installation was high because of the real estate required to build transmitters and the quality of transmission was marginal. Yet, even with smaller cells, the industry could not supply the growing subscription demand.

In 1982, the Federal Communications Commission (FCC) accepted cellular radio license applications from wireline telephone and mobile radio companies. At this time, the FCC limited each market, classified as Metropolitan Statistical Area (MSA) and Rural Service Areas (RSA) two competitors each. According to the FCC classifications, there are 306 urban markets and 428 rural markets. To this date, these regulations still apply although there has been a consideration by FCC to allow third party competition.

The current cellular system uses analog radio technology. Since each cellular call occupies a 30 Khz radio frequency channel, the analog system is extremely inefficient in utilizing radio frequencies. To expand the capacity of the radio frequency channels, a new system must be invented.

In 1988, the Telecommunication Industry Association (TIA) selected a digital network system using Time Division Multiple Access (TDMA) technology. The digital system makes it possible for multiple cell phones to have access to the same 30 Khz radio frequency channel by time sharing the radio frequency channel. The digital system will allow an additional capacity of 4-6 times the current analog system.

Not only would there be increased system capacity, conversion of analog to digital technology would provide many benefits to the consumer (Williams, 1990). To support the digital system, only radio transmission equipment would be needed as compared to the costly real estate and hardware required in analog technology. Thus, it allows the sharing of low infrastructure costs among a larger number of subscribers and the shared infrastructure costs would be much less than with the analog system. In addition, the digital system would improve the privacy of phone conversations. Because of the complexity of the digital system allowing multiple access capabilities, eavesdropping on digital cellular signals would be extremely difficult unless a device were specifically designed for that purpose. With the analog technology, a conventional scanner can easily monitor phone conversations over the air.

Appendix 3. Current Research in Cellular and Transportation Technology

SOCRATES

The largest on-going research program in cellular technology regarding traffic management and road operations throughout Europe is called "SOCRATES." SOCRATES is part of the DRIVE program to study the use of cellular radio for Road Transport Informatics (RTI) or Advanced Transport Telematics (ATT) in the European communities. RTE or ATT programs are similar to the program called "Intelligent Vehicle/Highway Systems" in the U.S. (Catling, 1991).

SOCRATES utilizes cellular technology for collecting and disseminating real-time traffic information. SOCRATES will use cellular radio infrastructure for two-way communication capabilities between motorists and control centers. But the system concept in SOCRATES is different from the conventional telephoning method in that calls are made on a one-to-one or point-to-point basis. In the case of SOCRATES, only one channel will be used for each cell. The size of the cells are typically one to two miles in diameter. Travel information will be gathered on a cell-by-cell basis; therefore, the data generated from vehicles equipped with cellular phones will be at the aggregated level. Using aggregate data, the privacy of motorists would be protected. Data verification and synthesis will take place at the control center. The SOCRATES control center will be able to monitor traffic flows and speeds in real time with accuracy. The travel information will not only be used for traffic management but also will be used for short-term traffic forecasts. The travel data will be disseminated by broadcasting information to equipped vehicles in a cell-by-cell basis. This means that all equipped vehicles on a cell will receive the same traveler information.

The Houston I-45/US-59 Project

To improve the accuracy and timeliness of real-time traffic information available to motorists, commercial vehicle operators, and transit agencies, the Texas Department of Transportation is currently developing a system to collect travel time and incident data directly from commuters traveling in the I-45 and US-59 Freeway Corridor in Houston, Texas (Balke, et al., 1991). Although a fully automated system is to be implemented in the future, the immediate goal of the project is to have a manual system using cellular technology. In the subsequent phase of the manual system implementation, the vehicle location and incident verification systems will be automated using the automated vehicle identification (AVI) system.

This experimental project will collect travel time and incident information directly from the probe vehicles during commute hours on selected freeway corridors. The travel information will be transmitted to the central traffic management center where the data will be processed and disseminated to drivers by means of various multiple communication media. Cellular and AVI technologies are to be tested for this project. The first stage of the experiment is to test the cellular technology and the second stage is concerned with AVI. With the cellular system, each probe vehicle will report to the centralized communication center. Operators will enter the information, including the identification number of the probe vehicle, the reference location, and the time of the call, into the computerized database.

The study plans to use 200-300 probe vehicles during commute hours. The number of probe vehicles was determined based on the results of a pilot study with 20 probes.

Appendix 4. Methodology

In selecting sample population and designing the survey instrument, the initial question was how should the effects of cellular phones on travel behavior be measured? In response to this question, two approaches were considered: 1) by comparing travel behavior of those who have cellular phones and of those who do not and 2) by comparing changes in travel behavior among those cellular phone users before and after acquiring cellular phones.

In the former case, the question arises from sampling different population of users. What should be the reasonable size sample population for each that will give an acceptable confidence level? For any geographical regions, we considered taking about 300-400 observations for each of those who drive with phones and for those who drive without phones, then comparing these two samples using techniques, such as difference of means. In doing so, it is necessary to recognize some technical problems associated with comparing two populations sampled from different pools. For this study, a sample of cellular phone users can be taken from the list of subscribers. A sample of non-users can be taken from random phone numbers or address files commercially available. But the question was how could the biases be corrected if we have vastly different response rates between the two sample populations? The likelihood is we will have a better response rate from users of cellular phones than from non-users. The assumption is that the willingness to participate in a survey is correlated with technology.

In the latter case, the nature of question lies on techniques in obtaining information before and after purchasing a cellular phone. An ideal situation would be surveying travel behavior at time 1 and wait until the driver buys a cellular phone then at time 2 or time 3 after a couple of years. Then, a few years later, we would ask the same question. But this was not acceptable because of time constraints. Thus, we asked, do cellular phone users perceive to have changed their travel behavior after purchasing cellular phones? f different behaviors were noted, were they due to technology or due to some other factors? Considering the limitations of survey techniques, budget, and time, the latter approach was chosen.

The next step of the research was then to choose a technique which will enable us to select samples representative of the cellular phone user population and survey method.

The generally acceptable sampling technique is, of course, the survey of households. One option considered was a telephone survey of Bay Area households by random digit dialing according to the geographic selection by home address (zipcode) or telephone number. In the Bay Area, about 40% of households have unlisted phone numbers. Random digit dialing would get unlisted phones and this would be the best way to get close to a true representation of population. But when the cost factor was considered, this approach was not viable. To get 10,000 households, it is necessary to dial at least 21,000 numbers.

As an alternative, the cluster method was considered, perhaps by using the Waxburg method which requires a sampling of about 15,000 slots for those communities that are likely to have a high cellular phone user population, i.e., affluent neighborhoods. The problem with this method is, of course, to get the truly representative samples of the cellular phone user population. Furthermore, it was expected that only 4%-5 % of the driving population would have cellular phones among those who have two or more cars per household. In such a case, getting a 300-400 sample population that would have cellular phones among the general population would be difficult and costly.

An alternate to these sampling techniques was to target sample population from the cellular phone subscribers. In California, the state utility commission regulates that only two suppliers can provide the subscription service for any given region. In the Bay Area, the two firms offering the cellular phone service are GTE Mobilnet and Cellular One. Between the two firms, GTE Mobilnet was chosen for their willingness to work with the university research team and they offer a greater range of service features than Cellular One.

To assess and minimize the impact of these biases, several methods were employed. The results of the study were compared with other studies of similar situations, i.e., the EMCI study. The sample size was made large enough to meet accepted standards for statistical precision. Assuming that we had obtained an unbiased sample of mail survey responses, 5,000 survey responses would have given an acceptable error of no more than $\pm$ 1.4 % at the 95 % confidence level.

The sample size of 35,000 was determined based on an expected return rate of 15% to 20%. Even with a 15% return, the sample size would be sufficiently large enough to obtain statistical precision for each variable considered.

Appendix 5. Survey Instrument

GTE Mobilnet

UNIVERSITY OF CALIFORNIA BERKELEY
INSTITUTE OF TRANSPORTATION STUDIES

Your participation is important. Please complete this questionnaire and return it in the postage-paid envelope no later than March 25, 1991.

PLEASE ANSWER ALL THE QUESTIONS RELATED TO YOUR USE OF CELLULAR PHONE(S).

Marking Instructions: Use No. 2 pencil only. Darken the circle completely. Erase cleanly any marks you wish to change. Do nqt make any stray marks on this form.

1. How many cellular phones do you have available in your household? Do not include cellular phones outside of your household if owned by your business. (Mark one)

- ◯ One
- ◯ Two
- ◯ Three or more

2. What kind of cellular phones do you have? (Mark all that apply)

- ◯ Permanent vehicle mounted
- ◯ Transportable
- ◯ Hand held portable

3. Does your primary cellular phone have hands free operation?

◯ Yes ◯ No

4. Have you replaced your cellular phone for any reason? (Mark all that apply)

- ◯ Have not replaced my cellular phone
- ◯ Wanted more features
- ◯ Sold vehicle with a cellular phone
- ◯ Phone was defective
- ◯ Phone was stolen
- ◯ Other (specify) ______

6. Who pays your cellular phone bills? (Mark one)

- ◯ Employer/business
- ◯ Yourself
- ◯ Both
- ◯ Family member
- ◯ Other (specify) ______

6. Would you recommend a cellular phone to your friends, relatives, and business associates? (Mark all that apply)

	Yes	No
Friends/relatives	◯	◯
Business associates	◯	0

7. What is the primary use of the vehicle equipped with a cellular phone? (Mark one)

- ◯ Company Business
- ◯ Personal

6. In an average month, about how often do you use your cellular phone for business and personal purposes? (Mark one for each purpose)

	Business purposes	Personal purposes
l-5 times	◯	◯
6- 10 times	◯	◯
1 1-20 times	◯	◯
2 l-30 times	◯	◯
30 times or more	◯	0'

9. On an average day, how many hours do you spend in a car equipped with a cellular phone? (Mark all that apply)

Time of day	None	Less than 1 hour	h s	h s	h s 5	More tha hou
6am - 9am	◯	◯		◯	◯	◯
		◯	◯			
3pm - 6pm	◯	◯	◯	◯	◯	◯
6pm - 6am	◯	0	0	◯	◯	◯

10. Why did you choose GTE Mobilnet service? (Mark all that apply)

- ◯ Cellular coverage
- ◯ Enhanced services
- ◯ Rate plans
- ◯ Roaming capabilities
- ◯ Other (specify) ______

11. What was your primary reason for getting a cellular phone? (Mark one)

- ◯ Safety -- make emergency calls
- ◯ Convenience -- have access to a phone at all times
- ◯ Reliability -- change appointments
- ◯ Reachability -- reach me at all times
- ◯ Efficiency -- avoid unnecessary trips
- ◯ Productivity -- take care of business while driving
- ◯ Other (specify) ______

12. For what purpose do you use your cellular phone most often? (Mark one)

- ◯ To check messages
- ◯ To schedule appointments
- ◯ To make changes in or inform people about delays in appointments
- ◯ To learn about destination directions
- ◯ To coordinate tasks
- ◯ Other (specify) ______

❑ mm000000mm0000000000000 01543
DO NOT MARK IN THIS AREA

13. When do you use your cellular phone for traffic information? (Mark all that apply)

- ◯ Whenever I expect traffic congestion while driving
- ◯ Before leaving home
- ◯ Before leaving work
- ◯ Before leaving any activities (meetings, events, etc.)
- ◯ Never
- ◯ Other (specify) ____________

14. In addition to the current GTE Mobilnet traffic information services (Information Network Traffic Report, DriverGuide, Mr. Rescue), what other traffic and road condition related information would you like GTE Mobilnet to provide? (Mark all that apply)

- ◯ Real-time traffic information
- ◯ Traffic report on other regions
- ◯ The fastest alternate route information
- ◯ Off-street parking availability
- ◯ Other (specify) ____________

15. What other enhanced service features would you like to have in addition to the features already provided by GTE Mobilnet? (Mark all that apply)

- ◯ Calling party pays for incoming calls
- ◯ Security system activation
- ◯ Protection from phone tapping
- ◯ Voice mail and paging
- ◯ Variable pricing based on zones
- ◯ Call accounting
- ◯ Voice activated calling
- ◯ Data transmission capabilities
- ◯ Other (specify) ____________

16. Would you like to have the capability of having a small screen monitor in your vehicle which displays visually the best route information for your destination considering traffic and road conditions?

- ◯ Yes
- ◯ No (skip to Question 18)

17. How much would you expect to have to pay for this device? (Mark one)

- ◯ Less than $500
- ◯ $501 - 1,000
- ◯ $1,001 - 1,500
- ◯ $1,501 - 2,000
- ◯ $2,001 - 2,500
- ◯ Over $2,500

18. In an average month, based on the traffic information provided by GTE Mobilnet (Information Network Traffic Report, DriverGuide) how often do you.. . (Mark one for each activity)

	Once a day or more	Once a week or more	Once a month or less	Never
a) take an alternate route?	◯	◯	◯	◯
b) change your destination?	◯	◯	◯	◯
c) reschedule your trip?	◯	◯	◯	◯
d) cancel your trip?	◯	◯	◯	◯

19. Because of cellular calls, in an average month, how often do you.. . (Mark one for each purpose)

	Once a day or more	Once a week or more	Once a month or less	Never
a) make unscheduled visits?				
Business purposes	◯	◯	◯	◯
Personal purposes	◯	◯	◯	◯
b) postpone your scheduled visits?				
Business purposes	◯	◯	◯	◯
Personal purposes	◯	◯	◯	◯
c) cancel your scheduled visits?				
Business purposes	◯	◯	◯	◯
Personal purposes	◯	◯	◯	◯

20. Since you acquired a cellular phone.. .

a) how has your trip frequency changed? (Mark one)

- ◯ Drive more often than before
- ◯ Drive as often as before
- ◯ Drive less often than before

b) how has your trip length changed? (Mark one)

- ◯ Drive longer than before
- ◯ No change
- ◯ Drive shorter than before

c) how has your trip scheduling changed? (Mark one)

- ◯ Change driving schedule more often than before
- ◯ Change driving schedule about the same as before
- ◯ Change driving schedule less than before

21 Which of the following statements best describes the way you use your cellular phone...

a) when making outgoing calls (Mark one)

- ◯ I make calls most often while driving
- ◯ I make calls most often while my car is not in motion
- ◯ I make calls sometimes while driving and sometimes while my car is not in motion

b) when answering calls (Mark one)

- ◯ I answer calls most often while driving
- ◯ I answer calls most often while my car is not in motion
- ◯ I answer calls sometimes while driving and sometimes while my car is not in motion

PLEASE ANSWER THE FOLLOWING QUESTIONS REFERRING TO THE ZONE NUMBERS INDICATED ON THE ACCOMPANYING MAP.

22. In an average month, how many calls do you make to the following locations?

Number of calls

	(0)	(1-20)	(21-50)	(50 or more)
From Zone 1:				
to Zone 1	○	○	○	○
to Zone 2	○	○	○	○
to Zone 3	○	○	○	○
to Zone 4	○	○	○	○
to Zone 5	○	○	○	○
From Zone 2:				
to Zone 1	○	○	○	○
to Zone 2	○	○	○	○
to Zone 3	○	○	○	○
to Zone 4	○	○	○	○
to Zone 5	○	○	○	○
From Zone 3:				
to Zone 1	○	○	○	○
to Zone 2	○	○	○	○
to Zone 3	○	○	○	○
to Zone 4	○	○	○	○
to Zone 5	○	○	○	○
From Zone 4:				
to Zone 1	○	○	○	○
to Zone 2	○	○	○	○
to Zone 3	○	○	○	○
to Zone 4	○	○	○	○
to Zone 5	○	○	○	○
From Zone 5:				
to Zone 1	○	○	○	○
to Zone 2	○	○	○	○
to Zone 3	○	○	○	○
to Zone 4	○	○	○	○
to Zone 5	○	○	○	○

23. **Your gender:** (Mark one)
○ Male ○ Female

24. **Your status:** (Mark one)
○ Married ○ Divorced/separated
○ Single ○ Widowed

25. **The highest level of education you have completed: (Mark one)**
○ Grade school ○ College
○ High school ○ Graduate school

26. **Your age:** (Mark one)
○ Under 18 ○ 45-54 years
○ 18-30 years ○ 55-64 years
○ 3 l-44 years ○ 65 years or more

27. **Your annual household income:** (Mark one)
○ Less than $25,000 ○ $100,001 - 150,000
○ $25,001 - 50,000 ○ $150.00 1 - 200,000
○ $50,001 - 75,000 ○ Greater than $200,000
○ $75,001 - 100,000

28. **Currently, what is your employment status?**
(Mark one)
- ◯ Employed full time
- ◯ Employed part time
- ◯ Self employed
- ◯ Not employed for pay (Skip to Question 33)
- ◯ Student (Skip to Question 33)
- ◯ Retired (Skip to Question 33)

29. **Category that best describes your occupation:**
(Mark one)
- ◯ Professional
- ◯ Managerial
- ◯ Technical
- ◯ Skilled labor
- ◯ Clerical
- ◯ Sales
- ◯ Laborer/agricultural worker
- ◯ Other (specify) ______

30. **Category that best describes the industry that you work in:** (Mark one)
- ◯ Agriculture, forestry, fishing
- ◯ Mining
- ◯ Construction
- ◯ Manufacturing
- ◯ Transportation, public utilities
- ◯ Wholesale, retail trade
- O Finance, insurance
- ◯ Real estate
- ◯ Medical related
- ◯ Government
- ◯ Services
- ◯ Other (specify) ______

31. **Is your primary work place at home?**
◯ Yes (Skip to Question 33) ◯ No

32. **Do you commute to work?**
◯ **Yes** ◯ No

33. **Number of employed people in your household:**
(Mark one)
◯ One ◯ Two ◯ Three or more

34. **Zipcode of your place of employment:**

					–				
0	0	0	0	0		0	0	0	0
1	1	1	1	1		1	1	1	1
2	2	2	2	2		2	2	2	2
3	3	3	3	3		3	3	3	3
4	4	4	4	4		4	4	4	4
5	5	5	5	5		5	5	5	5
6	6	6	6	6		6	6	6	6
7	7	7	7	7		7	7	7	7
8	8	8	8	8		8	8	8	8
9	9	9	9	9		9	9	9	9

35. **How many vehicles are in your household?** (Mark one)
◯ One ◯ Two ◯ Three or more

36. **Zipcode of your residence:**

					–				
0	0	0	0	0		0	0	0	0
1	1	1	1	1		1	1	1	1
2	2	2	2	2		2	2	2	2
3	3	3	3	3		3	3	3	3
4	4	4	4	4		4	4	4	4
5	5	5	5	5		5	5	5	5
6	6	6	6	6		6	6	6	6
7	7	7	7	7		7	7	7	7
8	8	8	8	8		8	8	8	8
9	9	9	9	9		9	9	9	9

37. **Your residence:** (Mark one)
- ◯ Single family detached
- ◯ Apartment or townhouse
- ◯ Other (Specify) ______

38. **Do you own or rent your residence?** (Mark one)
- ◯ Own
- ◯ Rent
- ◯ Other (Specify) ______

39. **May we contact you to follow up on this questionnaire?**
◯ **Yes** ◯ **No**

Your office or home phone number: ( ) —

Your cellular phone number: ( ) —

Your name (please print): ______
first name / last name (optional)

Convenient time to contact: ______
Day of Week / Approximate Time

Thank you for your help. Please return the completed questionnaire by March 25. No postage is required.

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Appendix 6. Survey Results

N: The total number of responses to each question.

***:** The categories within the question are not exclusive, so the sum of percentages is greater than 100 % .

Total number of cases =7,347

<u>Question 1</u>: How many cellular phones do you have available in your household?

One answer was to be chosen and was not to include phones outside the household if owned by his or her business.

One	77.5%	N = 6,808
Two	18.4	
Three or more	4.1	

<u>Question 2*</u>: What kinds of cellular phones do you have?

All answers that applied were to be chosen.

Permanent vehicle mounted	56.3%	N = 7,347
Transportable	39.9	
Hand held portable	20.9	

<u>Chest-ion 3</u>: Does your primary cellular phone have hands free operation?

Yes	65.2%	N = 7,246
No	34.8	

<u>Question 4</u>: Have you replaced your cellular phone for any reason?

All answers that applied were to be chosen.

Have not replaced my cellular phone	79.1%	N = 7,347
Wanted more features	3.6	
Sold vehicle with a cellular phone	2.6	
Phone was defective	4.6	
Phone was stolen	2.8	
Other	3.4	

Question 5: Who pays your cellular phone bills?
One answer was to be chosen.

Employer / business	38.4%	N = 7,154
Yourself	46.8	
Both ,	13.0	
Family member	1.0	
Other	0.8	

Question 6: Would you recommend a cellular phone to your friends, relatives, and business associates?
All answers that applied were to be chosen.

	Yes	No	
Friends / relatives	81.8%	18.2%	N = 6,573
Business associates	97.6%	2.4%	N = 6,932

Question 7: What is the primary use of the vehicle equipped with a cellular phone?
One answer was to be chosen.

Company business	71.8%	N = 6,917
Personal	28.2	

Question 8: In an average month, about how often do you use your cellular phone for business and personal purposes?
One answer was to be chosen for each purpose.

	Business purposes N = 6.647	Personal purposes N = 6.502
1-5 times	14.6%	33.9%
6-10 times	14.1	29.7
1 1-20 times	18.5	20.4
21-30 times	15.1	7.1
30 times or more	37.7	8.9

Question 9: On an average day, how many hours do you spend in a car equipped with a cellular phone?

All answers that applied were to be chosen.

	None	Less than hour	1-2 hours	2-3 hours	3-5 hours	More than 5 hours	
6 a.m. - 9 a.m.,	12.9%	57.9%	25.1%	2.7%	----	----	N = 6,416
9 a.m. - 3 p.m.	10.8	34.9	29.5	13.5	7.6%	3.8%	N = 5,986
3 p.m. - 6 p.m.	7.1	48.7	33.6	7.7	----	----	N = 5,945
6 p.m. - 6 a.m.	18.8	54.7	19.5	4.1	1.6	1.4	N = 5,532

Question 10*: Why did you choose GTE Mobilnet service?

All answers that applied were to be chosen.

Cellular coverage	53.7%	N = 7,347
Enhanced services	20.3	
Rate plans	28.1	
Roaming capabilities	27.5	
Other	24.2	

Question 11: What was your primary reason for getting a cellular phone?

One answer was to be chosen.

Safety	11.3%	N = 6,332
Convenience	34.0	
Reliability	0.8	
Reachability	12.1	
Efficiency	2.8	
Productivity	36.7	
Other	2.4	

Question 12: For what purpose do you use your cellular phone most often?

One answer was to be chosen.

Check messages	18.4%	N = 6,618
Schedule appointments	4.2	

Change or delay appointments	19.3	
Need directions	1.3	
Coordinate tasks	40.0	
Other	16.8	

Question 13*: When do you use your cellular phone for traffic information?
All answers that applied were to be chosen.

Expecting congestion	9.7%	N = 7,347
Before leaving home	0.8	
Before leaving work	0.7	
Before leaving activites	1.5	
Never	84.2	
Other	3.3	

Question 14: In addition to the current GTE Mobilnet traffic information services (Information Network Traffic Report, DriverGuide, Mr. Rescue), what other traffic and road condition related information would you like GTE Mobilnet to provide?
All answers that applied were to be chosen.

Real-time traffic information	26.2%	N = 7,347
Traffic report on other regions	5.5	
Fastest alternate route	33.3	
Off-street parking	10.6	
Other	10.5	

Question 15*: What other enhanced service features would you like to have in addition to the features already provided by GTE Mobilnet?
All answers that applied were to be chosen.

Caller pays for incoming calls	64.8%	N = 7,347
Security system activation	10.6	
Protection from phone tapping	20.3	
Voice mail and paging	18.8	
Variable pricing based on zones	19.8	
Call accounting	7.7	

Voice-activated calling	18.6
Data transmission	7.5
Other	7.0

Question 16: Would you like to have the capability of having a small screen monitor in your vehicle,which displays visually the best route information for your destination considering traffic and road conditions?

Yes	37.4%	N = 7,010
No (Skip to Question 18)	62.6	

Question 17: How much would you expect to have to pay for this device? One answer was to be chosen.

Less than $500	61.1%	N = 2,587
$501-1,000	29.2	
$1,001-1,500	7.7	
$1,501-2,000	1.4	
$2,001-2,500	0.3	
More than $2,500	0.3	

Question 18: In an average month, based on the traffic information provided by GTE Mobilnet (Information Network Traffic Report, DriverGuide), how often do you....

(One answer was to be chosen for each activity.)

	Onceaday or more	Once a week or more	Once a month or less	Never	
take an alternate route?	3.2%	7.8%	12.0%	77.1%	N = 5,444
change your destination?	1.5	3.5	7.0	88.0	N = 5,206
reschedule your trip?	1.0	3.1	7.5	88.3	N = 5,214
cancel your trip?	0.5	1.7	5.9	91.9	N = 5,190

Question 19: Because of cellular calls, in an average month, how often do you....

(One answer was to be chosen for each purpose.)

	Once a day or more	Once a week or more	Once a month or less	Never	
a. make unscheduled visits?					
Business purposes	8.6%	33.0%	24.8%	33.6%	N = 6,301
Personal purposes	3.5	22.1	34.3	40.1	N = 5,534
b. postpone your scheduled visits? ,					
Business purposes	5.5	30.7	33.8	30.1	N = 6,271
Personal purposes	2.2	16.6	36.8	44.3	N = 5,448
c. cancel your scheduled visits?					
Business purposes	4.0	23.5	37.1	35.4	N = 6,237
Personal purposes	1.8	12.4	36.4	49.4	N = 5,406

Question 20: Since you acquired a cellular phone....
(One answer was to be chosen for each purpose.)

a. how has your trip frequency changed?		
Drive more often than before	8.0%	N = 6,946
Drive as often as before	77.3	
Drive less often than before	14.8	
b. how has your trip length changed?		
Drive longer than before	5.8%	N = 6,916
No change	82.7	
Drive shorter than before	11.5	
c. how has your trip scheduling changed?		
Change driving schedule more often than before	16.6%	N = 6,433
Change driving schedule about the same as before	71.9	
Change driving schedule less than before	11.5	

Question 21: Which of the following statements best describes the way you use your cellular phone....
(One answer was to chosen for each activity.)

a. when making outgoing calls		
most often while driving	45.1%	N = 7,112
most often while my car is not in motion	6.2	
sometimes while driving and sometimes while my car is not in motion	48.6	

b. when answering

most often while driving	71.3%	N = 6,886
most often while my car is not in motion	2.8	
sometimes while driving and sometimes while my car is not in motion	25.8	

Question 22: In an average month, how many calls do you make to the following locations?

One answer was to be chosen for each zone in relation to the all the others within each category.

From Zone 1:	0	1-20	21-50	50 or more	
to Zone 1	62.8%	28.6%	6.2%	2.4%	N = 5,457
to Zone 2	67.8	29.8	1.9	0.5	N = 5,093
to Zone 3	77.9	20.4	1.3	0.4	N = 4,988
to Zone 4	71.2	26.6	1.8	0.4	N = 5,092
to Zone 5	88.4	10.9	0.5	0.2	N = 4,950

F r o m :					
to Zone 1	67.6%	30.9%	1.2%	0.3%	N = 5,128
to Zone 2	46.7	40.2	9.7	3.3	N = 5,230
to Zone 3	56.7	39.3	3.3	0.7	N = 5,009
to Zone 4	57.1	39.8	2.8	0.5	N = 5,017
to Zone 5	82.2	17.1	0.5	0.2	N = 4,849

F r o m :					
to Zone 1	79.1%	20.2%	0.5%	0.3%	N = 5,105
to Zone 2	56.1	40.5	2.7	0.7	N = 5,091
to Zone 3	46.5	37.9	11.0	4.7	N = 5,274
to Zone 4	56.9	39.5	2.8	0.7	N = 5,100
to Zone 5	69.1	28.6	1.8	0.4	N = 4,999

From Zone 4:					
to Zone 1	72.2	26.4	1.2	0.2	N = 5,156
to Zone 2	57.4	39.8	2.4	0.4	N = 5,070
to Zone 3	58.1	37.9	3.3	0.6	N = 5,089
to Zone 4	54.2	36.7	6.9	2.2	N = 5,155
to Zone 5	79.7	19.5	0.6	0.2	N = 4,899

From Zone 5:

to Zone 1	89.4	10.2	0.2	0.1	N = 5,055
to Zone 2	82.2	17.2	0.4	0.1	N = 4,951
to Zone 3	71.4	26.2	1.8	0.5	N = 5,051
to Zone 4	80.7	18.4	0.6	0.3	N = 4,947
to Zone 5	73.8	19.8	4.7	1.7	N = 5,074

Question 23: Your gender.

Male	79.8%	N = 7,188
Female	20.2	

Question 24: Your status.

Married	73.4%	N = 7,158
Single	15.8	
Divorced / separated	9.6	
Widowed	1.2	

Question 25: The highest level of education you have completed.

Grade school	0.7 %	N = 7,146
High school	23.5	
College	49.5	
Graduate school	26.3	

Question 26: Your age.

Under 18	0.0%	N = 7,173
18-30 years	11.7	
3 l-44 years	47.0	
45-54 years	27.4	
65 years or more	3.3	

Question 27: Your annual household income.

Less than $25,000	2.0%	N = 6,825
$25,001-50,000	15.1	
$50,001-75,000	22.6	
$75,001-100,000	21.2	
$100,001-150,000	20.3	
$150,001-200,00	8.8	
Greater than $200,000	10.1	

Question 28: Currently, what is your employment status?

Employed full time	56.3%	N = 7,138
Employed part time	2.0	
Self-employed	37.6	
Not employed for pay (Skip to Question 33)	1.4	
Student (Skip to Question 33)	0.4	
Retired (Skip to Question 33)	2.2	

Question 29: Category that best describes your occupation.

Professional	36.3%	N = 6,676
Managerial	24.1	
Technical	5.5	
Skilled labor	6.4	
Sales	21.8	
Other	5.9	

Question 30: Category that best describes the industry in which you work.

Agriculture, forestry, fishing	1.9%	N = 7,347
Construction	14.0	
Manufacturing	9.6	
Transportation, public utilities	4.2	
Wholesale, retail trade	10.0	
Finance, insurance	6.9	

Real estate
Medical-related
Government
Services
Other

Question 31: Is your primary work place at home?

Yes (Skip to Question 33)	15.7%	N = 6,754
No	84.3	

Question 32: Do you commute to work?

Yes	84.8%	N = 5,440
No	15.2	

Question 33: Number of employed people in your household.

One	37.2	N = 6,975
Two	52.4	
Three or more	10.4	

Question 34: Zipcode of your place of employment.

Question 35: How many vehicles are in your household?

One	9.5%	N = 6,606
Two	42.1	
Three or more	48.4	

Question 36: Zipcode of your residence.

Question 37: Your residence.

Single family detached	81.7%	N = 7,137
Apartment or townhouse	14.6	
Other	3.7	

Question 38: Do you own or rent your residence?

Own	82.4%	N = 7,160
Rent	15.9	
Other	1.7	

Question 39: May we contact you for a follow up on this questionnaire?

Yes	55.2%	N = 6,929
No	44.8	

Appendix. 7. Automobile and Telephone Traffic Patterns

a) Automobile traffic patterns

The automobile traffic patterns were obtained by using zipcodes of residences and employment locations. Therefore, the traffic patterns shown in Figures Al through A5 are home-based work trips between and within zones (Table Al). Work trips were made most frequently within the same zone. At lest twice as many of the work trips were made within the same zone compared to the number of work trips made between zones. The highest frequency of work trips occurred within Zone 3, where 21.6% of the total work trips in all five zones were made. The frequencies of work trips made within the same zone, in descending order, were Zone 3, Zone 1, Zone 4, Zone 2, and Zone 5. The frequencies of work trips made between zones, in descending order, were from Zone 1 to Zone 4, Zone 1 to Zone 2, and from Zone 2 to Zone 4.

b) Telephone traffic patterns

The telephone traffic was based on the number of calls made in an average month within and between zones (Table A2, Figures A6 through A10). In an average month most people made less than 20 calls either within zones or between zones. The telephone traffic showed that phone calls were most frequently made within the same zone. However, the frequencies of calls made within the same zones were not greatly different from the frequencies of calls made between zones.

Although our data in telephone and automobile traffic patterns were not comparable directly, some similarities and differences in traffic patterns were found. Automobile trips were made much more frequently within zones than between zones, while telephone traffic within zones was not much greater than between zones. In either case, there was a strong correlation between frequency and distance. The greater the distance, the fewer trips or calls that were made. As expected, telephone calls were less elastic with respect to distance than automobile trips. In this regard, it may be plausible that cellular phone calls were likely to substitute for distant trips more so than local trips (Figures Al 1 and A12).

Table Al. Automobile Traffic: Home-based Work Trips among Cellular Users

TO ZONE	FROM ZONE 1	2	3	4	5
1	745(16.35)	67(1.47)	14(.30)	16(.35)	4(.09)
2	155(3.40)	619(13.59)	65(1.43)	34(.75)	5(.11)
3	45(.99)	89(1.95)	983(21.58)	133(2.92)	66(1.45)
4	174(3.82)	102(2.24)	91(2.00)	626(13.74)	5(.11)
5	1(.02)	1(.02)	23(.50)	4(.09)	489(10.73)

Total cases = 5366
Missing cases= 810

Note: The values in the brackets are percentages

Figure A1.
Home to Work Auto Traffic
Patterns from Zone 1

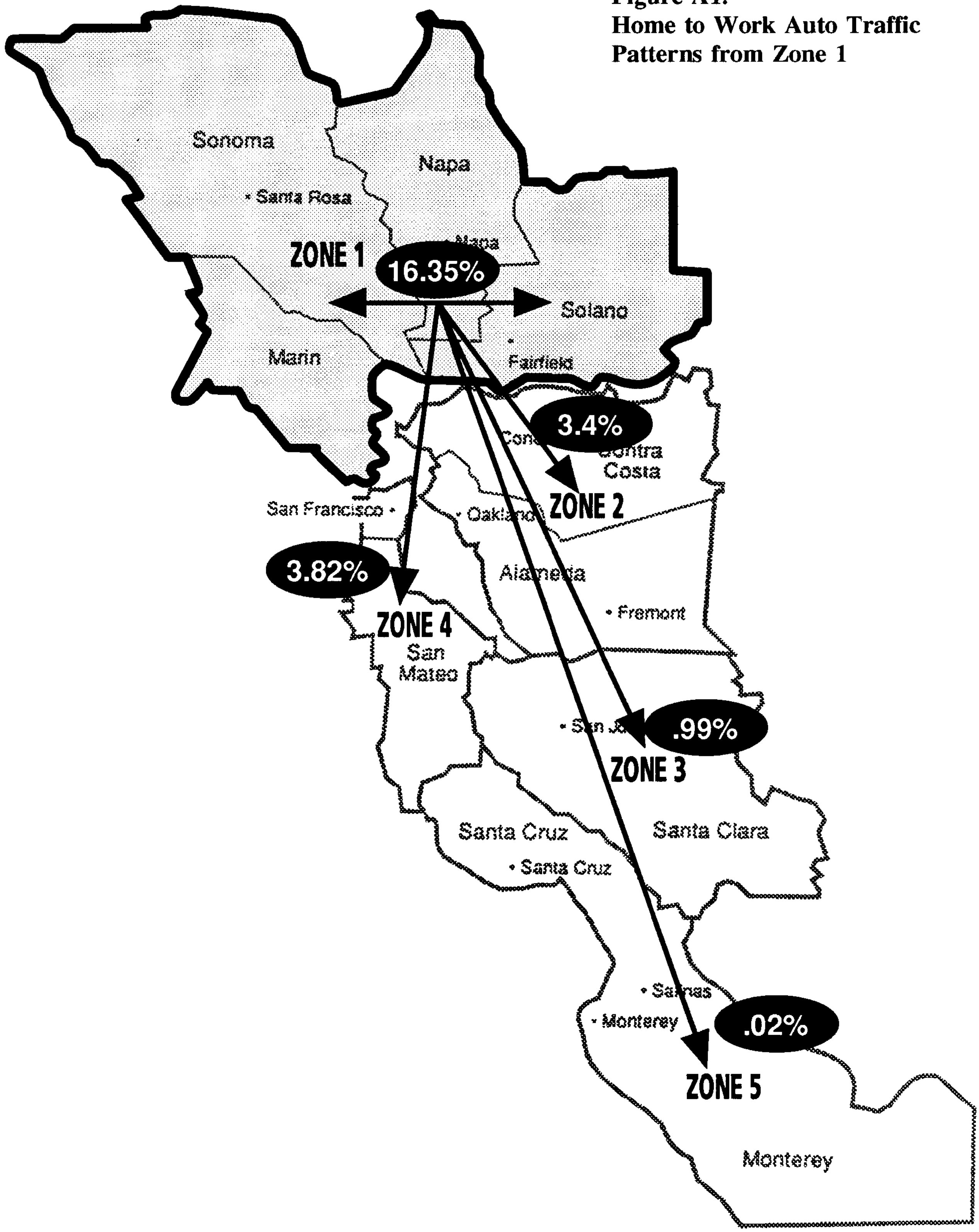


Figure A2.
Home to Work Auto Traffic
Patterns from Zone 2

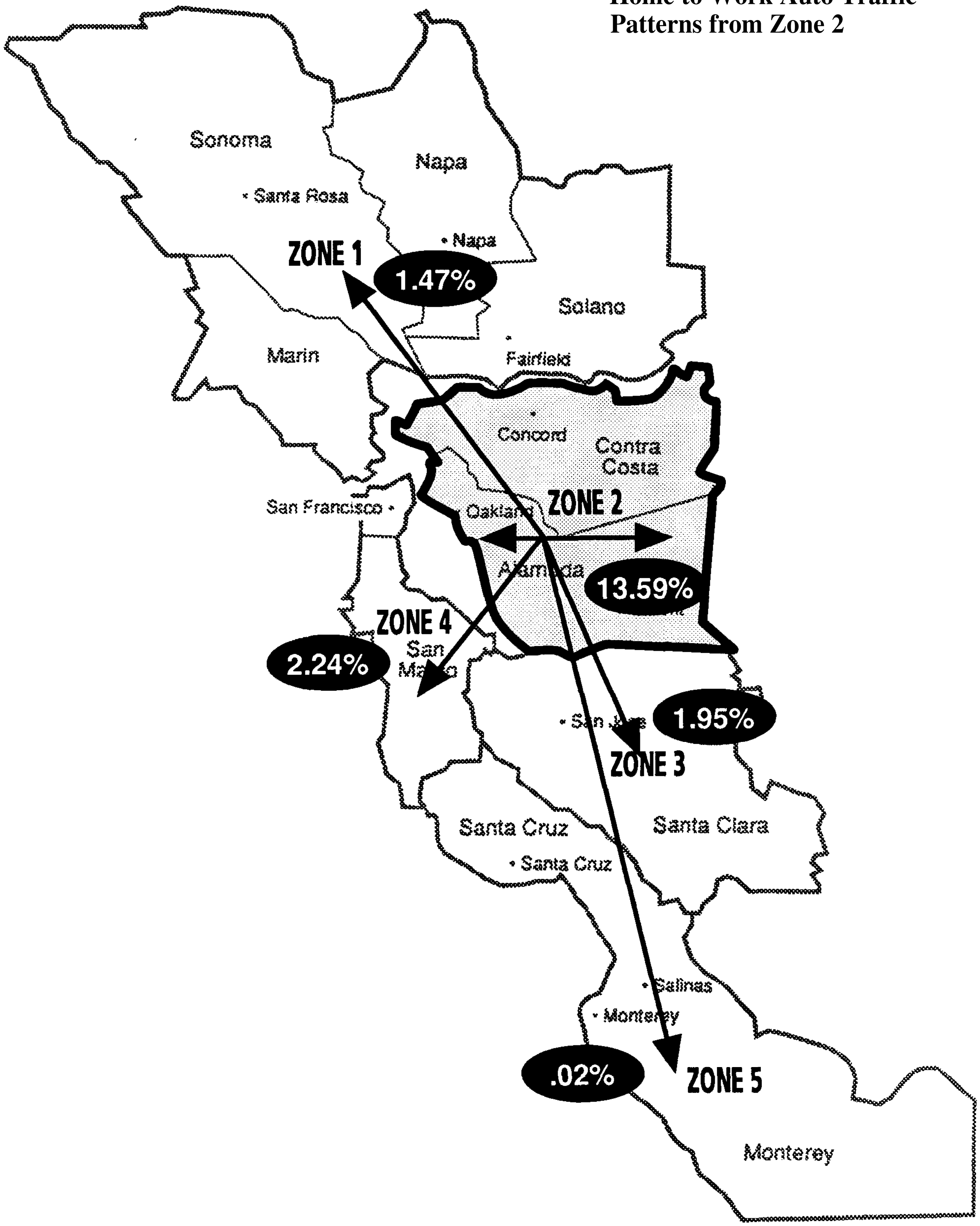


**Figure A3.
Home to Work Auto Traffic
Patterns from Zone 3**

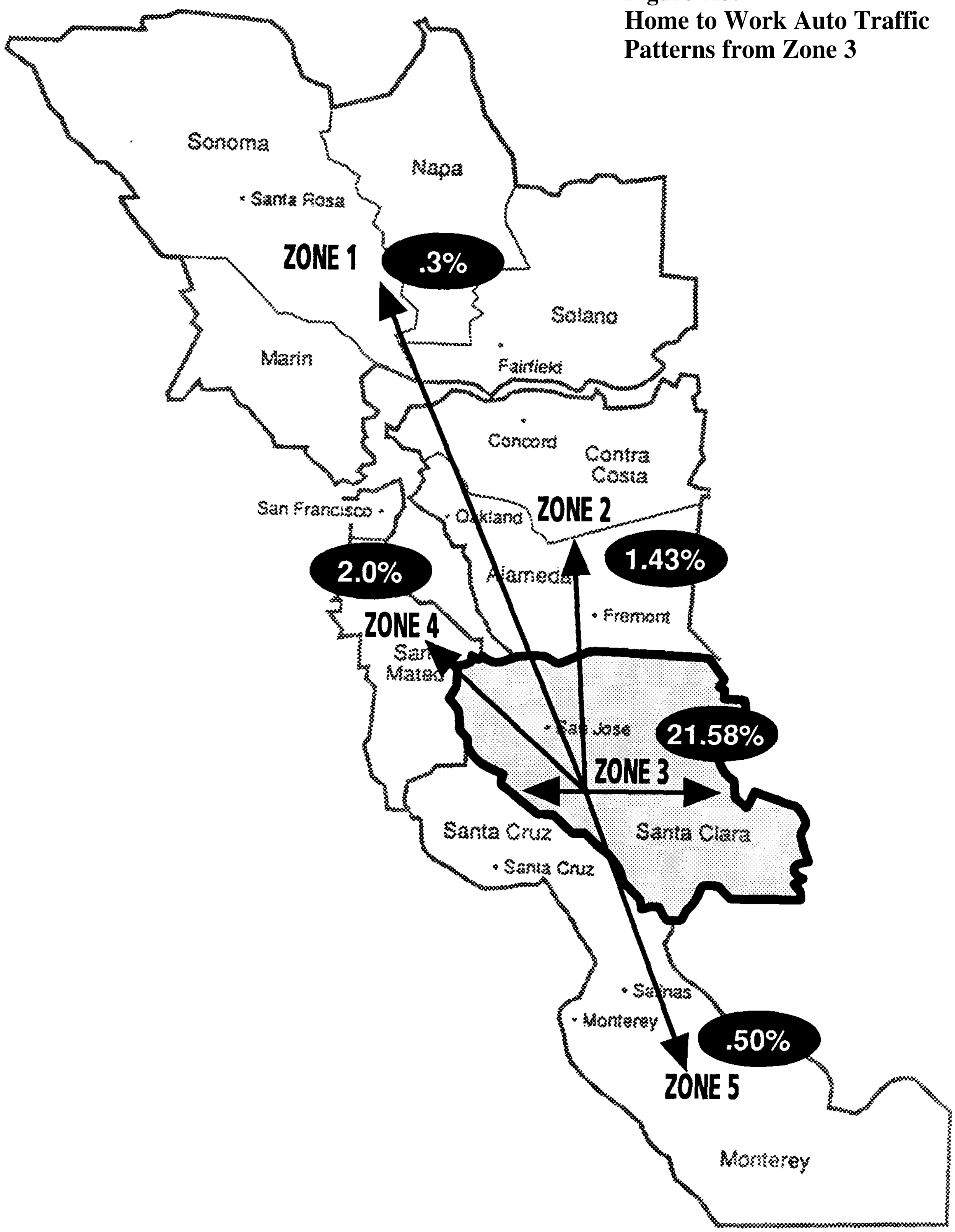


Figure A4.
Home to Work Auto Traffic
Patterns from Zone 4

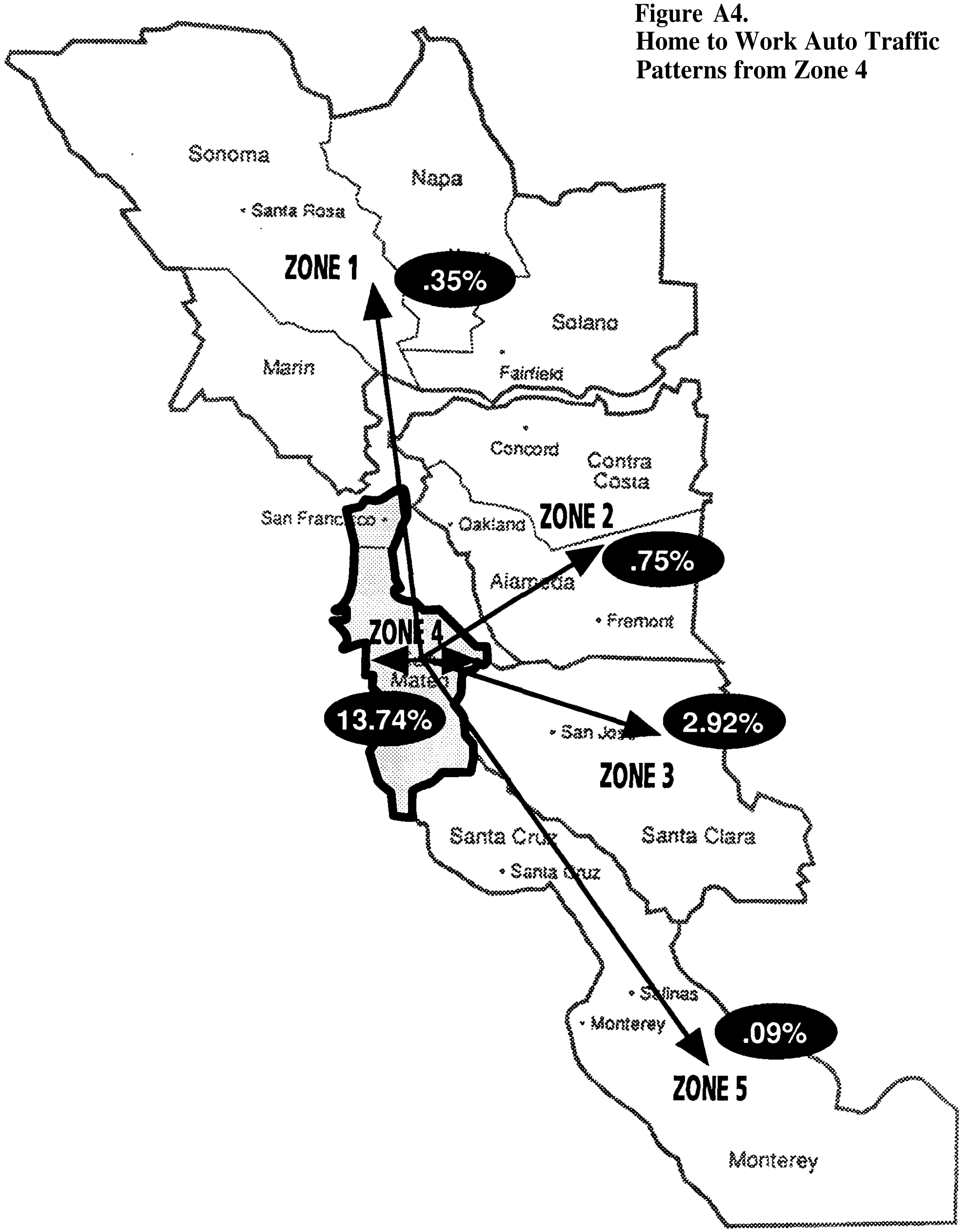


Figure A5.
Home to Work Auto Traffic Patterns from Zone 5

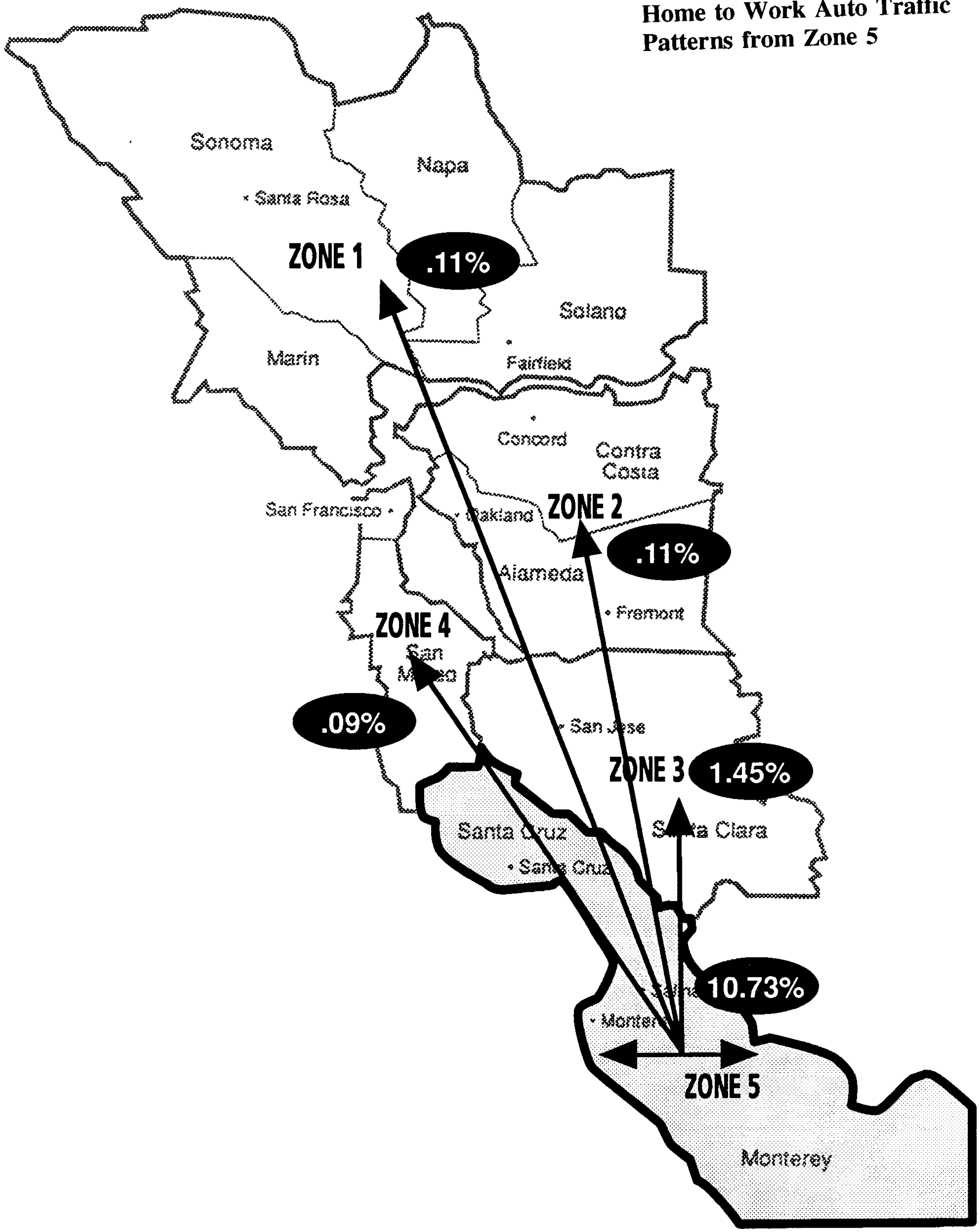


Table AZ. Cellular Call Traffic
number of calls made in an average month (N=5366)

Calls From Zone 1

	Total	Personal	Business
To Zone 1	36.5	10.40	26.02
To Zone 2	31.5	9.04	22.46
To Zone 3	20.9	6	14.9
To Zone 4	28.1	8.06	20.33
To Zone 5	11.1	3.19	7.91

Calls From Zone 2

	Total	Personal	Business
To Zone 1	31.6	9.07	22.53
To Zone 2	52.6	15.10	37.50
To Zone 3	42.3	12.31	30.53
To Zone 4	42.4	12.17	30.23
To Zone 5	17.3	4.97	12.33

Calls From Zone 3

	Total	Personal	Business
To Zone 1	19.7	5.65	14.05
To Zone 2	43.5	12.48	31.02
To Zone 3	53.6	15.38	38.22
To Zone 4	42.5	12.20	30.30
To Zone 5	30.6	8.78	21.82

Calls From Zone 4

	Total	Personal	Business
To Zone 1	26.9	7.72	19.18
To Zone 2	42.3	12.14	30.16
To Zone 3	41.3	11.85	29.45
To Zone 4	45.2	12.97	32.23
To Zone 5	19.7	5.65	14.05

Calls From Zone 5

	Total	Personal	Business
To Zone 1	9.9	2.04	7.06
To Zone 2	17.6	5.05	12.55
To Zone 3	28.7	8.24	20.46
To Zone 4	18.9	5.42	13.48
To Zone 5	26.2	7.52	18.68

Figure A6.
Cellular Business Calls
Traffic Patterns from Zone 1

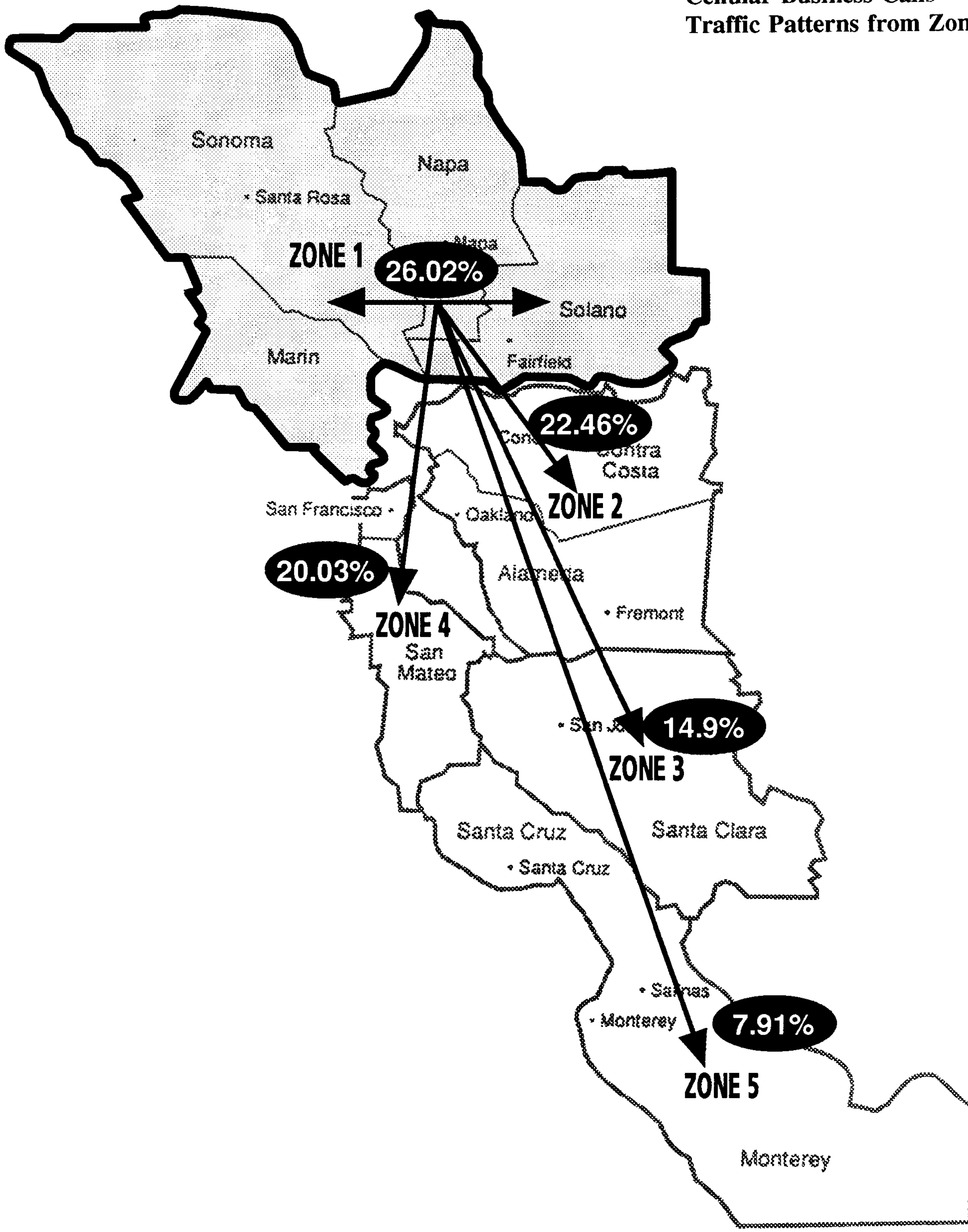


Figure A7.
Cellular Business Calls
Traffic Patterns from Zone 2

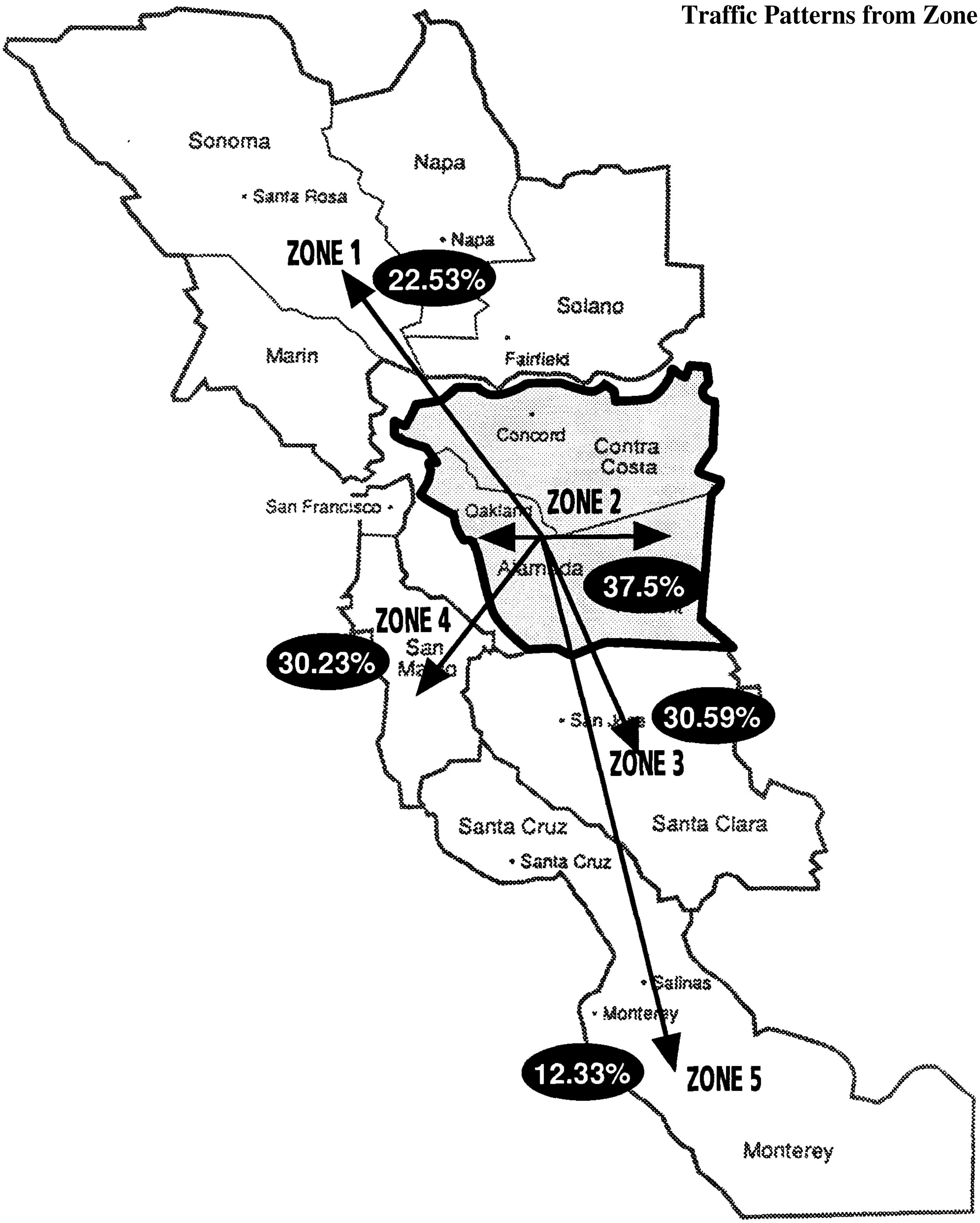


Figure A8.
Cellular Business Calls
Traffic Patterns from Zone 3

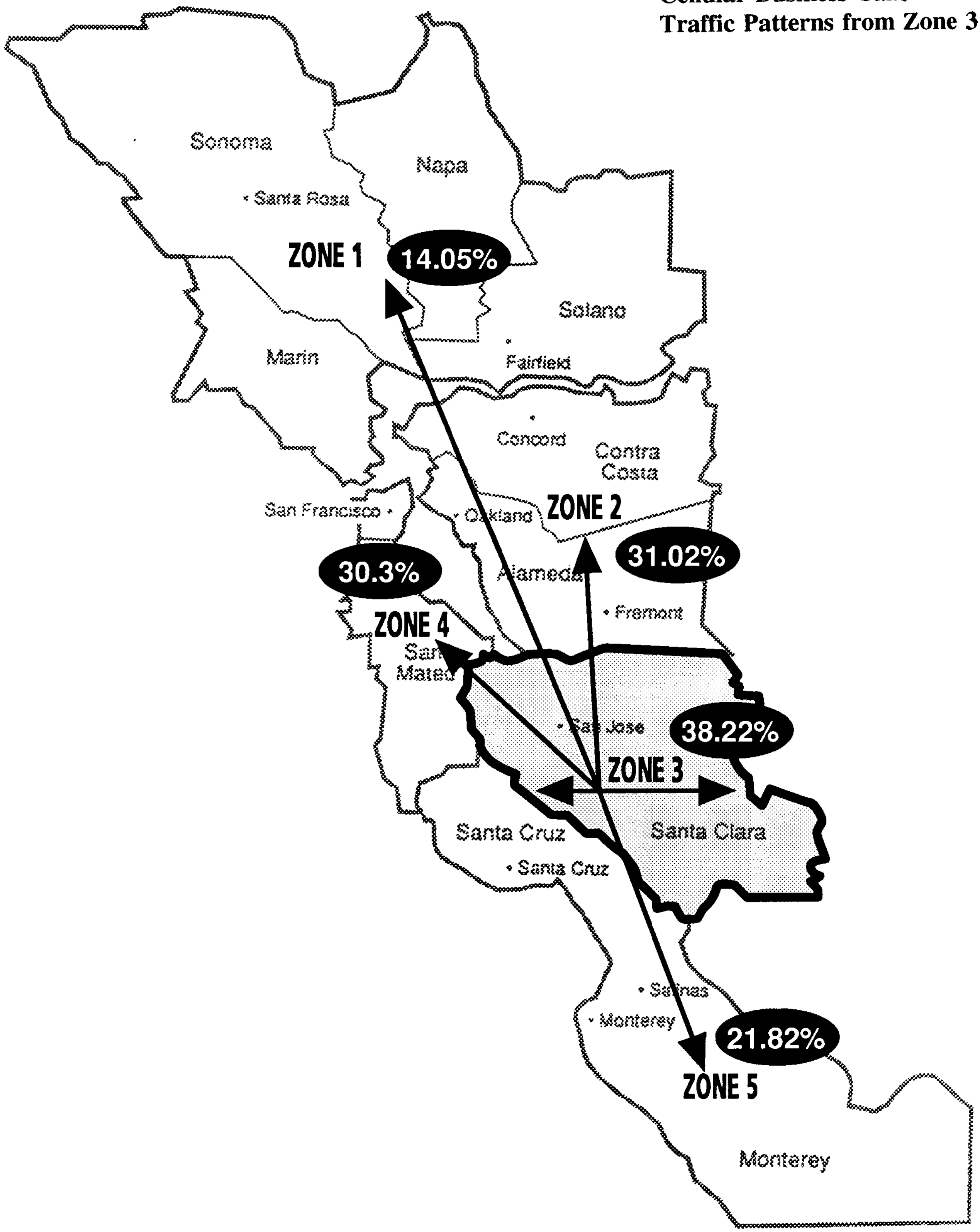


Figure A9.
Cellular Business Calls
Traffic Patterns from Zone 4

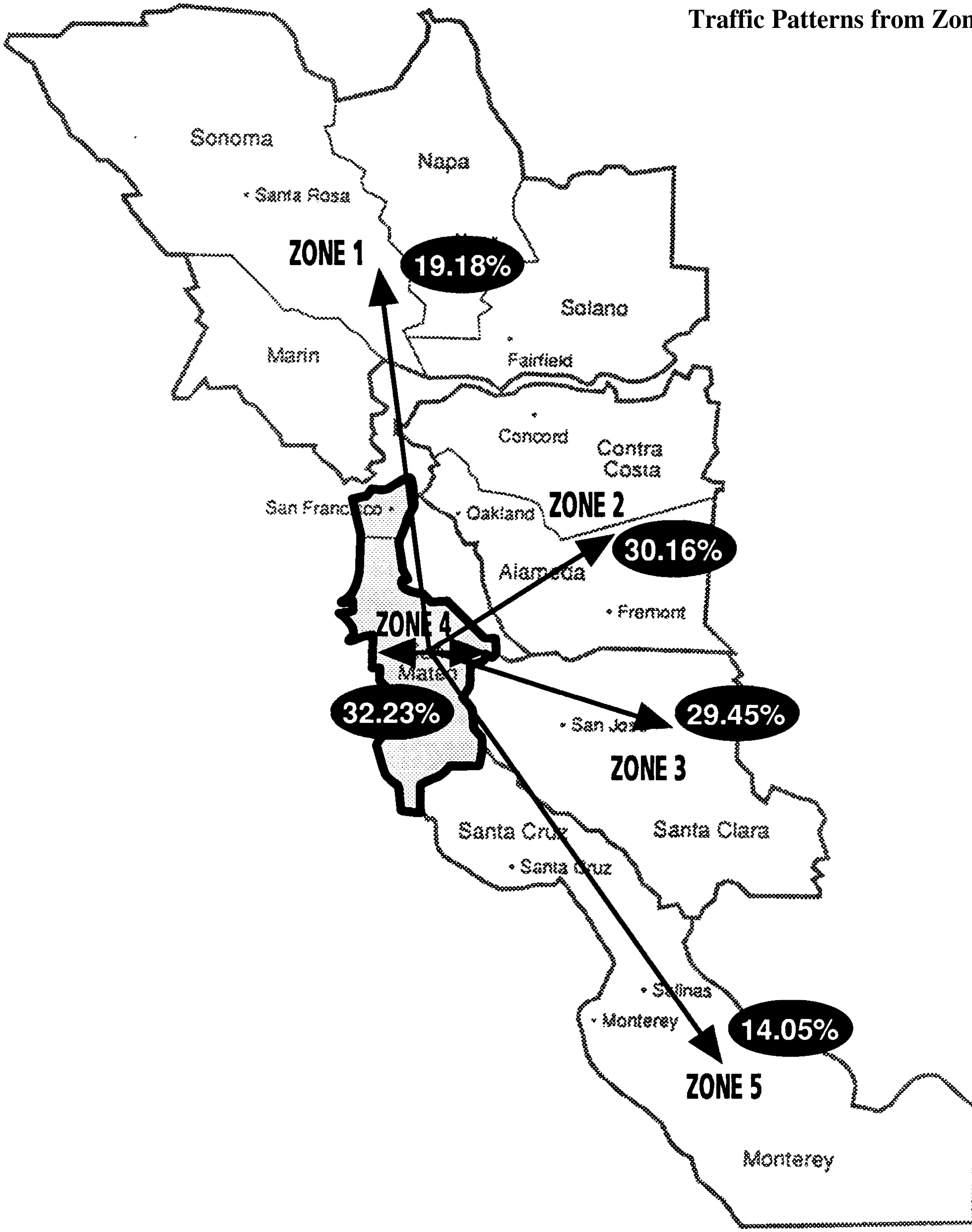


Figure A10.
Cellular Business Calls
Traffic Patterns from Zone 5

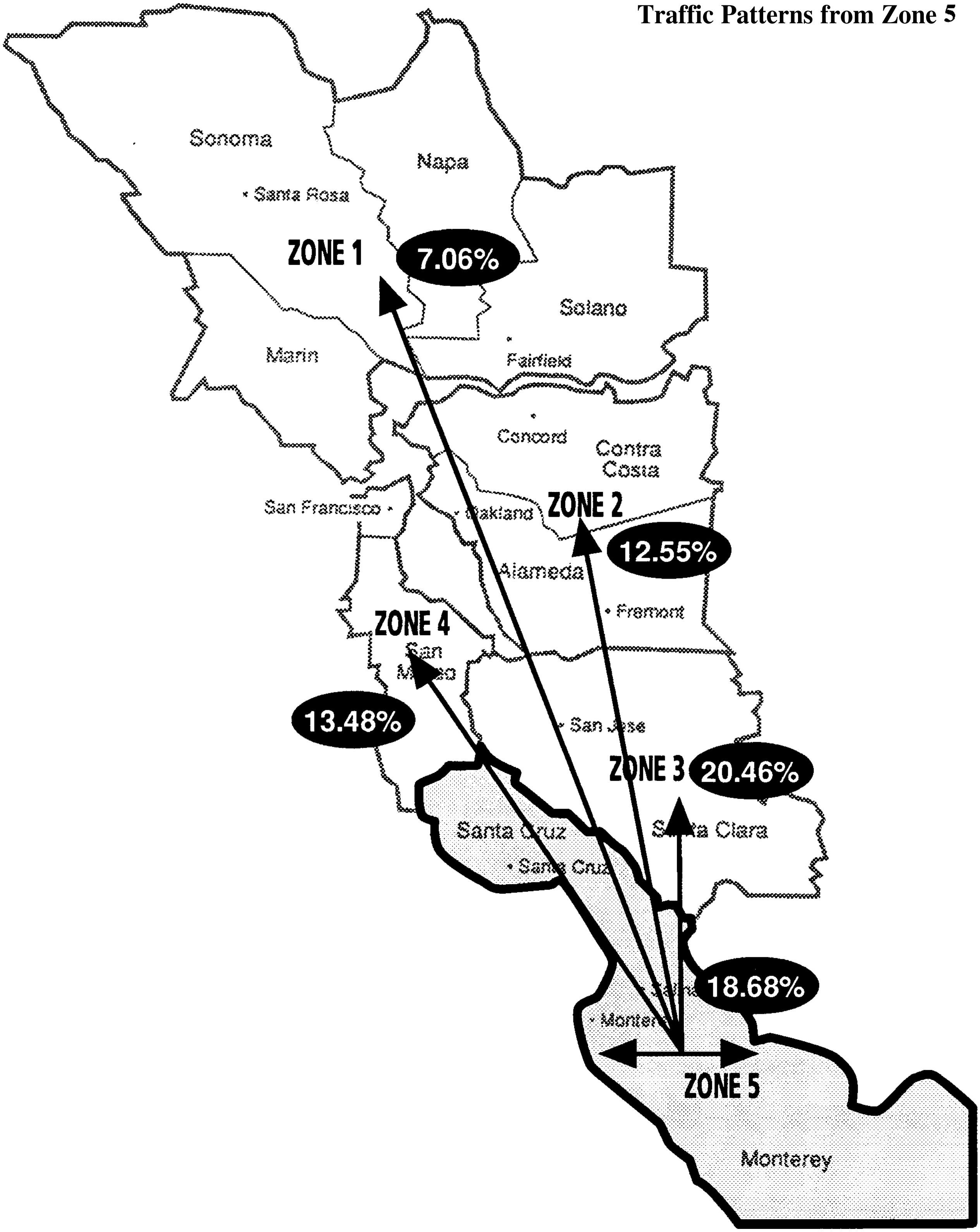
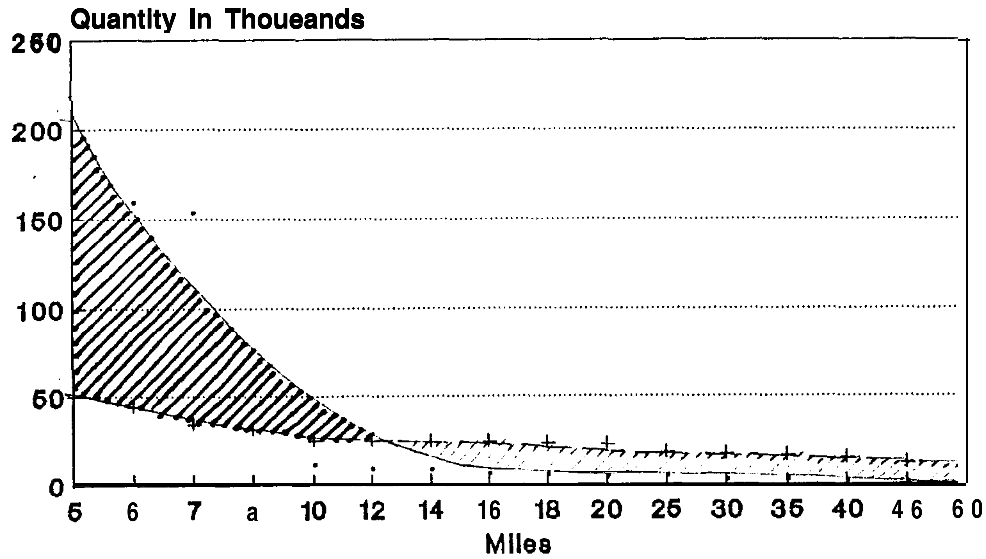


Figure All.

Total Daily Trips vs
Total Daily Cellular Calls

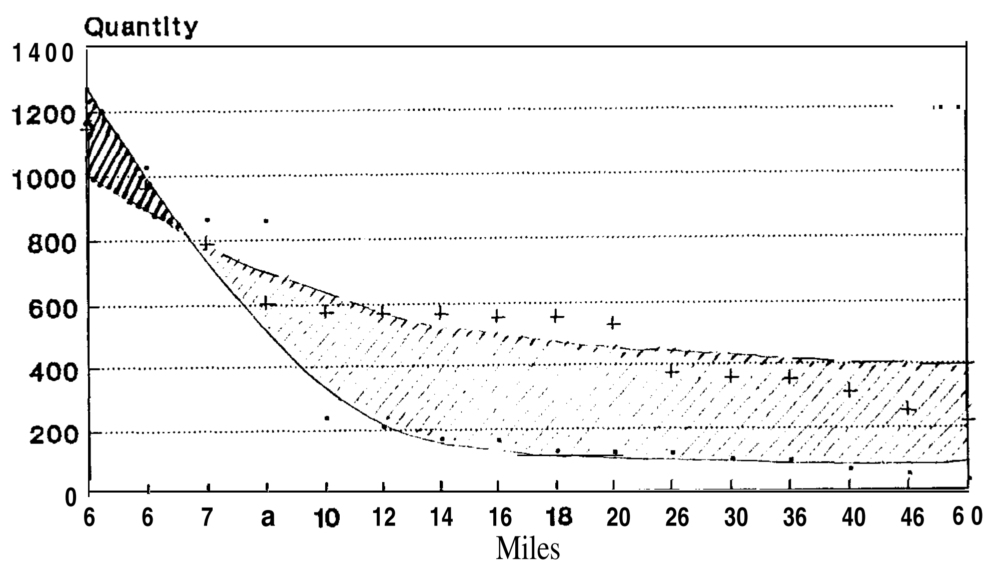


. Total daily vehicle trips by 150,000 Bay Area motorists (199 1, projected)

+ Total daily cellular calls by 150,000 Bay Area cellular subscribers(199 1)

Figure A12.

Commute **Trips vs Cellular Calls**
During Commute **Hours**



. Daily one-way commute trips by 7,347 Bay Area cellular subscribers during commute hours between 6AM-9AM (1991)

+ Daily cellular call traffic by 7,347 Bay Area cellular subscribers during commute hours between 6AM-9AM (1991)

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