Title

Benefits, Acceptance, and Marketability of Value-Priced Services: California's Route 91 Express Lanes

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BENEFITS, ACCEPTANCE AND MARKETABILITY OF VALUE-PRICED SERVICES: CALIFORNIA'S ROUTE 91 EXPRESS LANES

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1 ECONOMIC FEASIBILITY OF VALUE-PRICED SERVICES

1.1 Introduction

Transportation professionals have always been interested in how travelers respond to different transportation options. A new application of congestion pricing offers the opportunity to extend such research to situations where travelers face a priced alternative. Travelers along State Route 91 (SR 91) in Southern California can now pay a time-varying fee in order to travel on a set of essentially congestion-free "Express Lanes" located in the median of a very congested pre-existing freeway. For this study, we conduct a mail survey of such travelers to learn how they decide to use the free lanes or the toll lanes. We use the data to estimate route choice models and models that incorporate various types of real-time information about accidents, traffic conditions, and price levels into the route choice decision. This study provides new information about the acceptance of congestion pricing, the use of real-time information in making dynamic travel decisions, and individual travelers' interests in forming carpools.

The study corridor is ten miles long, located in Orange County, California, about 50 miles southeast of downtown Los Angeles (see Figure 1). It extends from the Riverside County line in the east to the junction with State Route 55 in the west; from there two freeways, SR 55 and SR 91, continue south and west toward major job concentrations in Orange and southern Los Angeles Counties. Thus our study corridor is just a portion of SR 91, which is also known as the Riverside Freeway. Traffic on the corridor is highly peaked, Westbound in the morning and Eastbound in the afternoon. The original four lanes in each direction carried over 200,000 vehicles per day with one-way delays as much as 50 minutes including time in queues at metered entrance ramps. The corridor now includes the four regular lanes and two Express Lanes (tolled) in each direction. There are just a few intermediate entrances and exits, none of them available to Express Lane users.

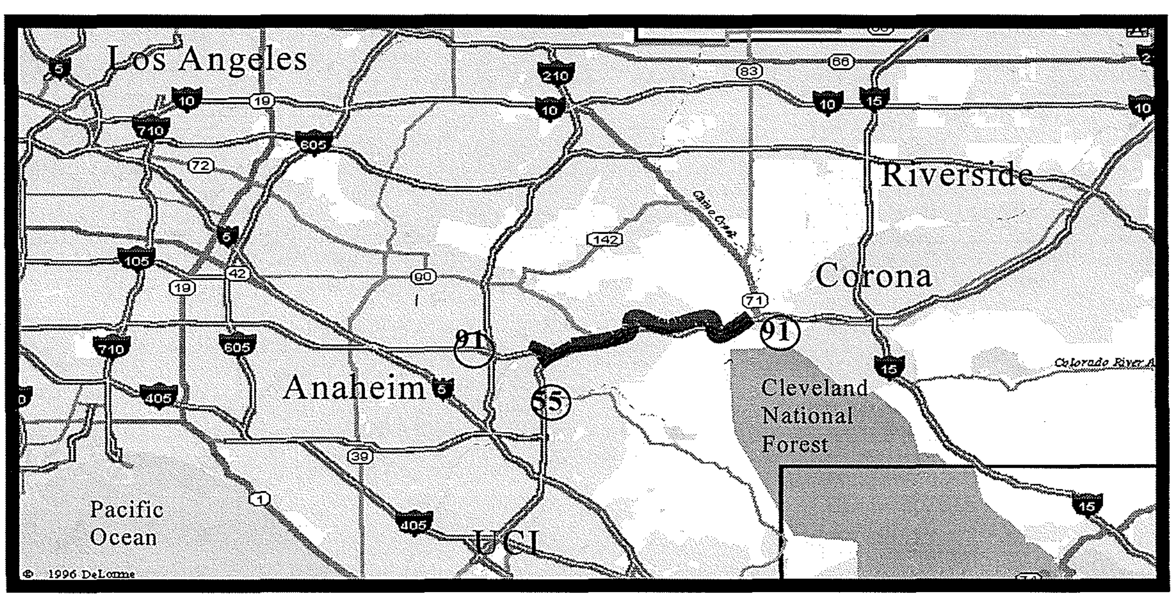

Figure 1.1: Portion of the Southern California Freeway System with 91 Express Corridor

To use the Express Lanes, a vehicle must have a transponder or "toll tag," obtained from the private company that built and operates the road, whose name is the California Private Transportation Company (CPTC). There is no charge for the transponder itself, but an account must be opened with an initial balance of $40. (Two other toll roads in Orange County use the same transponders.) Tolls vary by time of day following a predetermined schedule that is quite complex; at the time the survey was distributed there were four toll levels — $0.50, $1.00, $1.50, and $2.75 — and subsequently the toll schedule has been further refined with eight toll levels Westbound and eleven toll levels Eastbound (ranging from $0.60 to $3.20). The full history of toll schedules is presented in Tables 1.1 –1.4. During the time up to and including our survey, the highest toll level applied for four full hours in each direction: 5:00-9:00 Westbound and 15:00-19:00 Eastbound. We therefore refer to these time periods as the "peak hours." (The subsequent refinement included a slightly higher toll level during one hour of this four-hour peak period in each direction.) Vehicles with three or more people did not pay a toll, although they were required to carry a transponder and pass the overhead toll-tag readers in a special lane where occupancy is checked visually. (Starting in January 1998, these previously exempt vehicles began paying half the toll applicable to other vehicles.)

The Express Lanes opened in December 1995. Of the total capital cost of $126 million, about two-thirds of it was debt-financed. Their use increased steadily, reaching 32,000 vehicles per weekday by summer 1998 (Reza, 1998). By December 1997, 106,000 transponders had been distributed (CPTC, 1998). Revenues covered operating costs during its first year and as of mid-1998 are said by CPTC to also be covering the debt service during some quarters.

The Express Lanes also can be considered High Occupancy/Toll (HOT) lanes, in which lower-occupancy vehicles can pay to use the extra capacity on a lane that would otherwise be reserved for high occupancy vehicles (HOV). In most cases, proposed HOT lanes will be converted from prior HOV use (Fielding and Klein, 1993).[1] In this case, there were no prior HOV lanes, but county and state plans called for *one* HOV lane in each direction to be constructed eventually. The decision to use HOT lanes instead meant that two lanes rather than one was built in each direction, their construction was accelerated by several years, and they were opened as HOT lanes from the start.

The Express Lanes are the first roadway in modern California to be built and operated by a private corporation. Their history goes back to 1989, when new California legislation authorized four transportation projects to be selected from proposals by private firms. The four selected projects are all toll expressways, including two on which tolls would vary by time of day (Gomez-Ibañez and Meyer, 1993, pp. 172-193). The 91 Express Lanes were one of these four projects, and the only one built thus far. Profits are constrained by a ceiling on rate of return, negotiated with the State in a franchise agreement; otherwise the toll rates and structure are

[1]Some proponents of HOT lanes argue that one should later incorporate adjacent free lanes, one by one, into the HOT lane facility if there is adequate demand for faster service at a price. Such a scheme was proposed for the Seattle area and accepted by the Washington State Transportation Commission, although public opposition soon stymied that particular initiative.

Table 1.1: Toll rates, Route 91 Express Lanes Westbound

	1996		1 Jan 1997 - 13 Sept 1997[1]		14 Sept 1997- 18 April 1998[2]	
Weekdays:	M-Th	Fri	M-Th	Fri	M-Th	Fri
0:00- 4:00	$0.25	$0.25	$.50	$.50	$.60	$.60
4:00- 5:00	1.50	1.50	1.50	1.50	1.60	1.60
5:00- 9:00	2.50	2.50	2.75	2.75	2.85[3]	2.85
9:00-10:00	1.50	1.50	1.50	1.50	1.60	1.60
10:00-11:00	1.00	1.00	1.00	1.00	1.10	1.10
11:00-15:00	0.50	0.50	0.50	0.50	0.85	0.85
15:00-19:00	0.50	1.00	0.50	1.00	0.85[4]	1.10
19:00-24:00	0.25	0.25	0.50	0.50	0.60	0.60
Weekend:	Saturday	Sunday	Saturday	Sunday	Saturday	Sunday
0:00- 8:00	$0.25	$0.25	0.50	0.50	0.60	0.60
8:00-10:00	0.50	0.50	0.50	0.50	0.60	0.60
10:00-15:00	1.00	1.00	1.00	1.00	1.10	1.10
15:00-18:00	0.50	1.00	1.00	1.00	1.10	1.10
18:00-21:00	0.50	0.50	0.50	0.50	0.60	1.10[5]
21:00-24:00	0.25	0.25	0.50	0.50	0.60	0.60

1. Also new in Jan. 1997: "91 Express Club". For $15/month, club members get discount of $0.50 on every toll (raised to $0.60 in September 1997).
2. Starting Jan. 1998, previously exempt vehicles were charged half these rates. These vehicles include: carpools or vanpools of three or more people; motorcycles; and cars with special disabled licenses.
3. Monday through Thursday, this toll increases to $2.95 from 7:00-8:00.
4. Monday through Thursday, this toll decreases to $0.60 at 18:00.
5. On Sunday, the $1.10 toll lasts until 22:00.

Source: California Private Transportation Company, Corona, Calif.

Table 1.2: Toll rates, Route 91 Express Lanes Eastbound

	1996		1 Jan 1997 - 13 Sept 1997[1]		From 14 Sept 1997[2]	
Weekdays:	M-Th	Fri	M-Th	Fri	M-Th	Fri
0:00-7:00	$.25	$.25	$.50	$.50	$.60	$.60
7:00-8:00	0.50	0.50	0.50	0.50	0.85	0.85
8:00-12:00	0.50	0.50	0.50	0.50	0.75	0.75
12:00-13:00	0.50	1.00	0.50	1.00	0.85	1.10
13:00-14:00	1.00	1.50	1.00	1.50	1.10	1.95
14:00-15:00	1.50	2.50	1.50	2.75	1.95	2.95
15:00-19:00	2.50	2.50	2.75	2.75	2.85[3]	2.95
19:00-20:00	1.50	2.50	1.50	2.75	1.60	2.85
20:00-21:00	1.00	1.50	1.00	1.50	1.10	1.60
21:00-22:00	0.50	1.00	0.50	1.00	0.60	1.10
22:00-24:00	0.25	0.25	0.50	0.50	0.60	0.60
Weekend:	Saturday-Sunday		Saturday-Sunday		Saturday-Sunday	
0:00-10:00	$.25		$.50		$.60	
10:00-22:00	0.50		1.00		1.10	
22:00-0:00	0.25		0.50		0.60	

1. Also new in Jan. 1997: "91 Express Club". For $15/month, club members get discount of $0.50 on every toll (raised to $0.60 in September 1997).
2. Starting Jan. 1998, previously exempt vehicles were charged half these rates. These vehicles include: carpools or vanpools of three or more people; motorcycles; and cars with special disabled licenses.
3. On Tuesday and Wednesday, this toll increases to $2.95 from 17:00-18:00. On Thursday, this toll increases to $2.95 from 16:00-18:00.

Source: California Private Transportation Company, Corona, Calif.

Table 1.3 Westbound Toll Schedule, effective April 19, 1998
(Note that eight different toll levels are used.)

<table>
<tr><th>Time</th><th>Sunday</th><th>Monday</th><th>Tuesday</th><th>Wedsday</th><th>Thursday</th><th>Friday</th><th>Saturday</th></tr>
<tr><td>0:00-1:00</td><td colspan="7" rowspan="4">$0.60</td></tr>
<tr><td>1:00-2:00</td></tr>
<tr><td>2:00-3:00</td></tr>
<tr><td>3:00-4:00</td></tr>
<tr><td>4:00-5:00</td><td rowspan="6">$0.60</td><td colspan="5">$1.60</td><td rowspan="3">$0.60</td></tr>
<tr><td>5:00-6:00</td><td colspan="5">$2.85</td></tr>
<tr><td>6:00-7:00</td><td colspan="4">$2.95</td><td rowspan="2">$2.85</td></tr>
<tr><td>7:00-8:00</td><td colspan="4">$3.20</td><td rowspan="3">$1.10</td></tr>
<tr><td>8:00-9:00</td><td>$2.95</td><td colspan="4">$2.85</td></tr>
<tr><td>9:00-10:00</td><td colspan="5">$1.60</td></tr>
<tr><td>10:00-11:00</td><td rowspan="12">$1.50</td><td colspan="5">$1.10</td><td rowspan="5">$1.50</td></tr>
<tr><td>11:00-12:00</td><td colspan="5" rowspan="4">$1.00</td></tr>
<tr><td>12:00-13:00</td></tr>
<tr><td>13:00-14:00</td></tr>
<tr><td>14:00-15:00</td></tr>
<tr><td>15:00-16:00</td><td colspan="4" rowspan="4">$1.00</td><td colspan="2" rowspan="4">$1.50</td></tr>
<tr><td>16:00-17:00</td></tr>
<tr><td>17:00-18:00</td></tr>
<tr><td>18:00-19:00</td></tr>
<tr><td>19:00-20:00</td><td colspan="4" rowspan="5">$0.60</td><td colspan="2">$1.10</td></tr>
<tr><td>20:00-21:00</td><td colspan="2" rowspan="4">$0.60</td></tr>
<tr><td>21:00-22:00</td></tr>
<tr><td>22:00-23:00</td><td rowspan="2">$0.60</td></tr>
<tr><td>23:00-24:00</td></tr>
</table>

Table 1.4 Eastbound toll schedule, effective April 19, 1998
(Note that eleven different toll levels are used.)

<table>
<tr><th></th><th>Sunday</th><th>Monday</th><th>Tuesday</th><th>Wedsday</th><th>Thursday</th><th>Friday</th><th>Saturday</th></tr>
<tr><td>0:00-1:00</td><td rowspan="10">$0.60</td><td colspan="5" rowspan="7">$0.60</td><td rowspan="8">$0.60</td></tr>
<tr><td>1:00-2:00</td></tr>
<tr><td>2:00-3:00</td></tr>
<tr><td>3:00-4:00</td></tr>
<tr><td>4:00-5:00</td></tr>
<tr><td>5:00-6:00</td></tr>
<tr><td>6:00-7:00</td></tr>
<tr><td>7:00-8:00</td><td colspan="4" rowspan="6">$1.00</td><td rowspan="5">$1.00</td></tr>
<tr><td>8:00-9:00</td><td rowspan="2">$1.10</td></tr>
<tr><td>9:00-10:00</td></tr>
<tr><td>10:00-11:00</td><td>$1.10</td><td rowspan="9">$1.50</td></tr>
<tr><td>11:00-12:00</td><td rowspan="10">$1.50</td></tr>
<tr><td>12:00-13:00</td><td>$1.10</td></tr>
<tr><td>13:00-14:00</td><td>$1.10</td><td colspan="3">$1.60</td><td>$2.75</td></tr>
<tr><td>14:00-15:00</td><td>$1.95</td><td colspan="3">$2.25</td><td rowspan="5">$3.20</td></tr>
<tr><td>15:00-16:00</td><td colspan="4">$2.95</td></tr>
<tr><td>16:00-17:00</td><td colspan="2" rowspan="2">$2.95</td><td colspan="2" rowspan="2">$3.05</td></tr>
<tr><td>17:00-18:00</td></tr>
<tr><td>18:00-19:00</td><td colspan="4">$2.95</td></tr>
<tr><td>19:00-20:00</td><td colspan="4">$1.60</td><td>$2.95</td><td rowspan="3">$1.10</td></tr>
<tr><td>20:00-21:00</td><td colspan="4">$1.10</td><td>$1.60</td></tr>
<tr><td>21:00-22:00</td><td>$1.10</td><td colspan="4" rowspan="3">$0.60</td><td>$1.10</td></tr>
<tr><td>22:00-23:00</td><td rowspan="2">$0.60</td><td colspan="2" rowspan="2">$0.60</td></tr>
<tr><td>23:00-24:00</td></tr>
</table>

freely determined by the company. This flexibility was crucial to the project's viability and, in particular, to the builders' ability to apply time-varying tolls.

The SR 91 project was controversial in Riverside County, whose residents will pay most of the tolls, even though the project adds new capacity and the original lanes remain free of charge. The reason is that it substitutes for an originally planned single HOV lane in each direction, which was expected to be funded by Orange County. Riverside County had already built HOV lanes on its side of the border, and many of its leaders felt that its residents should not be contributing toward the cost of Orange County's lanes. This objection is partially ameliorated by the fact that the new lanes provide twice the capacity increment of the original HOV plan, and by the stipulation that the new lanes are free to vehicles with three or more occupants for at least the first two years of operation. Subsequent charges for these vehicles depend on financial conditions.[2] The project has received generally favorable ratings in opinion surveys, with 60-70 percent approving toll finance and 50-60 percent (up from 40-50 percent before it opened) approving time-varying tolls (Sullivan and El Harake, 1998).

There is a great deal of interest in how travelers will react in practice to congestion pricing (e.g.: Bhatt, 1993; Acha-Daza et. al., 1995; Small and Gomez-Ibanez, 1997) and to HOT lanes (Chu and Fielding, 1994; Oropeza and Orso, 1996; Orski, 1997). The 91 Express Lanes are the first example of congestion pricing to be implemented in the United States, and the first HOT lanes anywhere. They therefore offer a unique opportunity to study behavioral effects in a real field situation. A comprehensive study of the operational features and traffic effects of the Express Lanes is currently being conducted by researchers at California Polytechnic Institute, San Louis Obispo.[3] This report focuses more on modeling the complexity of individual traveler behavior.

The 91 Express Lanes project adds several interesting new elements to the factors governing traveler choice with real-time information. First, the availability of tolled lanes adjacent to the free lanes means that drivers have a particularly "pure" route choice, in that the two roads are essentially identical in their locations. Second, route choice now involves trading a travel-time saving against a toll rather than comparing travel times. Third, there is the possibility that the toll schedule itself could depend on traffic in real time and so be learned only during the course of the trip. This would invite drivers to decide "on the fly" based on updated information about both travel times and price. Such a policy, known as “dynamic pricing,” is under consideration by the private operator of the Express Lanes, but has been avoided thus far due to unfavorable reaction to the idea in focus groups. We consider dynamic pricing in Section 2.3.

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[2]See California Department of Transportation and California Private Transportation Corporation (1992), p. 2; or Fielding (1994), p. 392.

[3] See Sullivan (1996) and Sullivan and El Harake (1997). More current information is available on their Web site: http://www.ardfa.calpoly.edu/~jwhanson/newresults/sr91results.html.

1.2 Survey Description and Survey Statistics

Our travel behavior survey was mailed to users of the corridor in July, 1997, about 18 months after the Express Lanes opened. We chose a mail survey because of low cost and previous positive experience with mail surveys on information-related topics in the same region. The survey includes questions about general travel, use of the corridor including the Express Lanes, and changes in travel behavior since the opening of the Express Lanes. There are stated preference questions about how respondents would use the Express Lanes given different proposed scenarios. Respondents are asked reasons for and against using the Express Lanes, their switching behavior given accidents and traffic information, and demographic information. For the most part, the survey asks about the most recent work trip, trips taken last week, or (for the stated preference questions) expected trips next week. In an attempt to limit the number of questions asked of each respondent, half of the surveys focus on Westbound trips to work for the more detailed questions, the other half on Eastbound trips from work.

The general travel questions include trips made last week to various destinations (work, children drop-off, shopping, etc.). We also asked about the departure times on the trip to work, flexibility of work arrival times, mode of travel, and how their commute varies from day to day. Respondents are asked whether they use the portion of the 91 that includes the Express Lanes and, if so, they are asked to fill in a "diary" of last week's trips in this corridor. They mark trips in the appropriate hour and indicate, for each trip, whether they used the Express Lanes and whether they carpooled. The Eastbound version of this series of questions is shown in Appendix A, along with other questions used to form dependent variables in the models reported in this report. The complete questionnaires, both Eastbound and Westbound versions, are submitted separately as supplements to this report.

Other questions ask for "stated preference" in hypothetical situations. These situations include a lower toll during a marginal time period (to see if people are interested in switching travel times and using the Express Lanes); using the Express Lanes given information about accidents; carpooling and using the Express Lanes if the peak toll was raised, and using the Express Lanes if the prices were set dynamically (in real-time according to the current traffic conditions). Each respondent received one of ten different sets of thresholds or values in the stated preference section. For example, some respondents are asked about a hypothetical 15-minute time saving, others about a 25-minute saving. Additional hypothetical questions concern use of the Express Lanes if the respondent learned about an accident, given an expected delay length and a stated additional (dynamic) price charged because of the accident congestion. We also ask three questions about how traffic decisions are made; these are described further when the models are described below. With the ten alternative versions of the stated-preference questions, morning and evening questionnaires and "early"/"late" versions, we had a total of forty survey versions.

We mailed the survey to a total of 3000 people, whose addresses correspond to license plates that we observed from a bridge (Lakeview Avenue overpass of the 91 freeway in Anaheim Hills, California) over the regular and Express Lanes in the corridor. The license plates were observed with the naked eye when traffic was slow enough and with binoculars otherwise. The plate numbers were spoken into mini cassette tape recorders. The recorders were transcribed away from the field. It is likely that some errors occurred in both reading the plates of fast-moving vehicles and in the transcription. Permission was obtained from the Department of Motor Vehicles to get addresses that correspond to the plates. We had to put the license plates into the required format on specially-provided tapes. We got back addresses that matched approximately 80% of the license-plate numbers that were sent in. Not all addresses were residential--many went to leasing companies or banks, which we were unable to use.

We used a random sample of the matched residential addresses. Based on when we observed their license plates, we were able to split the respondents into morning and evening groups and into "early" and "late" peak-period groups, thereby helping us customize the survey. However, we sent morning versions to a third of the people that we observed in the evening and vice versa. We took a random sample, regardless of the location where people were registered in California, figuring that some people had moved and others may have other family members or friends driving their cars or that we observed them vacationing. This resulted in sending approximately 15% of the surveys to Northern California addresses and another 20-25% to Los Angeles and San Diego county addresses from which people probably do not commute using this corridor; many of these people did not respond, and most of them probably were incorrect license numbers or incorrect address matches.

Our response rate is approximately 39% (about 980 responses from about 2500 good addresses), which seems quite good given the length and complexity of the survey. The $500 incentive—offered to a respondent that was randomly drawn--seems to have been reasonably effective. Over one-third of the respondents sent their questionnaires only after receiving two reminder postcards and a second copy of the survey—an important follow-up since some researchers suggest that these late respondents are more typical of the average corridor user (Richardson, 1997). Up to a total of four reminder postcards were sent if necessary.

Our survey design is heavily dependent on choice-based sampling methods. In observing license plates in the field, we intentionally obtained potential respondents in desired proportions from possible choice categories along three choice dimensions: route, time of day, and vehicle occupancy.[4] Therefore, we must adjust for this when estimating models. We do this by recognizing that in computing descriptive statistics or estimating choice models, each data point in our sample represents a larger or smaller fraction of the total population of corridor users depending on whether our sampling scheme favored sampling similar people. More precisely, suppose we drew n_j sample members from a total population of N_j people who can be inferred to have made choice j, where j designates one of 32 categories indicating travel during any one of the eight possible peak hours, in a single-occupant or multi-occupant vehicle, on the Express Lanes or the regular lanes. Then each such a sample member represents N_j/n_j corridor users in the real population, and is therefore multiplied by this fraction in reporting statistics and estimating models.[5] (When we report weighted sample numbers we multiply all weights by n/N,

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[4]Route here means toll lane versus regular lane. In the case of vehicle occupancy, the control was only partial, in that we tried to oversample carpools but could not always identify the occupancy while recording a license plate.

[5]See Manski and Lerman (1977) or Lerman and Manski (1979) for a formal proof that this method provides consistent parameter estimates in the case of a multinomial logit model.

the fraction of all corridor users sampled, so that the weighted sample equals our actual sample in total size.) In practice we use our own traffic counts to estimate N_j for an average weekday peak period. The outside information used to estimate N_j is currently obtained from our own peak traffic counts. Our counts include vehicles that use the Express Lanes and the regular lanes at the Lakeview Avenue overpass and HOV-2+ vehicles on both routes.

For n_j we use several survey questions to determine the hour of their most recent trip, whether or not it was taken in a vehicle with one or more other people, and whether they had used the Express Lanes two or more times in the last week. We use the actual number of completed surveys in the relevant category, thus implicitly treating our sampling scheme as though we had known in advance what the response rate would be and had adjusted the number of surveys sent in each category accordingly. This may reduce bias from differential tendencies of people choosing different alternatives to return the survey. In particular, we suspect that frequent users of the Express Lanes are more likely to be interested in the survey than other people, so this procedure may serve as a crude substitute for a model of response bias.

Our survey is fairly complex and many respondents simply left some questions blank. It is hypothesized that reasons for blank answers include a combination of not having relevant information to respond, not wanting to answer "personal" questions such as income, "tiredness" at answering complicated questions, etc. There does not seem to be a pattern in the particular questions omitted, so models with a large number of independent variables have a greater chance of losing respondents because of missing variables. We therefore "impute" some of the variables, i.e. we estimate missing values for these variables using answers to other questions, in order not to lose all the other information for these respondents. In the models presented below, we use imputed values for the times of day that they traveled on the corridor based on what time they got to work or left work. These times affect the weights and the variables based on relative delay in the corridor.

Table 1.4 presents some weighted summary descriptive statistics for our data; variables are defined in Table 1.3. The first column of Table 1.4 shows statistics from all respondents, the second from those who have the option of using the full ten-mile-long corridor, and the third from those who used the Express Lanes at least once during the previous week. It should be noted that travelers in this corridor--with commutes averaging more than 40 miles in length and an hour in duration--have much longer commutes than the 20 miles or 30 minutes that are typical of Southern California as a whole or of the United States.

There are a few notable differences between the average corridor user and those who used the Express Lanes at least once during the previous week. Incomes and wages of Express Lane users are moderately higher — around 9 percent for household income — than those of all corridor users. Table 1.5 shows another picture of how income, as well as three other indicators, is associated with Express Lane use. This table gives the percentage of people in each category (e.g. low, medium, or high-income) who used the Express Lanes at least once (later referred to as "USERS"), and the percentage who used it at least eight times (later called "HEAVY" users), during the previous week. Medium and high-income groups are similar, especially in the fraction of "heavy" users; only the lowest income group has notably lower proportions of users, and even these differences are not very large. For example, 12.3 percent of respondents from

Table 1.5: Definition of Variables in the Statistics Table (Table 1.4)

Variable/ Survey Question Number	Definition
Flex schedule window (min)/ Question #8	The number of minutes between 0 and 120 within which the respondent must arrive at work. If they have to be at work at a certain time, this is 0; if their schedule is completely flexible, it's 120. If they must arrive between 8:00a.m. and 8:30a.m., then they are assigned 30.
Non-work trips per week/ Question #1	Number of shopping, drop-off, entertainment, etc. trips a week they make. A proxy for interest in travel.
Work trip variability/ Question #16	Number of times in the past week that their trip took 10 minutes longer than their last trip. Morning and evening trip variability is counted.
Switching Propensity/ Question #47	Number of times in the past two weeks that the respondent switched to surface streets or another freeway, or switched departure time due to a radio traffic report.
Use radio/ Question #46	Whether or not they listened to a radio traffic report in the past week.
Other information sources/ Question #46	The number of other information sources including electronic message signs, in-vehicle systems, and highway advisory radio that they used in the past week.

Table 1.6: Weighted Summary Statistics[1]

	All Respondents	Used Corridor Last Week	Used Express Lanes Last Week
Number of respondents	995	745	460
Travel with transponder	52%	67%	98%
Has transponder	48%	62%	96%
Express Lane Use (times/last week)	---	2.35	4.30
Carpool or Vanpool 3+	6.4%	8.3%	14%
Carpool with 2	8.4%	11%	11%
Employer Pays	3.3%	3.7%	7.4%
Household Income ($/year)	~$61,500	~$61,500	~$67,000
Wage rate ($/hour)	~$22.50	~$22.50	~$24.00
Trip distance (miles)	40.6	44.3	44.6
Trip length (minutes)	58.3	62.4	62.2
Flex schedule window (min)	50.2	49.0	51.3
Non-work trips/week	4.6	4.1	4.2
Age	42.2	41.8	41.6
Some college education	81%	81%	85%
Other language	14%	13%	10%
Male	65%	65%	62%
Work trip variability	3.9	4.1	4.1
Switching Propensity	---	1.6	1.3
Use radio	---	92%	92%
Other information sources	---	64%	58%

1. Our sample is choice-based. Weights are applied to attempt to show statistics representative of the population of people using the 91 corridor.
(Last updated November 18, 1997)

Table 1.7: Two-Way Cross-Tabulations:
Percentage of Various Subgroups who use Express Lanes

Category	Weighted number in sample	Fraction of corridor users (%)	% USERs (used at least once last week)	% HEAVY users (used at least 8 times last week)
Income:				
Low ($0-50K)	208	35.7	42.5	12.3
Medium ($50-70 K)	177	26.3	54.9	15.8
High (>$70K)	253	38.0	65.2	14.9
All:	638	100.0	54.9	14.3
Gender:				
Male	437	64.5	51.4	12.9
Female	231	35.5	59.9	16.9
Both:	668	100.0	54.4	14.3
Language spoken in home:				
English only	583	85.8	56.7	15.2
Other	90	14.2	39.4	8.7
Both:	673	100.0	54.4	14.3
Work-schedule Flexibility:				
No flexibility	337	52.2	51.2	15.4
Some flexibility	70	10.4	66.6	15.3
Very flexible	229	37.4	56.1	13.5
All:	636	100.0	54.9	14.7

Note: Data weighted to reflect all users of full 10-mile corridor.

low-income households (less than $50,000 per year) are heavy users, compared to 15.3 percent of the other two groups. So the "Lexus Lanes" appellation, used derisively by opponents of HOT lanes to suggest they are used only by the rich, is highly misleading; while there is some relationship between income and HOT lane use, it is far from a tight one.

Other demographic effects highlighted in Table 1.5 indicate that the Express Lanes are somewhat more heavily used by women than men, and considerably less heavily used by people who sometimes or always speak a language other than English in their home. There is also weak relationship with work-hour flexibility: people who report some but not complete tolerance for late arrival are somewhat more likely to use the lanes occasionally than people with no flexibility or people with complete flexibility. Of course, work-hour flexibility and other demographic characteristics are correlated with income, so these two-way tabulations are only suggestive in sorting out the independent effects of the characteristics under consideration. A fuller understanding of them can be obtained from the behavioral models described int the next section, in which the effect of each variable is measured while holding the others constant.

1.3 Route Choice Model

The first models of interest predict who uses the Express Lanes and how often. This can be formulated as a binary choice, for example by creating variables corresponding to the last two columns of Table 1.5: "USER" for anyone who used the Express Lanes at least once last week, or "HEAVY" for anyone who used them at least eight times. Or we can specify a multinomial choice: e.g. use always, use frequently, use infrequently, or never use. In these cases, we can use the well-known multinomial logit model, which assumes that each person i has a "utility" (i.e. net benefit) associated with taking each alternative n, and chooses the alternative with the highest utility. Utility is divided into a systematic component, V_{in}, that depends on measurable attributes, and a random component, ε_{in}. (The random component allows for unobservable factors or personal idiosyncracies which affect choice.) The random components are independently and identically distributed with an "extreme value" distribution, which means the probability distribution function of each random term is $f(\varepsilon)=\exp[-\exp(-\varepsilon)]$. The probability of individual n choosing alternative i is then $P_n(i)=\frac{e^{V_{in}}}{\sum_{j\in C_n} e^{V_{jn}}}$ (see Ben-Akiva and Lerman, 1985).

Alternatively, the multinomial choice can be modeled as an ordered choice. The idea is simply that a single explanatory function, known as a "latent variable", determines the proclivity to use the Express Lanes more often; and that the higher this variable, the more likely are the choices indicated by the higher-use categories. The advantage to the ordered model is that there are fewer parameters to estimate than in a full multinomial logit model, and it's easier to interpret the coefficients. Ordered logit is a fairly intuitive extension of multinomial logit (McKelvey and Zavoina, 1975; Greene, 1993). The observed choice j, taking possible values $0, 1, \ldots, J$, is assumed to depend on the value of the latent variable y^*, which can be written as a linear combination of explanatory variables x plus a random term: $y^*=\beta x+\varepsilon$ The model postulates that if y^* falls in an interval $(\alpha_{j-1}, \alpha_j]$, where the α's are constants to be estimated, then the response observed is j. Here the notational convention is that $\alpha_{-1}=-\infty$ and $\alpha_J=\infty$; so there are $J-1$ constants, which we call "cutoff values," to be estimated. If F(.) is the cumulative probability distribution of ε, then the probability of response j is $F(\alpha_j-\beta x) - F(\alpha_{j-1}-\beta x)$. The ordered logit model uses the fact that the alternatives have a rank order.

1.3.1 Dependent variables

From the survey "diary" (Questions 23-25), we have a week of one-directional data from each respondent. We determine how many times in the week the respondent travels in the corridor during peak (or all) hours and how many of those times the respondent uses the Express Lanes. If the respondent has used the Express Lanes once last week, then we label him or her a USER and we can run a model on USER/NON-USER. We can define EXTRIPS to be the number of Express Lane trips the respondent has made (last week).

We are interested both in occasional and more regular users of the Express Lanes, so we estimate models using both USER and HEAVY (as defined earlier). We can also calculate the ratio, USE, which is the number of times the Express Lanes are used divided by the number of times the respondent uses the full corridor. For our models it is convenient to discretize USE into four groups: never use (USE = 0.0), use infrequently (0.4 > USE > 0), use often (1.0 > USE >= 0.4), and always use (USE = 1.0). ("Never" and "always" refer, of course, just to the one week of data.) We can evaluate the USER, HEAVY, EXTRIPS, and USE models with the subsample of respondents that makes peak hour trips and the larger sample of all corridor users. The USER and HEAVY models are appropriately estimated as binary logit or probit models. The EXTRIPS and USE models can be estimated as ordered logit models.

We now discuss the independent variables we expect to significantly influence these route choice models. We have divided the variables into those that would comprise a minimal specification of the models and those possibly appropriate for enhanced specifications — the latter including variables for which the direction of causation is less clearcut. The coefficients for the models are also shown in Table 1.6, as estimated from our survey data.

1.3.2 Minimal specification

The first variable is "Express Lane advantage interacted with [multiplied by] household income." "Express Lane advantage" ("exadv") gives in minutes the typical time savings by taking the Express Lanes during the particular hour of the day that the person reported traveling. (These delays have been estimated roughly to obtain the results shown here.) Household income is a discrete categorization, taking values one through five according to the five categories in the survey question. We hypothesize that the general decision to use the Express Lanes is based on an overall household budget, so that household income would have greater explanatory power in the general route choice models than wage rate. We expect that higher income should make time savings more valuable; specifically, the form in which it is entered here allows the value of travel time to be proportional to household income. (We do not have to enter the cost difference because it is the same for everyone—namely $2.75—in the sample of peak travelers used for the model estimation.)

"Work trip distance" may influence people's valuation of travel time and variability. One hypothesis is that people have a non-linear resistance to travel time and trip length and thus the longer their trip is, the more anxious they are for reliability. Another hypothesis is that people willing to travel long distances have a lower than average value of time and a high tolerance of uncertainty, so are less likely to choose the Express Lanes. We include trip distance and trip distance squared to obtain quadratic effects.

The variable, "flexible schedule window", gives a quantitative measure (number of minutes) for the respondents' work schedule flexibility. We ask people (Question #8) if they must arrive by a certain time, have to arrive between a pair of times, or if their work hours are flexible. If people have to arrive at work at a certain time, then we infer that they have no flexibility and are given zero minutes for this variable. For those with some flexibility, we record the duration of the window (in minutes) that they indicate. For those who say they are unconstrained, we assign a high value arbitrarily taken to be 120 minutes. We expect that a more flexible schedule imposes less time constraints on the driver who then doesn't "have to" use the Express Lane in order to arrive on time for work. This would lead to a negative coefficient for this variable. However, it may be that professionals have flexible work schedules but they also have higher values of time (beyond what would be predicted from their income) and thus use the Express Lanes, which would be a counteracting effect.

We asked about the number of "non-work trips" taken during the previous week. We interpret a large number of non-work trips as an indication of an interest in travel and an active lifestyle. We therefore expect a positive coefficient.

We expect that there is some appeal to using the Express Lanes when there are two people in the vehicle who can split the cost. So we include a two-person "carpool dummy," expecting a positive coefficient.

1.3.3 Enhanced specification

The following variables are more likely to be partly endogenous, i.e. the causation may run partly from choice of Express Lanes to these variables. Thus they have a less certain interpretation.

"Work trip variability" comes from Question #16 asking how many times last week traffic caused their trip to or from work to be 10 minutes longer than usual. Since most of the respondents commute much further than the 10-mile corridor length, it is anticipated that much of this variability occurs on surface streets while waiting in entrance ramp queues, on other portions of the 91, and on other freeways. We anticipate that travelers with greater variability elsewhere in their trip would be more interested in using the Express Lanes to have some reliability for part of their trip. However, we acknowledge that some of the variability may also occur in the study corridor, so respondents with less variability may already be using the Express Lanes.

We asked how often in the last two weeks the respondent switched (a) from the regular lanes to the Express Lanes, (b) from Route 91 to another freeway, (c) from Route 91 to a surface street, or (d) to a different time of day, due to radio traffic information (Question #47). Obviously, switching from the regular lanes to the Express Lanes would be endogenous to the model (in fact it serves as a dependent variable in a switching model described in Section 2.2). We add together the other three switch responses to measure a "switch propensity" value. (Alternatively, each respondent could have a "switch route" variable and a "switch time" variable.) We expect that some people are more prone than others to making day by day adjustment in their trips, and therefore enter "switching propensity" quadratically, anticipating that it will first increase and then decrease the tendency to use the Express Lanes more often.

The "use radio" and "other information sources" variables come from Question #46 about which traffic information sources were used in the past week. We make the assumption that if they use the radio or other sources, then they are interested in improving their trip if possible and will be more likely to use the Express Lanes. The "use radio" variable is zero or one; "other information sources" is the number of other sources checked. Other sources include: highway advisory radio, electronic message signs, telephone/cellular phone, in-vehicle traffic information system, internet, and an employer provided service.

1.3.4 Results

Table 1.6 presents alternative models, all with roughly similar results. The model presented in the last column, "USE", is a good one to focus on as it appears that allowing for the full range of use frequency sharpens our ability to distinguish the effects of particular variables (compared to the more crude USE/NON-USE or HEAVY distinctions). This model provides a plausible picture of what determines the use of the Express Lanes.

By multiplying "express lane advantage" by household income, we identify in its most theoretically plausible form the "Lexus lane" idea. Specifically, the positive and highly significant coefficient on this variable indicates that income alone does not determine Express Lane use, but rather that income enhances the value that the individual places on time savings. In other words, high-income travelers are more sensitive to the amount of time they can save by using the Express Lanes. But a high-income traveler who travels near the edge of a peak period, when time savings are not so large, is still less likely to pay for the Express Lanes than a low-income traveler facing larger time savings.

The opposite signs on "trip distance" and "trip distance squared" indicate a complex but plausible relationship between length of trip and express-lane use. Together they indicate that the further you have to go, the more likely you are to take the Express Lanes but only up to a point — after a while, the effect diminishes as time savings becomes a smaller proportion of the total trip time. The diminishing effect sets in only for very long trips: increasing trip distance continues to favor Express Lane use up to a distance of over 100 miles.[6]

The most powerful demographic variable is "Male", which is negative in the model — indicating that other things held constant, men use the Express Lanes less regularly than women. Initially, based on the two-way cross-tabulation in Table 1.5, we expected other demographic variables including age, education, and use of another language to influence the models. However, we

[6] This can be seen by maximizing the function $(0.0786d - 0.0007025\ d^2)$, where d is (one-way) trip distance.

Table 1.8: Route Choice Model Results[1,2]

	DEPENDENT VARIABLES			
	USER	HEAVY	EX TRIPS	USE
INDEPENDENT VARIABLE	Binary logit coef. (t-stat)		Ordered logit coef. (t-stat)	
Minimal Specification				
Constant/Cut-off: alpha 1[2]	-2.341 (-2.677)	-4.195 (-3.747)	4.221 (.9134)	3.092(.8703)
Cut-off: alpha 2			5.622 (.9327)	3.566(.8744)
Cut-off: alpha 3			6.359 (.9464)	4.118(.8799)
ExLa adv * HH income	**.0256 (3.122)**	.0099 (1.227)	**.0252 (3.415)**	**.0237(3.414)**
ExLa advantage	-.0260 (-0.653)	-.0210 (-0.491)	-.0062 (-0.163)	-.0272(-0.748)
Trip distance	**.0684 (2.922)**	**.0969(2.541)**	**.0980 (3.195)**	**.07859(2.683)**
Trip distance squared	**-.000550 (-2.581)**	**-.000958 (-2.488)**	**-.000887 (-2.877)**	**-.000705 (-2.405)**
Flexible schedule window	.0027 (0.969)	.0034 (1.182)	.0023 (0.934)	.0044(1.803)
Number of non-work trips	.0400(0.915)	-.0287 (-0.686)	.0523 (1.446)	**.0761(1.992)**
Carpool (2 people) dummy	.8495 (1.632)	.1871 (0.516)	**1.001 (2.547)**	**.9360(2.125)**
Male	**-.6754 (-2.184)**	-.3930 (-1.216)	-.2286 (-0.851)	**-.5874 (-2.215)**
Enhanced Specification				
Work trip variability				
Switching propensity				
Switching propensity squ.				
Use radio				
Other information sources				
Number of observations	295	295	258	286
Log likelihood	-161.176	-140.448	-306.818	-300.57
Degrees of freedom	8	8	8	8
Rho-squared	0.1118	0.0395	0.0524	0.1214

1. All of the models can be estimated on the sub-sample of peak users and with all users.
2. The constant is used for the binary logit model. The cut-offs are used for the ordered logit models. Standard errors are reported for the cut-offs, not t-statistics.

discovered that once income and gender are controlled for as shown, other variables had no additional explanatory power. Thus they are excluded from the model shown in the table.

People in two-person carpools are more likely to take the Express Lanes. This is an important confirmation of a fact often overlooked in the arguments over carpool exemptions: even with no reduced fare, being in a carpool reduces the cost per person while maintaining the same time savings per person, and so leads to more frequent use of the Express Lanes.

As noted, we had expected that respondents who have to be at work by a certain inflexible time would be more interested in using the Express Lanes. Over half of our sample do report having to be at work by a certain time; however, our flexible schedule window variable is not significant in the route choice model. This may indicate that the expected effect is offset by a correlation between flexible schedules and value of time. Or it may just be that, because the ten-mile Express Lane corridor is often only a small part of the journey and using the Express Lanes does not guarantee reliable travel time on the rest of their trip, the effect is too small to detect.

None of the enhanced variables have a big effect on route choice and so they are not included in the models reported here.

The results of the USER, HEAVY, and EX TRIPS models, are displayed mainly for comparison purposes. The USE model described at length in this section performs better than the others. We expect the ordered model with multiple choices to do better explain travel behavior than either of the binary models. The overall weakness of the HEAVY model is a little surprising, but it indicates to us how difficult it is to assess the characteristics of people that use the Express Lanes frequently.

1.4 Conclusions

The 91 Express Lane corridor is a unique facility--the first High Occupancy/Toll corridor--thus, it is of great interest to see how people react to the new choices that are available. Here we analyze data from a mail-based survey. We can see from the descriptive statistics that income distinguishes Express Lane users from regular corridor users, but the difference is not as large as we may have first expected. We need to look at route choice models to discover some of the other variables that influence the decision to use the new roadway. The route choice behavioral models reveal that women are more likely than men to use the premium lane. Also trip distance influences the choice to use the Express Lanes.

Many people use the Express Lanes irregularly. This raises questions that are important for designing and marketing such projects. How and when do people decide whether to use the Express Lanes on a given day? Do they or would they use real-time information about changing conditions? How would they respond if the toll were adjusted in real time, as it has been since early 1998 on the I-15 "HOT Lanes" in northern San Diego County? These topics are covered in the next two sections.

2 TRAFFIC DATA, ALGORITHMS, AND REVENUE EFFECTS OF VALUE-PRICED SERVICES

2.1 Traffic Data and Monitoring

The California Private Transportation Company (CPTC), which operates the Express Lanes, has a large array of traffic technology available to them. Their traffic management center is located in their executive offices overlooking the Express Lanes in Anaheim Hills. Here they have complete camera coverage of the Express Lanes and most of the adjacent freeway lanes. They have computer monitors that display the current status of traffic on both the Express Lanes and the regular lanes, using inductive loops (electrical wires in the roadway that detect vehicles passing over them) and traffic algorithms. There is an agreement to share traffic and incident information with the Caltrans District 12 Traffic Management Center located fifteen miles away in Santa Ana.

The traffic management center has a full time staff that monitors current traffic conditions and responds to incidents and other problems on the Express Lanes. Abnormalities are generally "detected" visually with the cameras, which provide nearly full coverage of the corridor system. There are approximately 20 cameras, all with pan, tilt, and zoom capabilities. The operators in the control center have eight video monitors on which they can display the camera images. All of these are connected with fiber optic cables and so full, real-time images are available in the control center.

The operator workstations in the control center include computer monitors with a graphical image of the system, video camera adjusting equipment, and communication devices connected to Caltrans and the Express Lane Freeway Service Patrol vehicles, which are owned and operated by CPTC. The computer monitors show a graphic of the system: Express and regular lanes, each color-coded according to real-time traffic conditions (green for free-flowing traffic, yellow for slower traffic, and red for congested conditions). The software uses real-time readings from the inductive loops in the Express and regular lanes. Thus CPTC has the capability of using the real-time information to implement dynamic tolls, although they do not use this capability now because people in focus groups have told them that users prefer to know toll prices before they leave home.

The inductive loops, transponder readers, and cameras are all maintained by MFS Network Technologies which installed them and are responsible for their operation. MFS is under contract to provide 99.975% accuracy in reading individual transponders. Loops must be repaired within a day of malfunction. (In contrast, many systems report 50% or fewer loops working at one time in their system.)

The CPTC uses off-duty California Highway Patrol (CHP) officers under contract and vehicles and their own Freeway Service Patrol vehicles to help maintain their premium-service roadway. Part of the lease agreement CPTC has with the state of California is that it must pay for the CHP officers to "police" the roadway. They are available during peak hours and some other times to write tickets for general traffic violations (for example, speeding), driving without a transponder, and traveling in the carpool lane without two or more passengers. There are two Freeway Service Patrol vehicles and drivers during peak periods. One driver travels on the Express Lanes and stops to help stranded motorists (accidents, flat tires, empty fuel tanks, etc.). The other driver generally watches the 3+ lane for violators unless he is called out to help with some other problem. Calls increase during bad weather conditions (wind, for example) when there is more debris on the roadway.

2.2 Models of Use of Real-Time Information

The Express Lanes are a close substitute for the regular 91 lanes. We expect that some corridor travelers make the decision of whether or not to use the lanes on a daily or even on a real-time (given current traffic conditions) basis. This is further validated by the number of people that have transponders but do not use the lanes every day. Here we propose four models of decision making with variable traffic, two based on revealed preference data and two on stated preference data. We use ordered logit to estimate the models. Most of the independent variables used in the route choice model of Section 1.3 are included in these models as well. Table 2.1 summarizes the models and the independent variables deemed appropriate for each.

2.2.1 Switching model
As noted earlier, we ask the number of times respondents switched from the regular lanes to the Express Lanes because of radio traffic reports in the past two weeks (Question # 47 in the survey). The answer to this question, which we call "number of switches" is the dependent variable for one model of real-time behavior.

2.2.2 Time-of-decision model
Another question (# 45) asks when the decision to use the Express Lanes is made, allowing one or more of the following choices: "before I begin my trip", "when I see the electronic message signs," "when I see what traffic conditions look like," and "when I hear radio reports about traffic conditions." We estimate this as an ordered logit model with three choices: decide pre-trip, mixture of decisions including on radio (which may occur both pre-trip and en-route), or decide en-route. The idea of this model is to find those factors which make people more likely to decide en-route rather than before the trip begins.

2.2.3 Stated preference: Express Lane use and Dynamic Express Lane use
The next two models are based on two similar stated-preference questions. In each case, a hypothetical situation is described and the respondent is asked when the Express Lanes would be used: "never", "only on days when there is an accident", "only on days when traffic is normal," or "on all weekdays." For our analysis we combine the two middle categories and again treat the model as ordered logit with the dependent variable indicating Express Lane use never, sometimes, or all days.

The first of the two hypothetical questions (# 37) states that an accident will delay the trip by a stated number of minutes with the number either ten, twenty, or thirty. Thus a generic "time delay" variable with each respondent's given time delay is used in forming one of the independent variables in the model—specifically, we multiply time delay by the wage rate, in order to allow people's implied value of time to be proportional to the wage rate. We call this the model of "Express Lane use."

In the second hypothetical question (# 40) we describe dynamic pricing, in which pricing varies according to real-time traffic conditions. We then suggest that a dynamic pricing scheme could be implemented by reducing the usual peak toll by a small amount but adding a surcharge on days when there is an accident on the regular lanes. The price reduction is either $0.25 or $0.50, while the accident surcharge is either $1.00 or $1.75. A generic "cost differential" variable is then constructed with two possible values, $1.25 and $2.25. The cost differential is divided by the wage category for the independent variable in the model; thus cost influences the model proportionately to the respondent's wage.

2.2.4 Other independent variables

Specifications for each of these four models are illustrated in Table 2.1. Most of the independent variables are the same ones used by the Route Choice models in Table 1.6. One difference between these models and the route choice models described earlier is the use of wage rate rather than household income as the factor assumed to influence the value of time. The reason is that we hypothesize that when a decision is made "on the fly", one weighs the possibility of being late with a loss of wages or reputation at work, and the decision is driven more by individual than by household circumstances.

The variable "express lane advantage" (exadv) as defined above, is not appropriately applied in either of the stated preference models because we are providing hypothetical information about the time savings. Instead, we use a variable called "mid-peak dummy" to identify people who normally use the corridor during the most congested two hours of the four-hour peak period. We expect that if trips in the corridor occur in the middle of the peak hours (6-8 a.m. in the morning, 4-6 p.m. in the evening), then congestion is worse so there is a greater chance that the driver will use the Express Lanes. However, the estimated coefficient may be upward biased to the extent that people who choose the Express Lanes feel less need to shift their trips away from the mid-peak in order to reduce congestion.

In these models, it is anticipated that switching propensity and perceived travel-time variability are very important. Demographically, age and using another language are again tested. Traditionally, it is thought the males respond to traffic information and make changes more frequently than females. We test these hypotheses and discuss the results in the next section.

Table 2.1: Models of Use of Real-Time Information

INDEPENDENT VARIABLES	DEPENDENT VARIABLES			
	Switches **Ordered Logit** coef. (t-stat)	Time of Decision **Ordered Logit** coef. (t-stat)	SP: Ex Lane Use **Ordered Logit** coef. (t-stat)	SP: Dynamic Ex Lane Use **Ordered Logit** coef. (t-stat)
Minimal Specification				
Cut-off 1[1]	1.351 (1.790)	-2.630 (-1.454)	-4.435 (.9716)	-2.054 (1.266)
Cut-off 2[1]	2.755 (1.788)	2.1433 (1.440)	.1969 (.9022)	.2348 (1.249)
Cut-off 3[1]	4.359 (1.808)			
Exadv *wage rate	-.0173 (-1.099)	-.0166 (-1.118)		
Express Lane advantage	**.1078 (1.895)**	.0491 (0.852)		-.0414 (-1.145)
Wage rate			-.0703 (-0.290)	
Mid-peak dummy			-.3849 (-1.053)	
Cost differential/wage[2]				-.7668 (-1.354)
Trip distance	.0443 (1.416)	.0509 (1.541)	.0156 (1.487)	**.0214 (2.176)**
Trip distance squared	-.0003 (-1.096)	-.0004 (-1.448)		
Flexible schedule window	.0003 (0.085)	.0036 (0.953)	-.0023 (-0.722)	-.0038 (-1.297)
Number of non-work trips	.0428 (0.615)	-.0080 (-0.131)	.0319 (0.605)	.0319 (0.655)
Carpool (2 people) dummy	-.1100 (-0.182)	-.4934 (-0.830)	.5123 (0.957)	.1601 (0.331)
Male	-.4163 (-0.976)	**1.099 (2.583)**	**-1.291 (-3.452)**	**-1.013 (-3.118)**
Enhanced Specification				
Work trip variability				-.0698 (-0.978)
Switching propensity	**-1.358 (-6.649)**		.1320 (1.358)	
Use radio	.3304 (0.246)	**-2.099 (-2.677)**		.4848 (0.637)
Other information sources			**-4.435 (-4.564)**	
Number of observations	169	215	198	208
Log likelihood	-151.81	-130.56	-134.11	-203.06
Degrees of freedom	10	9	9	9
Rho-squared	.1827	.0850	.0971	.0779

1. The standard errors are reported for the cut-offs, not the t-statistics.
2. "Cost differential" is used in the fourth model.

(Table last updated January 6, 1998.)

2.2.5 Results

The estimated models are presented in Table 2.1. The models are specified reasonably consistently such that each model incorporates similar variables and the variables are the same as found in Section 1.3.

The first column of the table presents the switching model, which looks at the number of times people switched to the Express Lanes in the past two weeks. The Express Lane advantage is significant which implies that more people switch in real-time to the Express Lanes when there are more time savings from doing so. "Switching propensity" is highly significant here and has a negative sign; this is expected because if travelers are using other routes or changing their departure time, then they are not going to switch to the Express Lanes.

The same "minimal specification" variables are used to estimate the time of decision model (second column). Gender is significant and has a meaningful interpretation: males most often make their route decisions either en route or both pre-trip and en route. Interestingly, radio use is significant and has a negative sign. Thus, if they have radio information, people are more likely to decide ahead of time whether to use the Express Lanes. This may be because, with the radio information, they know whether or not there are delays ahead and can estimate the length of their delay.

The gender variable also plays an important role in the two models based on hypothetical questions (columns three and four). The message seems to be that males are strongly opposed to using toll roads. The other variable which appears significantly in one of the models is the use of "other information sources". The negative coefficient implies that drivers who use different information sources are probably actively seeking unpriced alternatives and do not use or plan to use the Express Lanes. A surprising result is that the time delay and cost variables do not influence the models. It is counterintuitive that the length of the delay, for example, would not influence the decision to use the Lanes. We suspect the complexity and novelty of the hypothetical scenarios we were describing caused respondents to ignore quantitative information about delays and costs which, in real life, they would take into account.

Some of these results seem surprising. We expected wage to influence the making of decisions in real time, but we could not detect any such effect. We also found age, education, and use of another language at home not to influence real-time decision-making. CPTC has stressed that demographics are a minor factor in using the Express Lanes; the insignificance of most of these variables largely support this.

Perhaps the biggest surprise was that the use of radio and other information sources appear significantly only twice in our models. We expected that people with more information would make more switching decisions, but the data do not seem to show this. It may be that radio is not significant because it is prevalently used in the corridor—perhaps the aggregated effects of radio's use by all drivers in the corridor "wash out" in the models. If we are interested in modeling drivers' information needs, our results here suggest caution; we cannot conclude that existing traffic information sources allow the typical driver to make fully informed en route or dynamic route choice decisions.

2.3 Revenue Effects of Dynamic Pricing

We now turn to the question of how sensitive revenues are to the pricing structure. With the advent of practical interest in congestion pricing, researchers have begun to examine the consequences of various constraints on pricing — for example being able to price only certain users or certain roads, or being able to vary the price only in a single step (Arnott, de Palma and Lindsey, 1990; Verhoef, Nijkamp and Rietveld, 1995; Yang and Lam, 1996). Typically, these investigators have had to make one of two simplifying assumptions: either demand is unchanging over the relevant time interval, or it is governed by a perfectly deterministic utility function that penalizes both travel time and deviations from a single desired trip completion time that is identical for everyone.

In practical cases, road operators may need guidance about the consequences of constraints in less idealized situations. Here we consider a case motivated by the decision facing the operator of the 91 Express Lanes about dynamic pricing. Since tolls are charged solely through electronic means, it is technically feasible to administer a toll structure even more finely tuned to demand than the current one. In particular, the operator has discussed the option of "dynamic pricing," in which the toll would vary continuously according to the degree of congestion on the free parallel roadway. It has not exercised this option for public relations reasons.

Here, we provide one methodology for analyzing the question of how much revenue could be increased by fine-tuning the toll schedule. We analyze a priced roadway with a substitute that differs only in the level of congestion. For reasons of simplicity, we focus on the case where there is ample capacity on the priced roadway. This not only simplifies the calculations, but also enables us to ignore the question of whether dynamic pricing could improve the reliability of the Express Lanes and thereby increase its attractiveness. We consider reliability only implicitly, in that some of the value that we assume people place on reducing travel delay may be due to the uncertainty associated with that delay; we implicitly assume that any such value is proportional to the travel delay, as suggested by Bates (1990).

Thus, our analysis considers only one of the benefits of dynamic pricing, which is the ability to make the price vary in fine increments instead of only in a few coarse steps. Our findings suggest that over intervals in which the revenue-maximizing price varies by ±25 percent or so from its midpoint, very little revenue is lost by setting it at a single value.

2.3.1 Theoretical Model

Two identical roads, A and B, connect the origin and destination. Only A can be tolled. For each traveler, there is some reservation toll (depending on congestion) at which he or she is indifferent between the two — i.e., the roads are perfect substitutes. Total demand for trips between the origin and destination changes over time but is exogenous at any given time.

Travel time for an individual traveling at time t on road i is governed by flow congestion on that road according to:

$$T_i(t) = T_0 + T_1[V_i(t)/C_i]^k , \quad i\text{=A,B} , \tag{1}$$

where V_i is traffic volume and C_i is capacity. T_0, T_1, and capacities C_A and C_B are all exogenous parameters. Equation (1) is commonly used for analyzing flow congestion — e.g. by Vickrey (1963), Solow and Vickrey (1971), Mohring (1979), and Kraus et al. (1976) — usually with values of k between 2.5 and 4. Small (1992, p. 71-72) shows that with a value $k \approx 3.3$ it fits averaged data from Boston expressways quite well, and with $k \approx 4.1$ it fits Toronto arterials. With values $k=4$ and $T_1 = 0.15 T_0$, equation (1) is the formula developed by the U.S. Bureau of Public Roads (1964) and incorporated into standard urban transportation planning software in the United States (Branston, 1976, p. 230).

Given the exogenous total demand $V(t)$ for trips at time t, the route-specific traffic flows $V_A(t)$ and $V_B(t)$ are determined endogenously by travelers' decisions about which road to take. Those decisions are made very simply. Every traveler has a value of time α, which varies across the population according to a uniform distribution on the interval $[0, \alpha_M]$. For any given travel times T_A and T_B and toll τ on road A, there is a critical value of time α_C for which all travelers with a lower value take the free road and those with a higher value take the toll road. This critical value is that which equates the "full price," i.e. time plus money cost, on the two roads:

$$\alpha_c T_A + \tau = \alpha_c T_B \,. \tag{2}$$

Traffic volumes are therefore

$$V_B = [\alpha_c / \alpha_M] V \tag{3}$$

and $V_A = V - V_B$. (For simplicity we have suppressed the notation indicating that V_A, V_B, and α_c depend on t, and we shall continue to do so for most of the remainder of the exposition.)

2.3.2 Equilibrium

Combining (1) and (2),

$$T_0 + T_1 (V_A/C_A)^k + \tau/\alpha_c = T_0 + T_1 (V_B/C_B)^k \,. \tag{4}$$

We will investigate cases where the capacity of the toll road is sufficient that it will never be seriously congested at the profit-maximizing toll. Therefor we make the approximation that

$$(V_A/C_A)^k << V_B/C_B)^k$$

so that (4) simplifies to:

$$T_1(V_B/C_B)^k = \tau/\alpha_c \,. \tag{5}$$

Substituting (3), we can solve for the volume-capacity ratio on the free road:

$$V_B/V = [\tau/(\alpha_M T_1]^{1/(k+1)} \cdot [C_B/V]^{k/(k+1)} \,. \tag{6}$$

The absolute value of the price-elasticity of demand for road A is therefore:

$$\varepsilon_A = -(\tau/V_A)\mathrm{d}V_A/\mathrm{d}\tau$$

$$= [1/(k+1)]V_B/V_A \,. \tag{7}$$

2.3.3 Revenue Maximization

By using (6) to compute traffic volume V_A=V-V_B, we can find the toll on road A that maximizes revenue. A simple short cut, however, is to note that revenue must be maximized where the price-elasticity is one. Setting (7) equal to one and substituting V_B=V-V_A yields:

$$V_A^*/V = 1/(k+2) \tag{8}$$

where the asterisk indicates the revenue-maximizing solution. From (6), the toll which achieves this result is:

$$\tau^* = \tau_a(V/C_B)^k \tag{9}$$

where

$$\tau_a = \alpha_M T_1[(k+1)/(k+2)]^{k+1} \,. \tag{10}$$

A numerical example based approximately on the 91 Express Lanes is useful. Consider a 10-mile section with free-flow speed 60 miles per hour, and take k=4 and T_1 = 0.15T_0 = 0.025 hours. Assume the average value of time, $\alpha_M/2$, is \$6.00 per hour or roughly half of the average wage rate as suggested by the review in Small (1992, pp. 43-45). Then τ_a=\$0.121 and V_A^*/V=1/6. In 1997, the 4-hour-long peak toll on the 91 Express Lanes was approximately \$3.00. In order that this toll be revenue-maximizing according to equation (9), it must be that V/C_B = $(3.00/0.121)^{1/4}$ = 2.233 over that four-hour period in each direction. This would imply that without the express lanes, peak travel delays on the free road would be $T_1(V/C_B)^4$ = $0.025(2.233)^{1/4}$ = 0.62 hours, probably not far from the average peak delay experienced before the 91 Express Lanes were built. This level of demand also would imply that with the opening of the express lanes, peak traffic on the free road would fall to $(5/6)V$ and travel delay would fall to $0.025(V_B^*/C_B)^4 = 0.30$ hours, or 18 minutes. This is not too different from reports that the Express Lanes currently save people about 12 minutes during the peak hours.

Finally, we note that the maximized revenue per unit time is

$$R^* = \tau^* V_A^* = \tau^* V/(k+2)$$

$$= [\tau_a C_B/(k+2)](V/C_B)^{k+1} \qquad (11)$$

and that equation (6), expressing the free road's share of traffic, can be written simply as:

$$V_B/V = (1/\lambda)(\tau/\tau^*)^{\lambda-1} \qquad (12)$$

where

$$\lambda \equiv (k+2)/(k+1)\,.$$

2.3.4 Imperfect Revenue Maximization

Suppose a toll other than τ^* is charged. Using (12) and $V_A=V-V_B$, we can compute revenue per unit time $R(\tau)\equiv\tau V_A(\tau)$ for any toll τ:

$$R(\tau) = \tau V[1 - (1/\lambda)(\tau/\tau^*)^{\lambda-1}]\,. \qquad (13)$$

We shall use this formula to analyze the revenue loss from a specific form of imperfect pricing. But first, we can gain insight into the magnitude of that loss by approximating it to second order in $(\tau-\tau^*)$. This is done by taking a second-order Taylor series of $R(\tau)$ about τ^*:

$$R-R^* \approx ½(\tau-\tau^*)^2(d^2R/d\tau^2)\big|_{\tau=\tau^*}$$

$$= -½(\lambda-1)(\tau-\tau^*)^2 V/\tau^*\,. \qquad (14)$$

Using (11) and (8), the proportional revenue loss is then:

$$(R-R^*)/R^* \approx -½\lambda[(\tau-\tau^*)/\tau^*]^2\,.$$

The fact that revenue loss is proportional to $(\tau-\tau^*)^2$ already gives us a clue that small deviations of the toll from τ^* will not matter much. Even less will it matter if the toll is sometimes smaller and sometimes greater than τ^*, as we now show.

Suppose the toll is constrained to be constant at value τ_c during some interval Δt during which demand varies as $V(t)$, so that the revenue-maximizing toll, according to equation (9), is

$$\tau^*(t) = \tau_a[v(t)]^k \tag{15}$$

where $v \equiv V/C_B$. Revenue over the interval is computed by integrating equation (13), now written explicitly as a function of time:

$$R_c = \int R(t)dt$$

$$= c_B \tau_c \bar{v}\Delta t - \frac{c_B}{\lambda} \tau_c^{\lambda} \int \tau^*(t)^{1-\lambda}\, v(t)dt \tag{16}$$

where $\bar{v}$ is $v(t)$ averaged over the interval.

Revenue is maximized by choosing τ_c so that $dR_c/d\tau_c=0$, which implies:

$$\tau_c^{1-\lambda} = \frac{1}{\bar{v}\Delta t} \int \tau^*(t)^{1-\lambda}\, v(t)dt\,. \tag{17}$$

The revenue-maximizing coarse toll is thus a sort of weighted $(\lambda$-1)-order harmonic mean of the revenue-maximizing fine toll over the interval — more precisely, $\tau_c^{\lambda-1}$ is the harmonic mean of $(\tau^*)^{\lambda-1}$, weighted by $v(t)$. (Recall that $1<\lambda<2$.)

As a simple example of using equation (17), assume demand grows linearly in time from V_0 at time t=0 to V_1 at $t=\Delta t$:

$$v = v_0 + at$$

where $a=\Delta v/\Delta t$, $v_0=V_0/C_B$, $v_1=V_1/c_B$, and $\Delta v \equiv v_1 - v_0$. Equations (15) and (17) can then be computed, from which:

$$\tau_c^{\lambda-1} = (\lambda \bar{v} \Delta v)\, \tau_a^{2/k} \left[(\tau_1^*)^{\lambda/k} - (\tau_0^*)^{\lambda/k} \right] \tag{18}$$

where $\tau_0^* \equiv \tau^*(0) = \tau_a v_0^k$ and $\tau_1^* \equiv \tau^*(\Delta t) = \tau_a v_1^k$. The revenue itself, from (16), is:

$$R_c = C_B \tau_c \bar{v} \Delta t/(k+2)\,. \tag{19}$$

The revenue loss from imperfect rather than exact pricing can be computed by comparing (19) with the revenue from charging $\tau^*(t)$ at every point in time. The result is:

$$\frac{L_c}{R_c} = \frac{\tau_1^* v_1^2 - \tau_0^* v_0^2}{(k+2)\,\tau_c \bar{v} \Delta v} - 1 \tag{20}$$

where

$$L_c = \int R[\tau^*(t)]dt - R_c \tag{21}$$

is the revenue loss.

The coarse toll and resulting revenue loss can be computed for two examples, again meant to illustrate possibilities for the 91 Express Lanes. For the first example, suppose total traffic as a fraction of capacity on the free lanes varies between 2.133 and 2.333. (Recall from our earlier computation that at the midpoint value, $\bar{v}$=2.223, the revenue-maximizing toll would be \$3.00.) We easily compute τ_0^*=\$2.50 and τ_1^*=\$3.58 from (9). The coarse toll, from (18), is τ_c=\$2.99, remarkably close to the toll that would apply if traffic were at its mid-point value throughout the interval. Furthermore, the revenue loss, computed from (19), is only 1.2 percent. In this example, then, the revenue-maximizing price would vary by ±20 percent from the best coarse price, yet the revenue loss is almost negligible.

In the second example, v varies from 1.4 to 1.6, from which the revenue-maximizing toll varies from τ_0^*=\$0.465 to τ_1^*=\$0.793, with value at mid-interval $\tau_a(1.5)^4$=\$0.613. The coarse toll is τ_c=\$0.615, barely distinguishable from the revenue-maximizing toll at mid-interval. The revenue loss from coarse rather than fine pricing is 1.1 percent. So at a lower level of congestion, revenue is even less sensitive: fine-tuning the price to vary approximately ±27 percent from this coarse toll would increase revenues by just over one percent.

2.3.5 Conclusion

Private toll road operators probably will not experience large losses in revenue if they are constrained to charge coarse tolls. Under reasonable conditions representing the SR91 corridor, fluctuations in optimal toll of ±25 percent result in losses of only 1 or 2 percent, relative to the case of perfectly fine-tuned pricing. Of course, we are accounting for only some of the possible benefits from dynamic pricing; in particular, we do not account specifically for the value travelers may place on the additional reliability it could foster. Also, we are not accounting for those rare incidents (traffic accidents) that might raise the toll by 50 percent or over 100 percent. Still, from other studies, it does not seem likely that travelers place so much more value on reliability as to overturn this result; and the infrequency of severe incidents makes them of more concern for traffic management than for revenues. We therefore think it likely that, once the operator has found the best tolls for each time period now distinguished in the toll schedule, additional revenue gains from dynamic pricing will be minor.

3 MARKETING STRATEGIES AND TOOLS FOR VALUE PRICING

3.1 Introduction and Operational History

There are many factors, in addition to the CPTC's marketing efforts, that have contributed to the 91 Express Lane's apparent success.

The 91 Express Lanes may be in a unique location and have benefited from unique circumstances. They are in a highly congested corridor in a canyon, with few alternate roadways. The traffic is highly directional serving a "bedroom" county on one side (Riverside) where 1/3 of the workers leave the county for work and major employment centers exist on the other side (in Orange County). Additionally, the roadway serves as the major gateway to weekend entertainment attractions including Las Vegas and mountain ski resorts. Before the Express Lanes opened, Eastbound travel on Friday afternoons slowed to a crawl from 2p.m. until 10p.m. When the freeway was designed and constructed in the 1950s, room for additional lanes was left in the median through the corridor. The state of California paid for an environmental impact study of high occupancy vehicle (HOV) in the median during the 1980s, but building the HOV lanes became a low funding priority given other Southern California roadway needs.

So when the California bill came into effect allowing companies to seek out potential sites for public-private partnerships in building and operating roadways in California, the 91 corridor became a clear, viable option. There was room in the median of an already congested corridor with obvious and growing traffic demands. The environmental impact statement was already completed which has turned out to be the barrier to other public-private California projects. It is not clear if such a corridor with all of the right elements exists elsewhere in California, in the States or even internationally.

The 91 Express Lanes are unique in some other ways as well. They are the nation's first fully-automated toll road. A "service mark" (analogous to trademark) the operators use in their marketing literature is "The toll road without toll booths." That is, electronic transponders are required in order to use the roadway. The technology exists for the system to work well, although there have been a few operational problems including having to locate the transponders in some vehicles away from metal vehicle identification plates which interfere with proper readings. Also, the private company is anxious that people are not incorrectly fined for violations due to computer error, so they manually read the license plate of violators by enlarging a photographic image taken of the violating license plate.

The 91 Express Lanes represent the nation's first implementation of "value pricing"—a phrase used now by congestion pricing proponents nationwide. That is, tolls differ by time of day and direction according to expected traffic conditions. Marketing value pricing is an important contribution of the CPTC. Their brochures, subscriber newsletters, and other marketing-based literature are filled with trademarked and other phrases that sing the praises of saving time and using the Express Lanes. These include "the lane change that could change your life," "kiss gridlock goodbye," "the car accessory that can shave up to 20 minutes off your commute," "it's about time", "Fast. Safe. Reliable. Satisfaction Guaranteed," and "the value of Value Pricing."

Holiday newsletters suggest to "Give the gift of time" (gift certificates). The brochures explain that this is "a new option: a 'pay-as-you-go road'" that was built "without a cent of federal or state tax money". A new product, the Two-Way Pass that requires a deposit but not a subscription, is advertised as "the quick fix for slow traffic." It's likely that the catchy phrases and accompanying colorful graphics have an impact on potential users. This is in contrast to the fairly staid banners and variable message signs that encourage drivers to call an 800 number to sign up to use the Lanes. Now subscribers are encouraged to "tell a friend" about their positive experiences on the Lanes. In general, the catch phrases seem to stay the same between brochures from two years ago and brochures now. The same upbeat message is reinforced in the quarterly newsletters distributed to subscribers.

The operators suggest that many people heard about the roadway through print news, TV news, or radio news. But much of the marketing for the Express Lanes has occurred in signs and banners along the roadway and in mass-mailings. Of course, the construction of the Express Lanes was free advertising in itself. Mailers were sent to homes of potential users in Riverside County in fall 1995 before the Express Lanes opened. The mailer consisted of a colorful brochure with pictures, graphics, a toll schedule, and an application and agreement form.

Over time, many of the marketing changes have centered around the varying payment options and plans. When the lanes first opened, one could have a credit card or direct debit account with a $40 balance and an unlimited amount of transponders, or a cash account with an $80 deposit per transponder. Accounts could be charged $1.00 per month service fee if no trips were made, although this was waived during the first year. Over time (by late 1996), they phased out the direct-debit option stating that not many had chosen it. In January 1997, the 91 Express Club Frequent User Discount Plan became an option; for a $15 subscriber fee, Express Club members receive a 50-cent discount on every toll. When the tolls went up in September 1997, the discount was raised to 60 cents per trip thus continuing to cover the full toll for late-night trips.

Now, there are three account options and all accounts are credit-card based: the Express Club, the Standard Plan, and the Convenience Plan. All fees and accounts are now per transponder. The Standard Plan requires a $5 minimum in monthly toll charges per transponder. The Convenience Plan has no monthly minimum, but requires a one-time non-refundable enrollment fee of $40 per transponder. The Convenience Plan is likely a response to the many transponders that were issued by CPTC and are rarely used. Texas Instruments, who sells transponders to CPTC and the other California toll companies, charge approximately $25-$32 per transponder (correspondence with Peter Samuel, January 13, 1998) so CPTC's deposit effectively covers their transponder/capital outlay plus a modest up-front fee for maintenance. There have been some complaints about account and fee changes, but as use of the toll lanes steadily increases, CPTC seems not to be adversely affected. It is not clear if the original business plan was to make it more expensive to have an account after a couple of years or if the changes were responses to revised information.

The toll schedule has changed twice in the two years since opening the Express Lanes. The first change, effective January 1, 1997, included raises from $2.50 to $2.75 during the peak period and from $.25 to $.50 during off-off peak. These changes were supposed to ensure free-flowing traffic during the peak periods and to reflect administrative costs during the off-peak period (the operators were concerned about using peak customers to subsidize the costs of running the system during off-peak). On September 14, 1997, the tolls rose again "to keep our commitment to you [the subscriber] for a reliable, congestion-free commute whenever you travel the 91 Express Lanes". With this change, the schedule got more complex and users are now tolled \$2.95 during a 1-hour period in each direction on most weekdays (see Tables 1.1-1.2). The toll during the rest of the four hour peaks (5:00 a.m. to 9:00 a.m. Westbound and 3:00 p.m. to 7:00 p.m. Eastbound) is now \$2.85. There are eight different toll levels in the Eastbound direction and six in the Westbound direction (\$2.95, \$2.85, \$1.95 (Eastbound only), \$1.60, \$1.10, \$0.85, \$0.75 (Eastbound only), and \$0.60). As of January 1, 1998, the operators charge carpools (three or more people in the same vehicle) 50% of the tolls.

Newspaper articles in Riverside County's Press Enterprise and the Orange County edition of the Los Angeles Times announce the changes in toll and policy. The articles include some interesting quotes from toll road proponents. CPTC spokesmen and other supporters say that the Express Lanes service is analogous to first class on airlines (August 20, 1997, Press Enterprise). Further, the choice to use the Express Lanes rather than the regular lanes is said to be analogous to the choices people make every day regarding cellular phone use, restaurants, and automobiles (Carl Williams quote, July 21, 1997, Press Enterprise).

In general, the press has not been very critical of toll increases or of the Express Lanes. Articles in local newspapers and national magazines written before the Express Lanes opened and during its first months of operation lauded the technical innovations, the fact that carpools traveled for free, and the fact that it was an alternative to the highly congested adjacent lanes. One more-recent article describes the Cal Poly result of income differences between frequent users of the Express Lanes and regular lanes (July 21, 1997, Press Enterprise), but the coverage is not incendiary.

Interestingly, press accounts and most of the marketing efforts barely touch on the fact that traffic has improved for all users of the corridor. Recently issued findings (Sullivan and El Harake, 1998) suggest that travel time in the corridor on the free lanes during the Eastbound (evening) peak has fallen from approximately 45 minutes in June 1995 to about 15 minutes in June 1996, 20 minutes in June 1997. Another graphic suggests that almost 9000 vehicles passed during the evening peak hour of 5-6 p.m. in February 1997, compared to 5600 in February 1995. These observations show that users of the free lanes have greatly benefited and that a latent demand for the corridor clearly existed.

3.2 Descriptive Analysis of the Survey Numbers

From a marketing point of view, it is useful to know one's clientele. Table 3.1 provides unweighted characteristics, using our survey data, of six overlapping groups that use the 91 corridor: those who only use the regular lanes, those who use the Express Lanes at least once in the a week, those who use the Express Lanes frequently (8 or more times during peak hours in the past week), those traveling in two-person carpools who use the Express Lanes at least sometimes, those traveling in two-person carpools but only on the regular lanes, and those traveling in three-person carpools (virtually all of whom use the Express Lanes since they were free at the time of our survey).

The numbers in Table 3.1 are reasonably self-explanatory, but a few are of special note. First, there is a substantial income and wage disparity between Express Lane users and those who only use the regular lanes. Those who travel in two-person carpools on the regular lanes have an even lower income, only 64% that of those in paying carpools on the Express Lanes. In fact, two-person carpools on the regular lanes have several striking differences compared to the other groups including lower income and wage, lower amount of education, a higher percentage speaking another language, and a larger number of females. The smaller differences among the characteristics of the other groups are not very surprising. Carpoolers and users of the Express Lanes include more women compared to solo travelers and those using the regular lanes. Carpoolers who use the Express Lanes have substantially more restrictive work schedules. These numbers suggest a profile of Express Lane customers who are moderately more affluent, more often female, better educated, and more likely to speak English only. Thus efforts at customer satisfaction need to be pay special attention to these factors, while recognizing that users are by no means a homogeneous group. Efforts to attract new users, in contrast, need to find ways to appeal to people with the opposite characteristics. sometimes, those traveling in two-person carpools but only on the regular lanes, and those traveling in three-person carpools (virtually all of whom use the Express Lanes since they were free at the time of our survey).

Table 3.1: Unweighted Descriptions of Six Groups that Use the 91 Corridor

	NON-USERS	USERS	HEAVY USERS[9]	HOV2 USERS[9]	HOV2 NON-USERS[10]	HOV3 USERS[9]
Respondents (Unweighted)	193 29.6%	460 70.4%	170 26.0%	72 11.0%	33 5.1%	74 11.3%
Weighted[1]	43.2%	56.8%	14.9%	7.1%	7.6%	5.4%
Income	$57,000	$66,825	$65,775	$68,750	$42,400	$63,150
Wage	$20.63	$24.38	$24.50	$24.13	$15.75	$22.63
Trip miles	42.3	44.6	45.1	47.5	48.6	43.7
Trip minutes	61.6	62.1	62.5	64.7	59.6	59.5
% No flex[2]	54.0%	51.9%	56.4%	59.2%	51.5%	64.4%
% Extreme flex[2]	37.5%	35.8%	30.9%	28.2%	39.4%	24.7%
Age	41.3	41.1	40.9	41.8	40.8	40.3
Education[3]	79%	83%	80%	78%	58%	76%
Other language[4]	18.6%	10.6%	10.0%	16.7%	36.4%	18.9%
% Male	65.6%	59.6%	57.1%	57.1%	51.5%	58.9%
Number of non-work trips[5]	4.3	4.2	4.3	4.4	4.0	4.6
% Employer pays[6]	1.0%	8.5%	12.3%	6.9%	0.0%	2.7%
Variable traffic[7]	4.42	4.17	3.9	3.78	3.5	3.54
Number of other passengers[8]	0.215	0.65	0.924	1.06	1.02	2.1

1. The weighted percentages are given as additional information only; the numbers presented here are the unweighted averages that describe each category. The weights reflect the fact that we intentionally over-sampled Express Lane users and carpoolers.
2. "No flex" and "extreme flex" comes from Question #8 where the respondent is asked if the time they start work is fixed. "No flex" means they have an inflexible, fixed work start. "Extreme flex" means they have a flexible work start and an arrival window of two hours or more.
3. Percentage with at least some college education. Question #55.
4. Percentage that speak another language at home. Question #54.
5. Used as a proxy for travel. Question #1.
6. Percentage that checked that their employer pays for Express Lane tolls. Question #28.
7. Number of times in the past week that traffic was bad enough to make the work trip at least ten minutes longer than usual. Question #16.
8. Number of other passengers that traveled with the respondent during the last work trip. Question #14.
9. These groups are also included in the USER group.
10. This group is also included in the NON-USER group.

3.3 Qualitative Analysis of Questions Related to Toll Road Acceptance

The survey includes questions about the advantages (Question #43) and disadvantages (Question #44) of using the Express Lanes. Additionally, about 40% of the respondents wrote comments on the last page of the survey. Table 3.2 shows how respondents selected the most important advantages and disadvantages. The first column of the table shows the percentage of users who chose the item as their most important advantage or disadvantage. The second column shows the percentage of users who marked the advantage or disadvantage as either first, second or third most important.

Table 3.2: Express Lane Advantages And Disadvantages

	Chose First	Concerned
Advantages		
Save travel time	52.0%	87.1%
Important appointment	14.3%	40.6%
Congestion unusually bad	14.2%	48.6%
Safer or nicer ride	13.3%	56.8%
Know time of travel	12.4%	57.2%
Other	6.1%	13.6%
Disadvantages		
Toll too high	62.0%	87.1%
No intermediate exits	20.7%	63.2%
Other	9.1%	26.8%
Transponder too hard to get or costly	7.6%	32.0%
Schedule confusing	4.7%	33.4%
Privacy concerns	1.7%	17.4%

It doesn't surprise us that the biggest advantage of the Express Lanes is to save travel time. But it may surprise some that over half of the respondents view the Express Lanes as providing a safer or nicer ride as well as a more predictable travel time. Other advantages, which some respondents wrote in, include three or more travel for free, stress relief, medical or other emergency, and less wear on the car.

Naturally, the main disadvantage to the Express Lanes is that the toll is too high. However, it is a surprise that over 60% of the people think that having no intermediate exits is a significant drawback. Text written in for the "other" choice here include the facts that accidents in the Express Lanes cause delays yet don't result in rebates, the existence of speeders on the Express Lanes, and difficulty in merging in and out of the Express Lanes.

Many of the people who wrote comments on the back of the survey stated that they liked the

Express Lanes. However, more people wrote that they didn't like the lanes: the toll was too high, and that their taxes already pay for roads. Others suggest that the Express Lanes are too short. Others have specific suggestions and complaints such as "we need a rail system that follows highways" and "at night, on-coming headlights blind me."

Researchers at Cal Poly have concentrated on general approval of toll lanes and congestion pricing in their panel survey (Sullivan and El Harake, 1998). In their results, approval for toll lanes has risen from 60% before the Express Lanes opened to 70% afterwards. Approval for congestion pricing has risen more dramatically, from 45% to 55-60% depending on the type of user that is asked. The Cal Poly study has also looked into reasons for disapproval. Interestingly, the percentage who think congestion-based tolls are "unfair" has decreased, while the percentage who think the toll "should be a flat fee" has risen from approximately 15% to 40%.

3.4 Conclusions

Acceptance of the Express Lanes has been gradual in terms of both survey data and use of the facility. People in the corridor are increasingly accepting of the concept. The toll lane operators have learned, by experimentation, to fine-tune its operation and revenue through various membership plans and increasingly complicated toll schedules. It is not clear if all such roads will need to follow the same process or can skip steps that this project had to learn the hard way. There is a continued need to appeal to a variety of potential users and to devise methods of making the premium roadway even more appealing to infrequent users.

4 CONCLUSIONS AND RECOMMENDATIONS

The 91 Express Lanes have proven successful during their first two years of operation. By summer 1998, after 30 months of operation, revenues have started to cover debt service. Both revenues and daily ridership have steadily increased. The private operator continues to fine-tune the toll schedule in order to make the most of the patronage there is. Public acceptance of the idea of "value pricing" was not bad to begin with, and has increased over the two years of operation to a level well above 50 percent. The facility operates smoothly and the company seems to have maintained generally good customer relations.

Perhaps the most striking discovery from our survey analysis is that the patrons of the Express Lanes are very selective and most do not use the lanes every day, even if they always travel during the peak period. Presumably, this means that the decision to use or not use the Express Lanes on a given trip depends on circumstances specific to that trip, such as level of congestion, nature of the traveler's work schedule, and any available information about possible delays.

The primary explanatory factors identified by our choice models are income, trip distance, and gender. Higher income travelers are more sensitive to the travel-time savings, and thus are especially important in efforts to promote "value pricing" as a way to pay for a faster trip. Nevertheless, there is a wide mix of incomes (and other demographics) to be found among Express Lane users, and it seems clear that financial success will depend on finding ways to maximize the appeal to all of these groups. In particular, many lower-income travelers are already occasional users, and thus can readily become more frequent users if there is enough incentive.

People with longer trips are more prone to use the Express Lanes, although this effect gradually diminishes as trip length approaches 100 minutes. It seems likely that this is due to a greater concern with reliability of travel on the part of people who already face long and somewhat uncertain travel times.

Finally, we find that women are somewhat more likely to use the toll lanes than men. This result is consistent with other evidence that women have difficult scheduling problems, caused in part by undertaking more shopping and child-care activities than men, so that a more reliable schedule may have greater value to women on average. We find also that women are more willing to consider paying tolls that are not fully predictable.

Equally notable are some factors that do not seem to be important, once the three just mentioned are taken into account. Education, native language, and age all seem to have only minor if any effects. Thus these factors do not seem to present any special social or psychological barriers to consideration of the Express Lanes, despite the novelty of the value-pricing concept. Furthermore, Express Lane use does not seem to be affected by whether the traveler seeks out traffic information from any of several sources.

Overall, then, use of the Express Lanes seems to be determined through rational calculation by individuals of widely differing circumstances. The differing circumstances mean that patronage will not be drawn from any one narrow market segment, but rather from a variety of people whose individual situations make it worthwhile to them. Furthermore, these people probably react to changes in the system in ways that are amenable to prediction and analysis using the tools of transportation demand forecasting that focus largely on a balance between additional cost on the one hand, and time savings and improved reliability on the other.

A somewhat stylized model of a toll road competing with a parallel free road enables us to examine how important it is to set the tolls exactly at their revenue-maximizing levels. Using parameters meant to approximate the 91 Express Lanes, it appears that not much revenue is lost by keeping a constant toll over a time interval in which the revenue-maximizing toll would vary by up to 25 percent in either direction. This suggests that dynamic pricing, in which the toll could vary over even short time intervals, will probably not enhance revenue much. Dynamic pricing may have greater value in terms of maintaining the reliability of the trip, a factor we do not analyze.

The operator of the 91 Express Lanes has mounted a sophisticated and mostly successful campaign of marketing and public relations in order to make potential users comfortable with the idea of value pricing. The most consistent element of the approach has been to emphasize time savings. This has been presented in a variety of ways designed to stress the enhancement of people's quality of life, especially by providing more leisure time but also by reducing the stress of being late. At the same time, customers have been made to feel that the Express Lanes are safer, more pleasant, and a way to pamper themselves a bit.

The operator has avoided any marketing that would give the Express Lanes an aura of exclusivity. They apparently recognized that the potential ridership is diverse and that many would be repelled by a suggestion that the Express Lanes are only for the upper class. They also recognized the danger of adverse public reaction to such an appeal, especially given the virulent opposition to the entire idea of private highways by some members of the legislature who coined the term "Lexus lanes" to deride them. The closest approach to marketing based on exclusivity is the creation of the Express Club, which may appeal to those who would rather not decide each day which lanes to use; but even here, the sales pitch was aimed at hard dollars and cents, pointing out that the monthly fee is saved in toll discounts if the lanes are used for more than 13 round trips per month.

Probably the biggest surprise has been the prevalence of occasional users. As of mid-1998, the operator had distributed over 100,000 transponders, yet daily traffic in both directions combined averaged only about 32,000. Our survey finds that for every "heavy" user making four or more weekly round trips on the Express Lanes during peak hours, there are three additional people who use the lanes once a week or more. Furthermore, except for carpoolers, the profile of these heavy users is not very different from that of more occasional users, the main exception being that heavy users have less flexible work arrival times (and so presumably are paying to ensure an absence of unexpected delays). CPTC has attempted to increase the loyalty of those users who have gone to the trouble of getting transponders and setting up accounts; these efforts include raising the monthly account minimum fee, establishing the Express Club with discounted fares, and issuing occasional marketing flyers to its account holders stressing the safety and comfort of the lanes.

Our results suggest that travel time savings is by far the most important factor in attracting patronage, and that this factor has greater appeal for people with greater household income. To the transport analyst, this is a strong endorsement of the idea that people have a value of time and that they make rational decisions based on it.

The 91 Express Lanes in southern California are a first-in-the-world demonstration of value pricing, also known as congestion pricing, using modern technology to manage traffic in a sophisticated way. Our research shows that people do respond in predictable and rational ways to value pricing. They react strongly to the monetary incentive created by the varying price for the express-lane option. They make rational comparisons between the extra cost and the time savings, and make decisions accordingly. They demonstrate their constant attention to these varying factors by the fact that most users of the Express Lanes do not use them automatically on every trip, but rather only a few days a week. Thus they tailor their use to specific circumstances on a day-to-day basis.

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APPENDIX A: PORTIONS OF THE SURVEY

Here are replications of the questions in the survey that were used to obtain the dependent variables for the route choice and real-time information models. Again there are Eastbound and Westbound versions of the survey, early and late versions, and ten sets of values used in the stated preference questions. These questions come from just one of the 40 versions.

23. Please use the table to show trips in which you traveled **Eastbound** for the full 91 Corridor (from Highway 55 to the Riverside/Orange County line). Mark all periods in which you used either the **regular lanes or the Express Lanes last week**. Use a **W** for trips to and from work and an **N** for non-work trips. Please put each trip in the time slot when you passed the Highway 55 interchange.

Travel on Eastbound 91 Last Week:

	AM	PM (After Noon)									
	7-12	12-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Mon											
Tue											
Wed											
Thu											
Fri											
Sat											
Sun											

(If today is a Saturday or Sunday, please try to predict this weekend's trips, otherwise use last weekend.)

24. Please return to the table and **circle** all trips in which you used the Express Lanes (the lanes that require a transponder). For example, mark

25. Again, please return to the table and place an **X** by the trips when you carpooled with one other person and **XX** when you carpooled or vanpooled with 2 or more other people. For example, mark **W**^{X} or **N** ^{XX}.

29. How many times did you travel **Westbound** (toward Orange/L.A. Counties) on the Express Lanes last week?

From 5:00-9:00 a.m., Mon-Fri: [ ]

During Other Times:___ [ ]

47. How many times in the last two weeks did you do any of the following because of radio traffic reports? (Please answer al that apply.)

_____ Switch from using the 91 to another freeway

_____ Switch from the 91 to a surface street

_____ Travel at a different time

_____ Switch from the regular lanes to the Express Lanes

45. When and where do you make decisions about whether or not to use the Express Lanes? (Please check all that apply.)

I don't have a transponder
Before I begin my trip (at home or at work)
When I see the electronic signs for the Express Lanes
When I see what traffic conditions look like
When I hear radio reports about traffic conditions
Other ____________________

37. Suppose highway message signs told you when an accident on the 91 Corridor regular lanes would delay your trip by more than 10 minutes. When would you use the Express Lanes?

Never
Only on days when there is an accident
Only on days when traffic is normal
On all days

Suppose that tolls depend on traffic conditions so they might be lower on a normal day and higher on a day when traffic is especially heavy. Assume you would not know the toll until you saw the message signs as you approached the Express Lanes.

40. Suppose the normal toll from 3-7 p.m. Eastbound was $0.25 less than now, but a $1.00 surcharge was added on days where there was an accident on the regular lanes. When would you use the Express Lanes?

Never
Only on days when there is an accident
Only on days when traffic is normal
On all days