STUDY OF ROAD INFRASTRUCTURE REQUIREMENTS FOR INNOVATIVE VEHICLES

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By

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1. INTRODUCTION

The United States faces substantial public investment in the surface transportation infrastructure during the 1990s, in both maintenance and expansion of road and rail networks. Although the Federal Government has allocated large sums of funding for highway and transit projects [i.e., the Intermodal Surface Transportation Efficiency Act (ISTEA)], that capital is spread thinly for this huge undertaking. To continue to support development and growth, local funding will be relied on more extensively than ever to accomplish some of the major construction projects. The California Department of Transportation, recognizing the importance of allocating monies wisely, sponsors numerous studies to assess new technologies, to promote public transit initiatives and, in their more traditional role, to study highway design and fund construction projects. This study was conducted by Booz·Allen & Hamilton Inc. for the University of California at Berkeley, specifically the Berkeley Institute of Transportation Studies under purchase order PP B000660. The report provides a methodology and preliminary assessment of infrastructure issues related to a new transportation concept for a commuter car.

Expanding infrastructure is one means of alleviating congestion. Optimization of existing infrastructure through advanced technologies is another approach. For example, advanced train control systems will help improve the utilization of the existing rail infrastructure; similarly, Intelligent Vehicle Highway Systems (IVHS) technology is projected to increase the capacity of the nation's highway system by allowing vehicles to bypass congested areas or travel closer together in convoys controlled by on-vehicle computers. As road and rail construction have become more expensive, the race to improve the capacity of existing infrastructure has accelerated.

In addition to more widely known technologies such as IVHS, the California Department of Transportation is sponsoring the study of an innovative vehicle concept developed by a major automotive manufacturer. The concept is aimed at reducing inefficiencies of most urban automotive travel, where commuters frequently drive without any passengers. For example, the average passenger automobile occupancy in Los Angeles of 1.2 passengers per car illustrates the low capacity utilization of automobiles; yet the road network the in Los Angeles metropolitan area is among the most highly utilized systems of any in the nation, with average operating speeds of 30 miles per hour (mph) and average daily traffic per freeway lane of nearly 20,000 vehicles. Continuing efforts to induce the public to carpool, either through dedicating lanes on existing highways as High Occupancy Vehicles (HOV) lanes, or by providing preferential parking, have had only limited success in most areas of California.

The concept with which this report is concerned approaches road congestion from the vehicle side of the problem. Why drive a full-size automobile if one commutes to work alone? Why build road networks to support the use of full-size vehicles if many of those vehicles are single occupant? The development of this vehicle concept has been driven by these types of questions concerning efficiency. This vehicle concept offers the opportunity to improve passenger throughput by reducing the required supporting infrastructure; this is possible because of its comparatively small footprint and narrower width when compared to a standard passenger automobile. The intent is that many drivers will convert to the new vehicle in the interests of cost savings (both purchase price and operating cost) and/or favorable travel times, ***if a complementary infrastructure system is developed to support a large number of the vehicles.***

2. DESCRIPTION OF VEHICLE CONCEPT

The commuter car is an innovative vehicle concept that is comparable to a motorcycle in size, but offers advantages similar to an automobile in comfort, utility and safety. The commuter car is a three-wheel, rear axle drive vehicle that is highly aerodynamic and may accommodate a driver and/or passenger, depending upon the configuration. The vehicle is less than 4 feet wide, shorter than 12 feet long and approximately 4 feet high. Production vehicles are projected to weigh 500 to 700 pounds, depending on selected options and final design. Passenger amenities similar to those available in a standard passenger automobile would be offered as options. Those options include climate control systems, high quality radio/cassette systems, and passenger restraint devices. At this time, there are no immediate plans to manufacture this vehicle and only functional prototypes exist. **Exhibit 1** is an illustration of the vehicle concept. **Exhibit 2** compares projected physical characteristics and performance data of the commuter car to a standard passenger automobile.

The commuter car concept offers consumers several advantages that are inherent in its design. Driving the commuter car is an experience comparable to skiing, since the passenger compartment of the vehicle leans into turns to reduce the centrifugal force on the driver and/or passenger and to reduce or minimize the turning radius of the vehicle. Furthermore, the fixed rear axle provides a measure of safety by enhancing vehicle stability through turns to preclude rolling the car—only the front wheel rotates off vertical as the passenger compartment leans into the turn. Cost savings are estimated to be fairly significant for the commuter car, since the vehicle would be smaller and lighter than a full-size automobile. The purchase price has been estimated at $6,000 to $8,000 for a new vehicle. In addition, operating costs are expected to be lower due to projected fuel economy of 80 to 100 miles per gallon as well as reduced servicing and maintenance costs. State officials may provide additional incentives for ownership by charging lower registration and licensing fees.

EXHIBIT 1
Commuter Car Concept

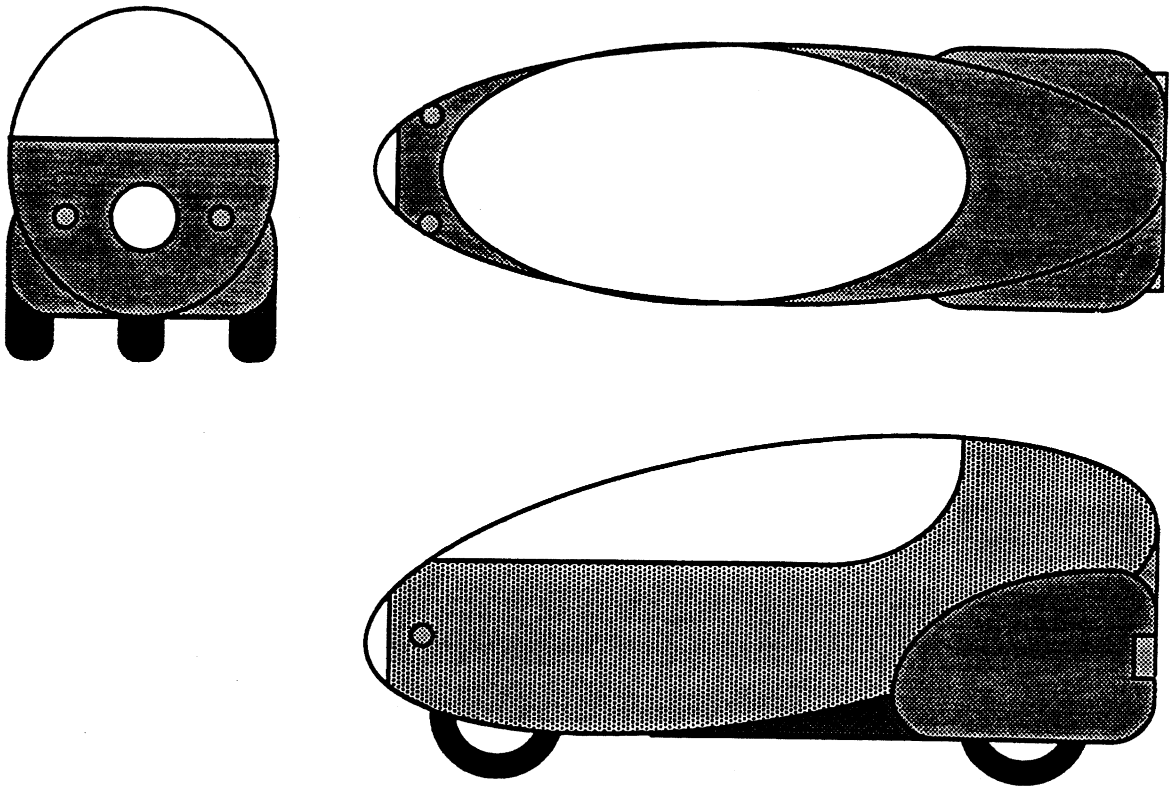


EXHIBIT 2
Commuter Car Versus Standard Passenger Automobile

	Commuter Car (Projected)	Conventional Compact Car	Commuter Car as a Percentage of Compact Car
Width	3-1/2 feet	6-1/2 feet	54%
Length	9 feet	15 feet	60%
Weight	500 to 600 lbs.	2,000 to 2,500 lbs.	22%
Passengers	2	4	50%
Fuel Economy	80 to 100 MPG	30 to 35 MPG	300%
Price	$6,000 to $8,000	$10,000 to $13,000	60%

Source: Booz·Allen & Hamilton estimates

The commuter car also offers several distinct advantages for transportation planners faced with limited opportunities for infrastructure expansion and congested road systems. The commuter car can be parked in a much smaller space than a full-size automobile. A traffic lane dedicated for commuter cars would be only 5 or 6 feet wide instead of the standard 10 feet, 9 inches—thus dramatically lowering highway construction costs as well as reducing road maintenance costs. In significant numbers, the commuter car provides the opportunity to increase the capacity on existing roadways. Perhaps most importantly, the commuter car would help to both reduce emissions from automobiles, and reduce dependence on petroleum due to dramatically improved fuel economy.

3. METHODOLOGY

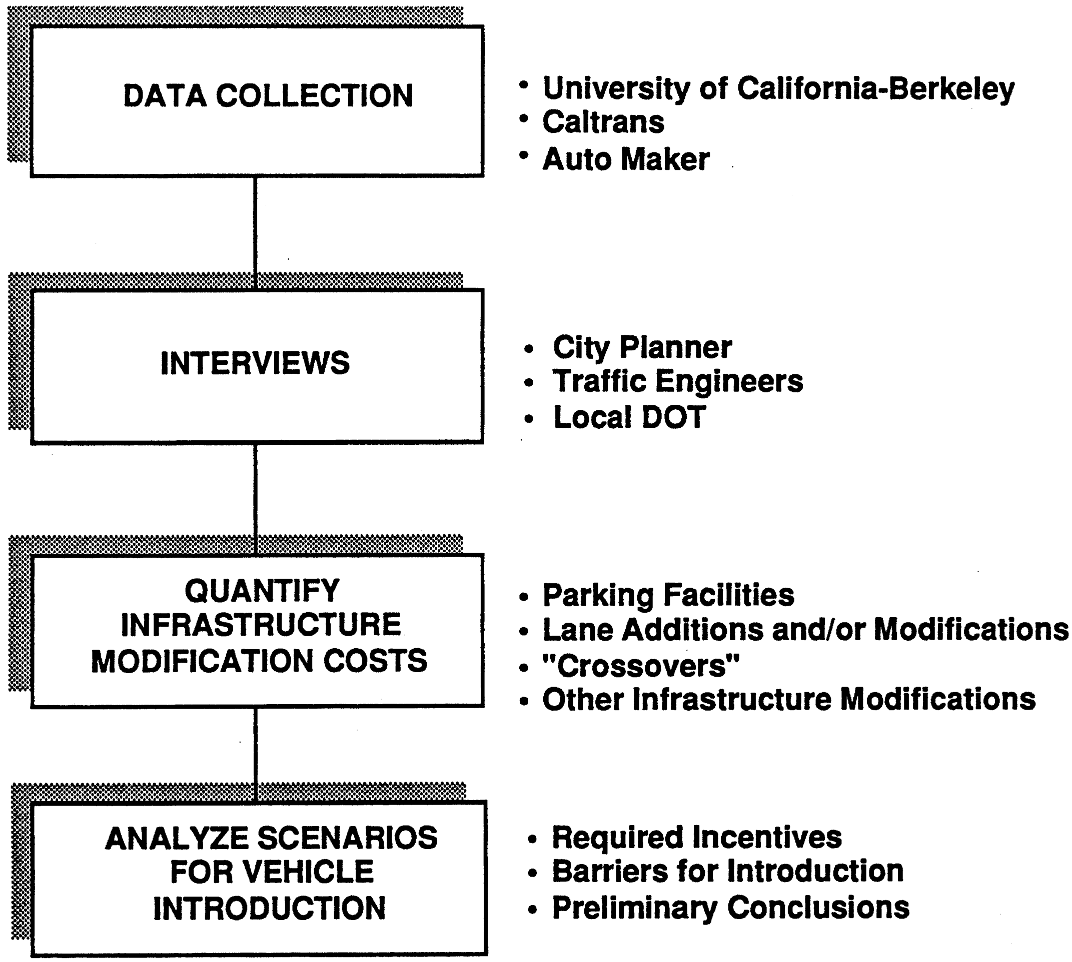
Our objective in this Interim Task Report is to identify infrastructure development issues that may promote or hinder the success of the commuter car concept. The California Department of Transportation has chosen two California cities on which to base the infrastructure assessment, San Francisco and Los Angeles. San Francisco is typical of many West Coast cities in that the downtown area represents a dense hub of business and social activity with a large majority of commuters traveling to and from the city center each day. In contrast, Los Angeles has numerous business centers, and traffic patterns are more complex and varied than in San Francisco.

Our approach to this assignment is shown in **Exhibit 3**. As a first step, existing reports and "white papers" developed by Caltrans, the University of California at Berkeley and the auto manufacturer were reviewed. Next, Booz·Allen conducted interviews with selected transportation planning officials in San Francisco and Los Angeles. The purpose of these interviews was to introduce the commuter car concept to those not already familiar with the vehicle, and to gain city and traffic planners' perspectives on a variety of issues related to the vehicle introduction including:

- Would municipalities be interested in promoting the use of the commuter car?
- What change(s) in the personal-vehicle infrastructure system might promote commercialization of the commuter car? How much would the changes cost and how long would they take to implement?
- What level of coordination with other local governments and/or state agencies is required (to improve the chances for commercial success of the vehicle)?
- What are the primary barriers concerning infrastructure development?

Essentially, the primary objective of these interviews was to explore a range of potential infrastructure issues with key decision-makers at the local level. Interviews were conducted with local transportation agencies at Long Beach, the City of Los Angeles, Sunnyvale and Glendale. The concept was also reviewed with planners at the California Air Resources Board and at the South Coast Air Quality Management District.

EXHIBIT 3
Approach to Assignment



Next, preliminary estimates of infrastructure modification costs were developed in cooperation with Caltrans. Cost data and infrastructure modifications presented in the University of California-Berkeley's report entitled, "Restructuring the Automotive/Highway System for Lean Vehicles," was heavily referenced for this part of the assignment.

For the final task of this assignment, three different levels, or scenarios, of infrastructure modifications designed to increase the utility of the commuter car were examined. Each infrastructure scenario represents an increasing commitment to the commuter car concept in terms of cost and dedicated percentage of the available infrastructure network. For each scenario the costs and benefits, in terms of increased vehicle capacity, were examined.

4. PRELIMINARY FINDINGS

This section of the report reviews preliminary findings of the infrastructure analyses and is organized as follows:

- Interview summary
  - Initial impressions
  - Infrastructure planning process
  - Need for a coordinated effort
- Description of potential infrastructure modifications
  - Parking facilities
  - Roadway network
- Cost/benefit review of selected infrastructure modifications.

4.1 Interview Summary

The following sections present summaries of discussions on selected key issues that surfaced during interviews with transportation planning officials at the local level. While a wide range of information about the commuter car concept was discussed, the issues and ideas presented here were common among all interviewees.

> ***Initial Impressions.*** Those transportation officials already familiar with the concept demonstrated a high level of enthusiasm for the vehicle. The advantages of road requirements, parking space and operating efficiency were recognized as the major "selling points" of the vehicle. A noteworthy remark about the concept is particularly poignant in the California environment: Californians are accustomed to personal freedom and mobility provided by automobiles. While constructing permanent, fixed guideway transit systems is a solution, some of those interviewed contend that Californians will not embrace quickly a mode of transit that constrains their personal freedom; therefore, the commuter car offers a unique opportunity in California, where drivers are linked to and identify with their automobiles.
>
> In addition to preserving strong ties to automobile use, the commuter car offers distinct advantages in new infrastructure construction. ***Planners liked the concept because of the capacity increases possible with fixed funds.*** Depending upon the lane configuration, approximately twice the vehicle capacity can be added for a dedicated commuter car expansion project as compared with an expansion project to serve full-size autos and trucks. Planners also appreciated the reduced cost of purchasing and operating such a vehicle.

While transportation planning officials at the local level were generally enthusiastic about the concept, they expressed concern over market acceptance. They believed that safety would be a major issue and must be demonstrated if the vehicle was to be a significant market success. They also believed that general handling, performance, and operating environment of the commuter car should be designed closer to an automobile than to a motorcycle.

Finally, officials at air quality agencies [California Air Resources Board (CARB) and the South Coast Air Quality Management District (SCAQMD)] were tentatively supportive of the vehicle because of projected reduced emissions compared to standard passenger automobiles. They also appeared enthusiastic regarding the relative ease of adapting the vehicle to an alternative fuel.

Officials at the SCAQMD were somewhat less enthusiastic than regulators at CARB. ***The SCAQMD was concerned that funding for commuter car projects could potentially detract or delay funding for a variety of mass transit projects including light and heavy rail and commuter rail.*** Essentially, they were supportive of commuter cars as a substitute for full-size cars but they would rather have a commuter sitting in a light or heavy rail car than in a commuter car. ***SCAQMD was generally not supportive of new, specialized infrastructure for commuter cars.*** Lane restripping and/or modifications to existing roadways, however, seemed to be a more acceptable option. In fact, AQMD officials seemed amiable to any idea that detracted from infrastructure capacity for standard size vehicles. In contrast, CARB was more supportive, contending that because of the low price of the commuter car it would help accelerate the attrition rate of older, higher polluting vehicles.

Infrastructure Planning Process. An important reoccuring message was expressed in interviews with transit planners—major infrastructure expansions, modifications and redirections are currently in the planning stages in many cities and counties in the State; and proposed changes address both near-term and long-term infrastructure needs. Landmark infrastructure development plans are currently being developed by agencies such as the Los Angeles County Transportation Commission, the Orange County Transportation Commission, and the Bay Area Transportation Commission. The increased level of planning activity has resulted from the following:

- A clear mandate for change from California citizens, as evidenced by the passage of several ballot initiatives focused on improving the transportation system in the State (and which provide significantly increased State funding for transportation system improvements).

- Increased Federal funding for transportation projects as a result of the ISTEA legislation.

- Increased concern with air quality problems and the impact of alternative transportation modes on air quality (as evidenced by the recent passage of the 1990 Federal Clean Air Act and the 1991 California Clean Air Act).

- Increased concern over petroleum dependence (i.e., both the recent passage of the National Energy Security Act, and the Gulf War).

- Increased concern over California marketplace competitiveness and its relationship to the State's transportation system (i.e., recent major departures of industry from California, and lost productivity due to congestion).

Essentially all of the local transportation planners interviewed made it clear that the transportation infrastructure system in California is in a major renaissance period, and that dramatic changes will occur over the next 30 years. Plans are being developed ***now*** for new roads, freeways, commuter rail and light and heavy rail projects. Plans for major surface street modifications and maintenance are also being developed as a result of the ISTEA funding. IVHS technology investment will also grow dramatically over the next decade. Transportation planners further suggested that because of these planning activities, the next few years represent a major opportunity for tailoring the infrastructure system for the commuter car—*"If such a concept is not planned for during the next 3 to 5 years the opportunity to accommodate the commuter car may be lost,"* Long Beach Transportation Planner.

These interviews highlight two important issues. First, that opportunities to modify the infrastructure (perhaps substantially) do exist, and the road system is not as "fixed" as many would suggest. Changes to the system may occur slowly and gradually, but change is inevitable. New roads, interchanges, and freeways are continually being modified and constructed. The important point to recognize is that we must not get caught in the trap of pointing to existing limitations on existing roads as arguments against the potential market acceptance of the commuter car. The concept must be thought of as a medium- to long-term solution that must be planned for today. Second, the State of California is at a crossroads in the development of its transportation infrastructure. More funding has been provided by both State and Federal legislatures to revitalize the system at this point in time than at any other time in the last 30 years. Plans for accommodating the commuter car concept should begin to infiltrate long-term transportation system designs during the next 5 years if market penetration rates are to be maximized.

Need for a Coordinated Effort. As noted, interviewees were receptive to the overall concept of the commuter car. However, generally they indicated a reluctance to endorse even moderate modifications to the local road system unless such modifications were supported by a statewide, or at a minimum regional, plan for introducing the commuter car. Transportation planners were concerned that modifications they might make would become obsolete or "orphaned" if a statewide plan was not in place and the market did not develop. In general, they felt that a few simple changes in a single local community (such as parking cost adjustments or selected lane re-striping) would be insufficient to encourage the development of a "meaningful" size market. Most commuters cross through several municipalities going to and from work. Pleasure trips and daily household trips also often involve using a vehicle over a wide geographic area. Transportation planners' argument is that if benefits of the commuter car are only available in a confined area, only a few consumers who did the majority of their driving in that area would be motivated to purchase a commuter car. In addition, interviewees were especially concerned with making modifications to the infrastructure that would detract from the utility of the system to serve standard size passenger cars. Again, this concern was particularly acute if a regional or statewide plan was not in place to support changes made at the local level. Transportation planners were reluctant to be the first to make the necessary infrastructure changes if they thought they "would be out there all alone." ***These interviews suggest that it will be important to establish a statewide plan for infrastructure modifications that can be tailored at the regional level.*** A coordinated effort between local transportation authorities, regional authorities, and statewide transportation planners will be needed to move forward quickly with commuter car plans.

4.2 Description of Potential Infrastructure Modifications

The University of California at Berkeley researched numerous infrastructure modifications that can be made to facilitate the operation of commuter cars. A summary of infrastructure modifications which may be implemented to promote the commuter car is presented in **Exhibit 4** with approximate timeframes for development and implementation.

EXHIBIT 4
Infrastructure Modifications

TIME FRAME	DEVELOPMENT ITEM	
	PARKING/VEHICLE STORAGE	ARTERIAL
Short Term	• Add stripes to existing lots • Conversion of "dead" space • Reduced parking fees • Preferred parking	• Two-in-one lane traffic • Restriping of lanes • Lane prioritization schemes
Intermediate Term	• Restripe parking facilities	• Exclusive lanes on existing roadway or shoulders • Flyovers • Outrigger lanes
Long Term	• Parking structures designed for commuter cars	• Elevated roadways • IVHS links • Dedicated right-of-way • Expansion of network

Source: Booz·Allen analysis

To accommodate commuter cars, modifications could be implemented slowly, approximating the order shown in the exhibit. As the market grows and becomes more predictable, planners will be able to modify development plans as appropriate.

Our description of infrastructure modifications is organized into two areas for discussion:

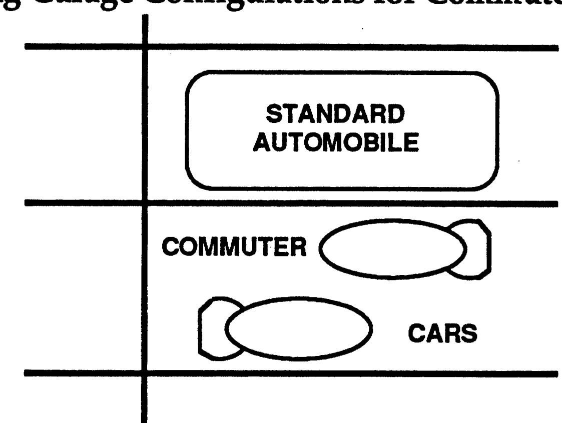
- Parking facilities
- Roadway network.

(Infrastructure modifications summarized in this section are developed in detail in a Program on Advanced Technology for the Highway (PATH) Research Report UCB-ITS-PRR-91-7.)

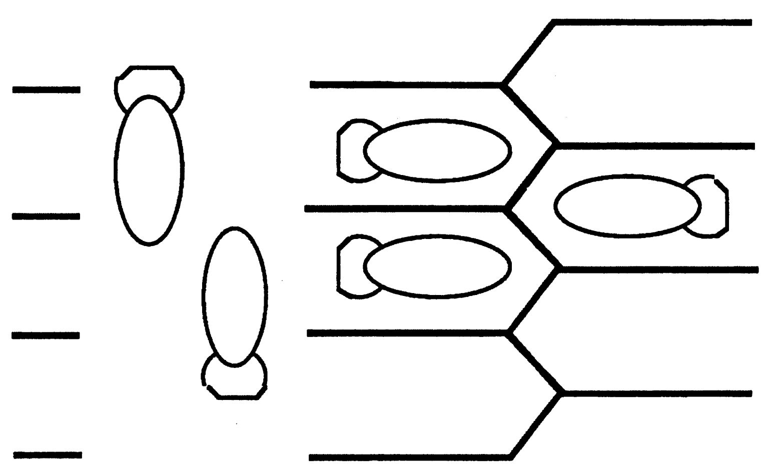
Parking Facilities. The first area of infrastructure modifications identified by the University of California at Berkeley were parking facility modifications. All of these modifications are categorized as incentives for embracing the commuter car concept—from the perspectives of both consumers and planners. From a planner's perspective, a large population of commuter cars would reduce the parking area required at a given facility—presuming commuter cars would be substitute primarily for full-size automobiles. Consumers, on the other hand, may be offered more available space and/or reduced parking fees. The objective of this section is to demonstrate the benefits and opportunities this concept presents.

Benefits in parking configuration are realized due to the reduced footprint and high maneuverability of the commuter car. **Exhibit 5** illustrates two potential space configurations for parking facilities. Exhibit 5a illustrates a short-term modification to a parking facility, the two-in-one concept, which can be implemented with little planning and public investment, yet increases the vehicle capacity of a given facility. In addition to authorizing two-in-one parking configurations, municipalities may utilize "dead space" in parking facilities, where a full-size automobile may not fit, but a commuter car would. Utilization of dead space requires some redesign of an existing facility, but would require little capital investment. Spaces would be designed individually and would resemble the spaces depicted in Exhibit 5b—measuring approximately 4 feet by 9 feet.

EXHIBIT 5
Parking Garage Configurations for Commuter Cars



5a. TWO-IN-ONE CONCEPT



5b. RESTRIPE CONCEPT

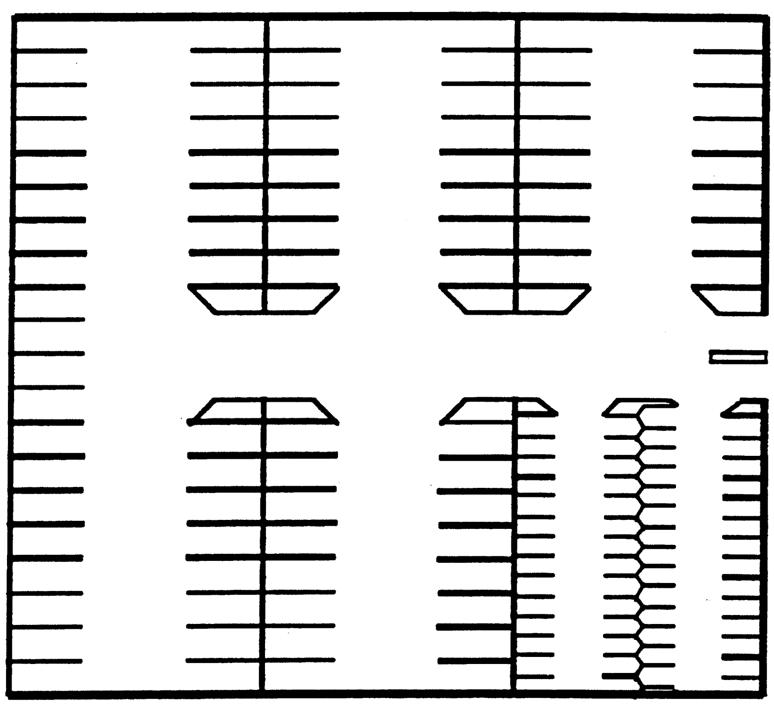
LM5/1.4

Source: SAE Technical Paper 901485, "Lean Vehicles: Strategies for Introduction Emphasizing Adjustments to Parking and Road Facilities"

A longer term development effort is depicted in **Exhibit 6**. The objective of this design is to optimize parking configuration based specifically on the size and shape of the commuter car. Larger investments are required to analyze each parking facility to determine the optimal configuration for commuter car spaces, remove existing lines on pavement and apply new lines to the surface.

This is an investment that would be made based upon growth of the vehicle market and demand for parking. The objective of Exhibit 6 is to illustrate that garages and parking lots could be planned to accommodate the commuter car. Structural benefits would result from reduced loads on parking structures due to the low weight of the commuter car compared to a full-size automobile. This would offer cost benefits in constructing parking facilities, due to reduced structural requirements. In a standard 100-space parking lot, shown in Exhibit 6, redesigning space for 16 full-size automobiles would yield 56 commuter car spaces, thereby leaving 84 standard spaces.

EXHIBIT 6
Long-Term Parking Lot Modifications



From a lot owner's perspective, the daily revenue calculation would be as follows.

Assume: 1. $8/day fee for standard space
2. $4/day fee for commuter car space
3. Configuration A: 100 full-size spaces
4. Configuration B: 84 standard spaces, 56 commuter car spaces
5. Lot filled to capacity, in both configurations

Revenue: Configuration A: 100 vehicles x $8/day = $800/day
Configuration B: 84 vehicles x $8/day + 56 commuter cars x $4/day = $896/day

Cost:

1. Stripe removal: 18 x 16-feet = 288 x 2.00/ft = $ 576.00

2. Add stripe: 14 x 4 x 8-feet = 448 feet x $.80/ft = $ 358.40

3. Install signs: 2 signs @ $100 each = 2 x 100 = $ 200.00

$1,134.40

4. Planning: 1 senior engineer $6,000/month = $3,000
2 junior engineers $3,000/month = $3,000
$6,000

$7,134.00

Payback Period: $75,000 / $96 / day profit = 79 days at full capacity

Source: PATH Research Report, UCB-ITS-PRR-91-7.

The example illustrates the expansion of the parking facility from 100 to 140 vehicles, or a 40 percent increase in driver access. The payback period for the investment is 79 days, or about 4 months at full capacity. Given sufficient demand, a lot owner would recognize the value in accommodating commuter cars.

Alternatively, a city-owned lot could use parking as a disincentive to full-size automobile use, in order to stimulate use of other modes, such as commuter cars or public transit systems. If all 100, full-size spaces were converted, daily revenue would reach $1,400 (350 commuter cars x $4.00 , assuming demand would fill the lot capacity).

The conversion cost would be approximately $30,000, while daily revenue would increase $600 over the original amount collected using the old lot configuration. The investment would be recovered after approximately 2-1/2 months of service at full capacity. Furthermore, there is parking space for more vehicles.

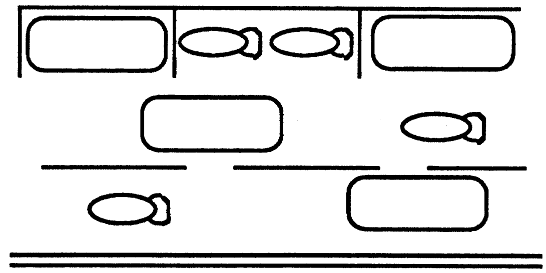
This example illustrates that investment incentives exist for modifying parking facilities and that investments can be made incrementally to meet demand in order to optimize returns.

The University of California at Berkeley also studied alternate parking configurations for on-street parking. There are similar advantages in space requirements for parking commuter cars on streets as compared to within parking facilities. The most obvious concept is a two-in-one arrangement for parallel, on-street parking, as depicted in **Exhibit 7a**.

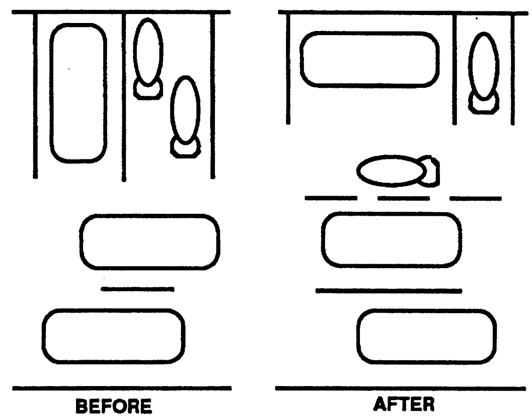
An intermediate term investment is to re-stripe on-street parking to capitalize on the smaller size of the commuter car, as depicted in **Exhibit 7b**. Another possibility is illustrated in **Exhibit 7c**. These exhibits demonstrate that many on-street parking configurations are available.

This brief analysis of parking scenarios demonstrates that there are numerous economic incentives for municipalities to offer specialized commuter car parking facilities. Fewer capital dollars are required to build new parking lots and, depending upon planning issues, revenue may be higher to operate the lot. In some cases, preferential parking similar to that granted to carpool vehicles may be provided to further enhance the benefits of driving a commuter car. An important point in investing in parking facilities is that no regional coordination of planning activities is required to implement the incentives; the only requirement is that there is demand for commuter car parking in the particular municipality.

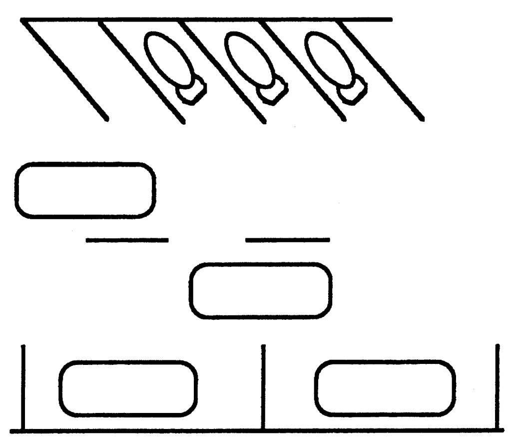
EXHIBIT 7
Street Parking Configurations for Commuter Cars



7a. PARALLEL STREET SPACES:
TWO-IN-ONE CONCEPT



7b. PERPENDICULAR STREET PARKING:
RESTRIPE CONCEPT



7c. PARALLEL STREET PARKING:
RESTRIPE CONCEPT

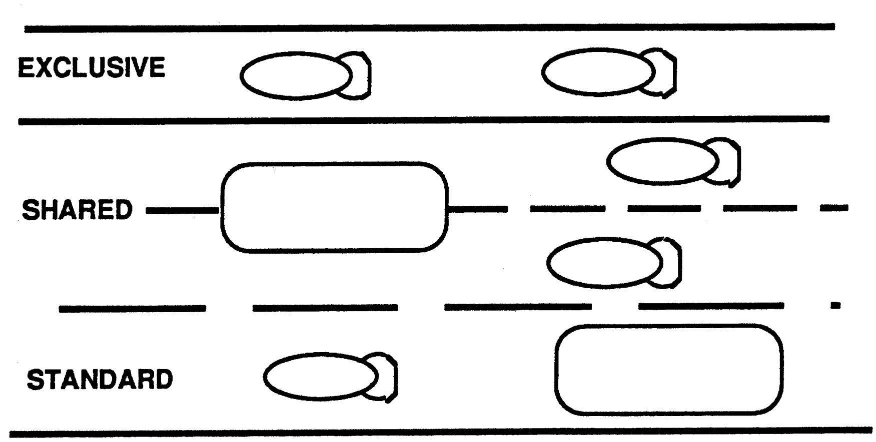
LM5/1.4

Source: SAE Technical Paper 901485, "Lean Vehicles: Strategies for Introduction Emphasizing Adjustments to Parking and Road Facilities"

Roadway Network. Advantages in constructing parking facilities are clear for the commuter car concept; however, more significant incentives exist concerning the roadway network. The advantages for commuters would include shorter travel times which in turn leads to reduced fuel and maintenance costs. Advantages for public transportation agencies include lower road construction costs and improved capacity on existing rights-of-way. Benefits are derived from the shorter length of the commuter car—9 feet versus 15 feet —and narrower width —3-1/2 feet versus 6-1/2 feet (a 6-foot wide lane is sufficient). The objective of this section is to briefly introduce modifications to the roadway network to demonstrate advantages of the concept.

Road capacity benefits are realized for several reasons. The shorter length of the commuter car as well as the shorter required distance between vehicles (due to enhanced braking ability) result in an increase in vehicle capacity for a given length of road and travel speed. Increased maneuverability and acceleration will also add to the potential increase in capacity. **Exhibit 8** illustrates three potential configurations for mixed traffic comprising commuter cars and standard vehicles. The standard configuration offers no special accommodation for commuter cars, yet depending upon the mix of vehicles, there is a capacity increase realized beyond the maximum road capacity if no commuter cars are in the traffic flow. The shared configuration obviously offers some capacity benefits, allowing commuter cars to pair in standard width lanes. The most significant capacity increase results from the exclusive lane concept, limiting traffic to commuter cars only.

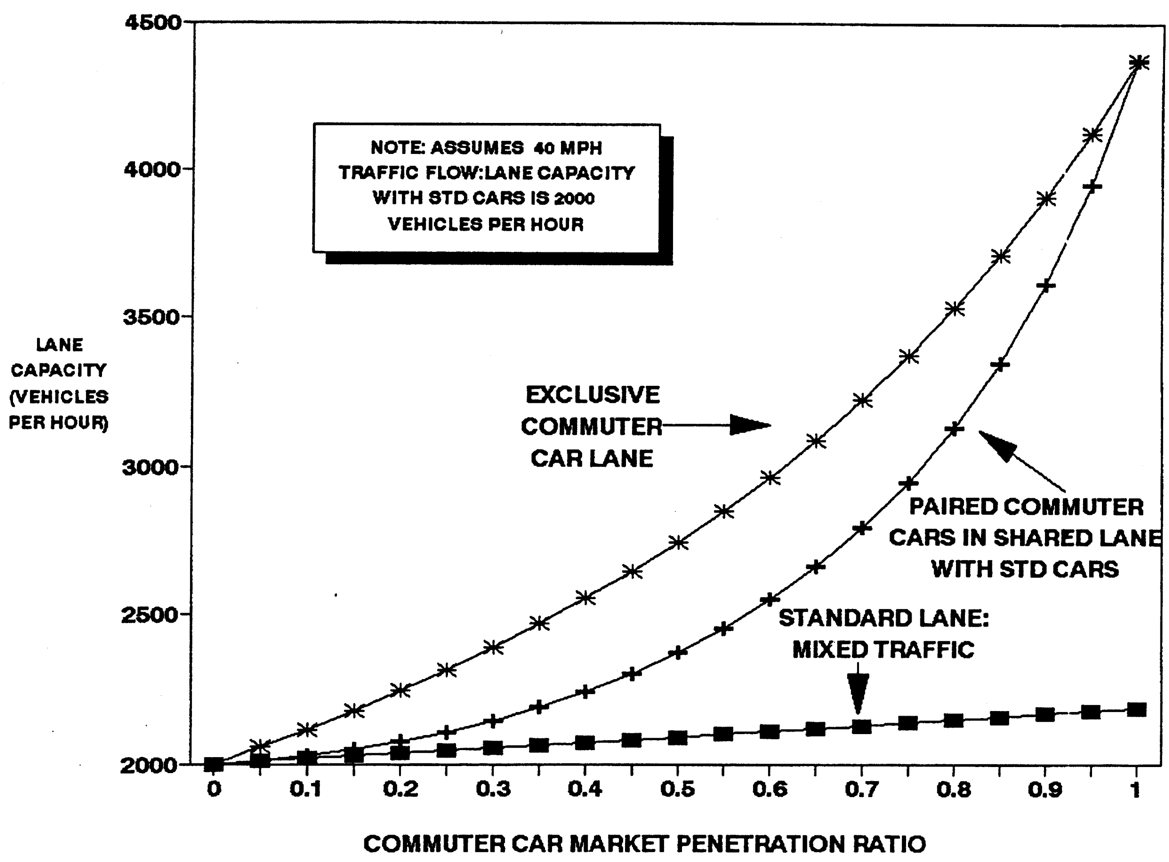
EXHIBIT 8
Arterial Infrastructure Modifications
Shared and Exclusive Special Lanes



Source: SAE Technical Paper 901485, "Lean Vehicles: Strategies for Introduction Emphasizing Adjustments to Parking and Road Facilities"

Exhibit 9 compares the capacity increases for each of the three flow configurations at various commuter car market penetration ratios. The equations used to generate the curves in Exhibit 9 are based on commuter car length, maximum road capacity of standard-width vehicles at 40 mph, and the probability of commuter cars pairing-up in traffic flows. Note that 100 percent commuter car composition in the paired lane arrangement yields a capacity increase of over two times that of standard vehicles. The maximum capacity of one, exclusive commuter car lane would be approximately 4,400 ÷ 2 or 2,200 vehicles per hour, while 2,000 standard vehicles per hour is the capacity for a traffic lane of standard vehicles (18-feet long, traveling at 40 mph).

EXHIBIT 9
Capacity Analysis—Commuter Cars Driving Side-by-Side



Perhaps the area of infrastructure design offering the most opportunity for leveraging the commuter car concept is elevated roadway. Elevated sections of road capable of accommodating the commuter car could be constructed at a fraction (perhaps 1/2 to 1/4) of the cost needed for elevated roads capable of accommodating cars and trucks. As importantly elevated roadways for commuter cars, because of the inherently low structural and space requirements could be integrated into the existing infrastructure much easier than elevated roads for cars and trucks.

One such elevated roadway concept is knows as a "flyover" section which is generally used by traffic planners at complex and/or busy intersections to increase throughput. The flyover would allow those commuter cars not wishing to make a turn to go over the intersection without stopping at the light. This type of project requires less lane space than for a standard-width vehicle, and the project would cost about one-fourth to one-third as much. **Exhibit 10** illustrates the flyover concept at an intersection.

EXHIBIT 10
Commuter Car Flyover Concept at an Intersection

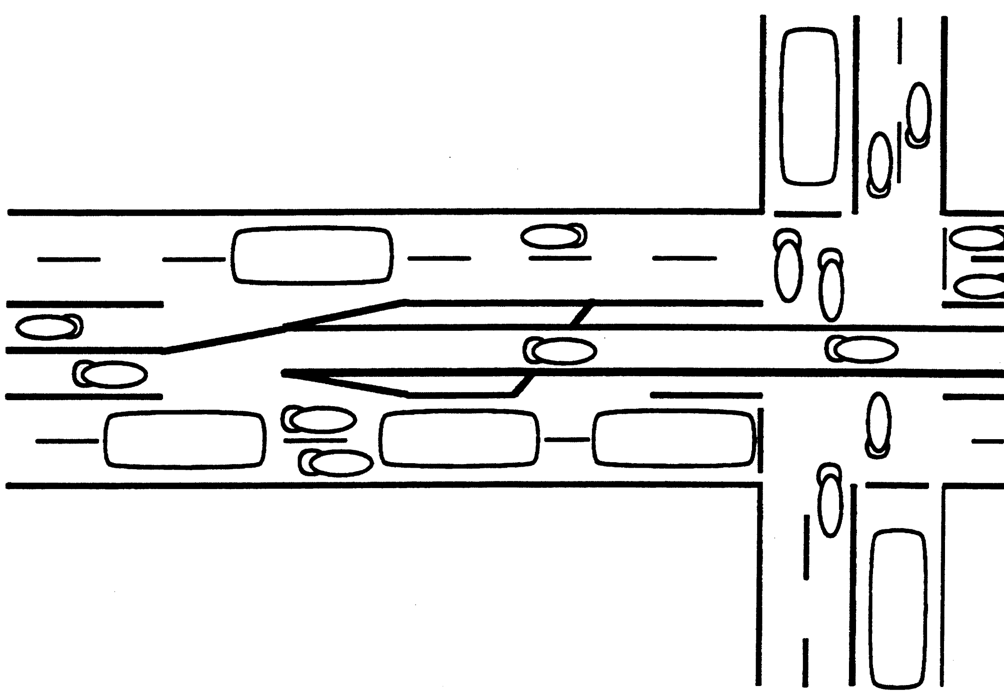
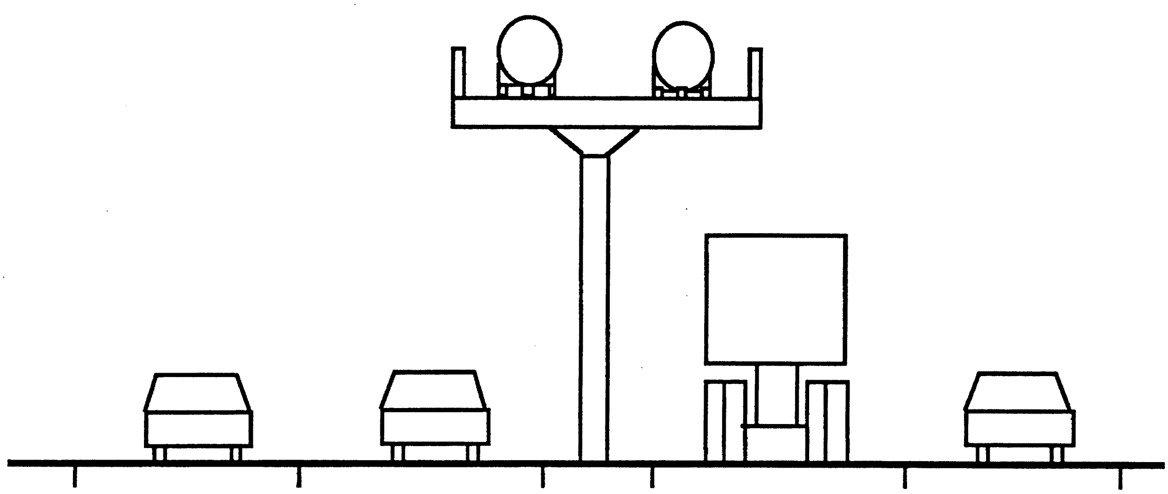


Exhibit 11 illustrates another type of elevated roadway concept for the commuter car. Elevated sections could be constructed in the median of divided highways where at-grade highway expansion has reached its maximum limit due to a variety of right-of-way constraints. The cost advantages of building elevated road sections in this design concept are dramatic for commuter cars. Estimates range from one-half to one-quarter the cost to construct comparable exclusive lanes for standard vehicles.

EXHIBIT 11
Arterial Infrastructure Modifications
Elevated Lanes in Freeway Median

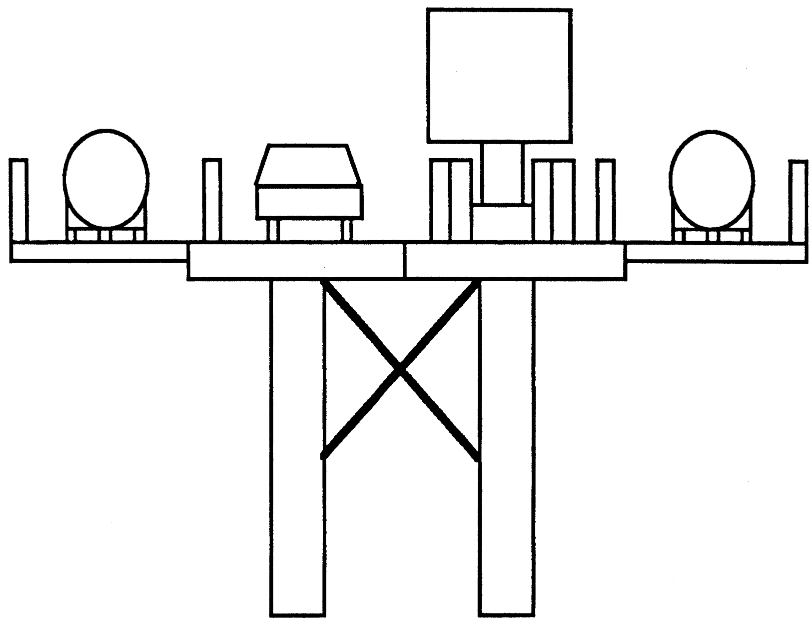


Source: SAE Technical Paper 901485, "Lean Vehicles: Strategies for Introduction Emphasizing Adjustments to Parking and Road Facilities"

Exhibit 12 presents a similar expansion opportunity. Bridges are often bottlenecks for traffic flow, typically flanked by entrance and exit ramps at either end of the bridge. The construction of outrigger lanes is useful where bridge expansion has usurped shoulders and, short of constructing another bridge, the section is at maximum capacity.

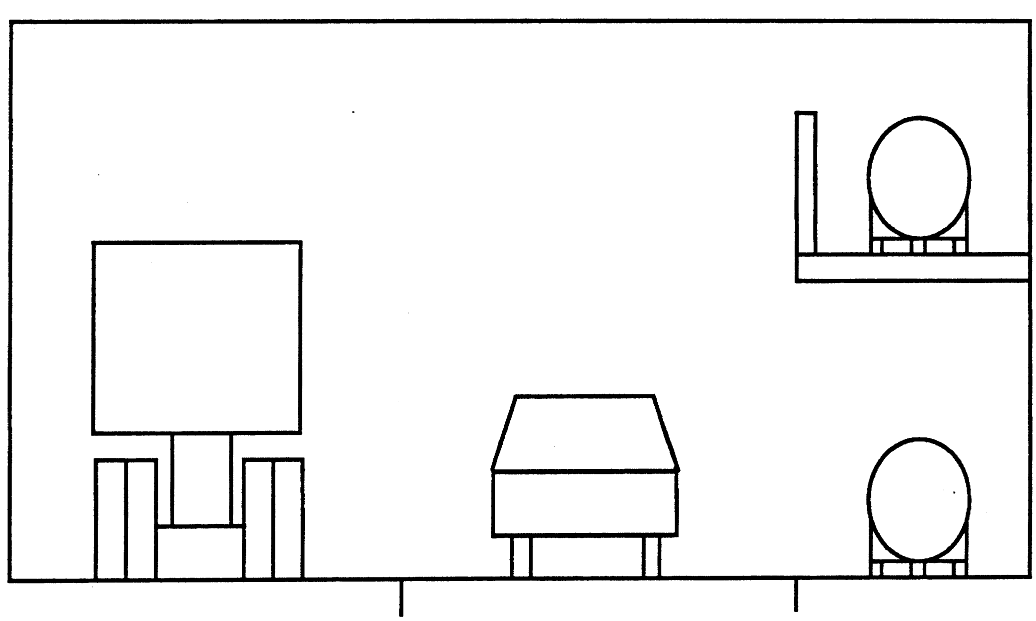
Capacity expansion opportunities also exist in tunnels, where an elevated road may be constructed within the tunnel to form two commuter car lanes. This concept is shown in **Exhibit 13.** Clearly, constructing an additional tunnel would be significantly more expensive than this "stacked" roadway configuration.

EXHIBIT 12
Arterial Infrastructure Modifications
Outrigger Lanes on Bridge or Viaduct



Source: SAE Technical Paper 901485, "Lean Vehicles: Strategies for Introduction Emphasizing Adjustments to Parking and Road Facilities"

EXHIBIT 13
Elevated Roadway in a Tunnel



Source: SAE Technical Paper 901485, "Lean Vehicles: Strategies for Introduction Emphasizing Adjustments to Parking and Road Facilities"

4.3 Cost/Benefit Review of Selected Infrastructure Modifications

There are a number of roadway modification scenarios that may be implemented to optimize infrastructure capacity. The costs for undertaking infrastructure modification projects for commuter cars were studied by the University of California at Berkeley. The California Department of Transportation also provided estimates for highway construction projects. **Exhibit 14** contains a variety of cost estimates for modifying and constructing roadway infrastructure.

EXHIBIT 14
Cost Parameters for Infrastructure Expansion

Element	Cost Basis	Cost	Life Estimate
Stripe Removal	$1.50/ft.	$5,000/mile	10 years
Stripe Addition	$0.60/ft.	$2,500/mile	5 years
Signal Intersection	$210/each	$1,000/mile	5 years
Resurfacing	$5,000/ft.-mile	$5,000/ft.-mile	5 years shared; 10 years exclusive
New Lanes (Existing ROW)			
Freeway (outside shoulder)	$21,000/ft.-mile	$21,000/ft.-mile	10 years
Highway (outside shoulder)	$12,000/ft-mile	$12,000/ft-mile	10 years
Elevated Lanes and Flyovers			
Standard Vehicle	$30/sq. ft.	$158,400/ft-mile	20 years
Commuter Car	$25/sq. ft.	$132,000/ft-mile	20 years
Road Maintenance	$250/ft.-mile-year	$250/ft.-mile-year	1 year
Convertible Lane Signals	$100,000/intersection	$100,000/mile (4 signals)	10 years
Signal Maintenance	$1,000/signal-yr	$4,000/mile-year	1 year
Changeable Message Sign (CMS)	$100,000 each	$100,000/direction	10 years
CMS Maintenance	$3,400/sign-year	$3,400/direction-year	1 year
Closed Circuit TV	$27,000/camera	$27,000/direction	10 years
Closed Circuit TV Maintenance	$2,300/camera-year	$2,300/direction-year	1 year
Movable Barriers for Reversible Lanes		$8,000/direction-year	1 year

These estimates are used to compare the costs of various commuter car projects with similar projects focused on standard size vehicles. For each case, assumptions are outlined, and the benefits or capacity increases are derived. It should be noted that capital cost differences between the projects are calculated based on differences in required lane widths. We suspect that actual cost differences in the projects would be larger than indicated here due to the reduced structural load requirements of the commuter car infrastructure. Also, we have assumed that right-of-way already exists for the expansion projects (no costs are attributed to ROW purchases). In reality the ROW acquisition cost could double or even triple the costs of the project. Since commuter car lanes would require purchase of a more narrow ROW, cost difference between commuter car and standard car projects could be larger than the costs shown in the following scenarios.

The first case illustrates a short- to near-term modification that compares the costs of an at-grade expansion project for commuter cars versus a similar project for standard-width vehicles. The project is a two-lane divided highway, 6 miles long, with room for expansion into the shoulder. Capacity increases are derived as discussed previously and Exhibit 14 provides the cost parameters for construction estimates.

Exhibit 15 compares the two projects. Exhibit 15 indicates that expansion of a single lane for commuter cars yields a 54.5 percent increase in capacity and a 25 percent increase in annual maintenance costs. On the other hand, expansion for a single lane of standard vehicle yields a 50 percent increase in capacity and a 50 percent increase in maintenance. In this case the capital required for each project is $483,000 for commuter car lanes and $915,000 for a standard vehicle.

EXHIBIT 15
Analysis of Commuter Car Scenarios—Case 1 Expansion of Two-Lane Divided Highway (Add One Lane)

Assumptions:

- *Two-lane divided highway*
- *6-mile evaluation length*
- *Average 40 mph at peak period*

Comparison of Implementation Costs

Item	Unit Cost	Amount		Total	
		Standard-Size Car	Commuter Car	Full-Size Car	Commuter Car
Remove Stripe	$5,000/mile	6 miles	6 miles	$ 30,000	$ 30,000
New Lane	$12,000/ft.-mile	12 feet wide	6 feet wide	$ 864,000	$ 432,000
Restripe	$2,500/mile	12 miles	12 miles	$ 9,000	$ 9,000
Planning Sr. Engineer	$6,000/mo.	1 mo.	1 mo.	$ 6,000	$ 6,000
Jr. Engineer	$3,000/mo.	2 mo.	2 mo.	$ 6,000	$ 6,000
			TOTAL	$915,000	$483,000

Benefit Analysis

	Add Standard Lane	Add Commuter Car Lane
Increased Capacity	50%	54%
Maintenance Costs		
Before Addition	$36,000	$36,000
After Addition	$54,000	$45,000
% Increase in Maintenance Costs	50%	25%

Case 2, shown in **Exhibit 16,** is a study of road expansion in which elevated sections must be built because existing right-of-way is at capacity. This is relatively common in California, in both the Los Angeles and San Francisco metropolitan areas. This type of situation illustrates the significant benefits of commuter cars when existing rights-of-way are at 100 percent utilization. Substantial capital costs are involved in constructing elevated sections, and commuter cars will require less than one-half as much capital to construct as standard vehicles. Capacity expansion and annual maintenance costs are comparable to those in Case 1.

EXHIBIT 16

Analysis of Commuter Car Scenarios—Case 2 Expansion of Four-Lane Divided Highway (Add Two Lanes)

Assumptions:

- ***Four-lane divided highway***
- ***6-mile evaluation length***
- ***Average 40 mph at peak period***

Comparison of Implementation Costs

Item	Unit Cost	Amount		Total	
		Standard-Size Car	Commuter Car	Standard-Size Car	Commuter Car
Elevated Section Standard Car	$158,400/ft-mile	12 miles, 12 ft wide	—	$ 22,809,600	—
Commuter Car	$132,000/ft-mile	—	12 miles, 6 ft wide	—	$9,504,000
Stripe	$2,500/mile	36 miles	36 miles	$ 90,000	$ 90,000
Planning				$ 36,000	$ 36,000
Sr. Engineer	$6,000/mo.	6 mo.	6 mo.	$ 36,000	$ 36,000
Jr. Engineer	$3,000/mo.	12 mo.	12 mo.		
			TOTAL	$22,971,600	$9,666,000

Benefit Analysis

	Add Two Standard Lanes	Add Two Commuter Car Lanes
Increased Capacity	50%	54%
Maintenance Costs		
Before Addition	$72,000	$72,000
After Addition	$108,000	$90,000
% Increase in Maintenance Costs	50%	25%

Case 3, shown in **Exhibit 17**, is built on the premise of achieving at least 8,000 vehicles per hour capacity by expanding an existing three-lane highway section. Two projects are determined to meet demand. The first is conversion of one standard lane to accommodate two streams of commuter cars. (It is also assumed that creating a commuter car lane on an existing highway would require road resurfacing.) The second alternative is to add an additional lane to accommodate standard vehicles, but it must be elevated due to lack of at-grade expansion opportunities. The capacity increase assumes there are enough commuter cars to fill the capacity and that the two commuter lanes are exclusive. In this case, expansion for commuter cars compares very favorably in all three areas—capital, annual maintenance and capacity increase. However, on the downside, standard vehicles would lose one lane to the commuter cars.

EXHIBIT 17
Analysis of Commuter Car Scenarios—Case 3 Expansion of Three-Lane Divided Highway (Convert One Lane)

Assumptions:

- ***Three-lane divided highway***
- ***6-mile evaluation length***
- ***Average 40 mph at peak period***

Comparison of Implementation Costs

Item	Unit Cost	Amount		Total	
		Standard-Size Car	Commuter Car	Full-Size Car	Commuter Car
Elevated Roadway	$30/sq. ft.	6 miles	N/A	$11,404,800	N/A
Remove Stripe	$5,000/mile	N/A	6 miles	N/A	$ 30,000
Resurface	$5,000/ft.-mile	N/A	12 feet wide	N/A	$360,000
Restripe	$2,500/mile	6 miles	18 miles	$ 15,000	$ 90,000
Planning					
Sr. Engineer	$6,000/mo.	4 mo.	1 mo.	$ 24,000	$ 6,000
Jr. Engineer	$3,000/mo.	8 mo.	2 mo.	$ 24,000	$ 6,000
			TOTAL	$11,467,800	$492,000

Benefit Analysis

	Convert One Standard Lane	Add Two Commuter Car Lanes
Increased Capacity	33%	0%
Maintenance Costs		
Before Change	$54,000	$54,000
After Change	$72,000	$54,000
% Increase in Maintenance Costs	33%	39%

5. CONCLUSIONS

The analysis of infrastructure issues relating to the commuter car concept yields several important conclusions. There are no insurmountable barriers in the infrastructure analysis that would preclude the introduction and success of the commuter car. The most important issue, which was confirmed during the interviews, is that infrastructure modifications may serve as incentives, to varying degrees, to potential customers to purchase vehicles. In addition to embracing infrastructure modifications, many planners are interested in studying the commuter car concept as an integral link in the transit system, operated in a number of possible manners that would ultimately reduce congestion, enhance transit ridership, and capitalize on the relative advantages in efficiency that the commuter car offers over standard-width vehicles. Overall, city planners were enthusiastic about the concept and confirmed the advantages inherent in its design from traffic management and public investment perspectives.

A summary of key infrastructure issues is presented below:

- Because major shifts in infrastructure development are currently in the planning stages in California, the next few years represent a critical opportunity for introducing the commuter car. Planning for the commuter car must begin now.
- Modification of arterial roads and freeways will require significant levels of coordination among local transportation agencies, regional planning commissions, and state agencies to realize fully the benefits of an investment in infrastructure. Isolated infrastructure changes at the local level will likely have marginal benefits for expanding the market.
- There are suitable economic incentives for planners to embrace this technology and provide support in the form of innovative traffic policies and supporting infrastructure
- Upon full utilization of existing rights-of-way, the benefits of the commuter car for increasing infrastructure capacity are tremendous.
- Infrastructure modifications can be implemented incrementally, paralleling market growth. Early stage investments are nominal.
- In many municipalities, lower level investments (parking, lane re-striping) may be incurred exclusive of other cities' activities.
- Creative application of these vehicles in conjunction with the transit system may provide additional incentive to consumers. Cooperatives may form to share costs of owning the vehicles.

It is important to recognize the infrastructure factors which will drive the market penetration of the commuter car. One observation made by a city official highlighted the requirement for a central planning and organizational body to coordinate any long-term design efforts and encourage all cities to participate in the roadway modification program. This program demands leadership to provide assistance to practitioners in traffic planning and highway construction.

APPENDIX A
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