AMF

APPENDIX

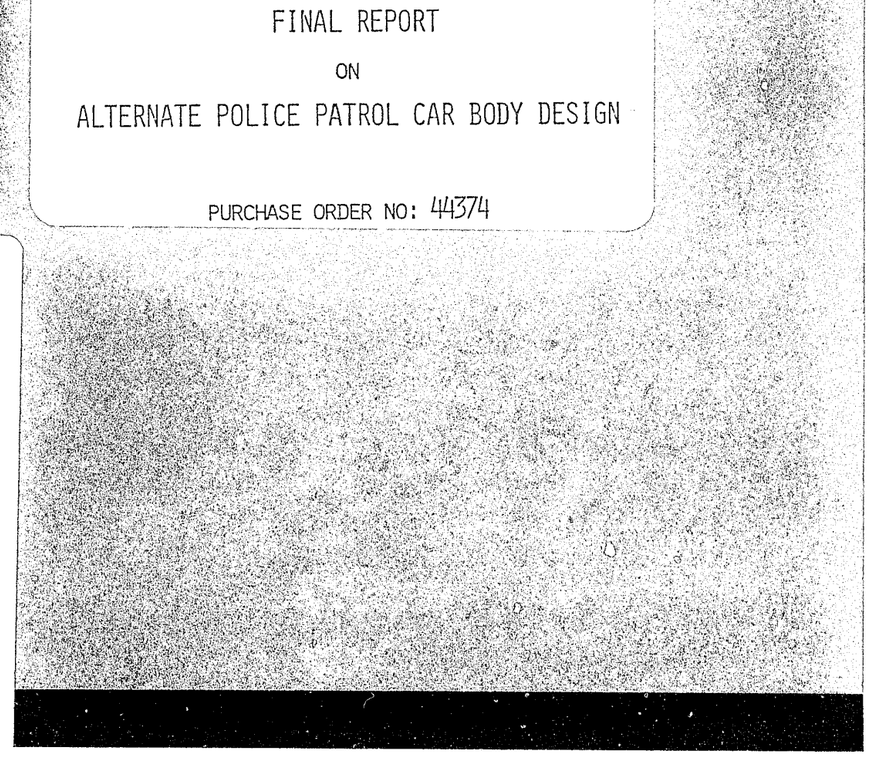
TO

FINAL REPORT

ON

ALTERNATE POLICE PATROL CAR BODY DESIGN

PURCHASE ORDER NO: 44374



ADVANCED SYSTEMS LABORATORY

Santa Barbara, California

J-LEAA-025-73

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FEBRUARY 1976

Performed for:

THE AEROSPACE CORPORATION
955 L'ENFANT PLAZA, S.W.
WASHINGTON, D.C. 20024

Performed by:

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1.0 INTRODUCTION

This Appendix contains the details of work done and analyses made in the course of conducting the Alternate Police Patrol Car Body Design Program. It describes the preliminary requirements analyses, the initial lines of design concept investigation, the first preliminary design investigations and their comparative evaluations. In addition, it presents the breakdown of cost estimates contained in the report proper and some observations on life cycle costs.

2.0 REQUIREMENTS ANALYSIS

The first step towards a successful alternate police patrol car body design was to find out exactly what is needed — the requirements. This was determined in two ways:

- By definition, from a list of what requirements are specified, beginning with the types of people and equipment to be carried.
- By inquiry, asking enforcement agencies what their current practices and experiences are, what changes or improvements they would like.

Insight into police patrol practices and problems was gained (a) by visiting and talking to half a dozen law enforcement agencies, and (b) by conducting a limited nationwide survey.

During effort (a) the following law enforcement agencies and persons were visited or talked to:

- Santa Barbara Police Department
- Santa Barbara County Sheriff Department
- California Highway Patrol (CHP), Santa Barbara Office
- Los Angeles Police Department

- Los Angeles County Sheriff Department
- Mr. John Christy, Special Reserve Deputy and Executive Editor of "Motor Trend" Magazine

The results of this effort (a) consisted of a variety of statements about the desirable and undesirable features of present and future patrol cars. The majority of those statements were presented in the first part of this report.

A special meeting was arranged with Mr. Bill Kulzer from the Automotive Bureau of the Los Angeles Police Department (LAPD) to discuss their experience with maintenance and repair of police vehicles with particular emphasis on the body. Following is a summary of the obtained information:

1. LAPD retires most police vehicles at 70-75,000 miles.
2. Body problems are not significant. Most frequent repairs are to driver's door systems.
3. Driver's seat covering is not durable.
4. LAPD has a preventive maintenance program. It includes a complete replacement of the front suspension at 48,000 miles.
5. Area to attack for reducing cost of maintenance is vehicle chassis.
6. LAPD personnel are very cost conscious.

In effort (b), a questionaire was put together and sent to 20 small and large law enforcement agencies across the country. Nine agencies, or 45% responded.

The questionnaire, the results in tabulated form, and some comments are shown on the following pages.

(1.) What is the approximate size of your agency's patrol car fleet?

	Number of Cars
(a.) Standard size cars	_____
(b.) Intermediate size cars	_____
(c.) Compact size cars	_____

(2.) Is the majority of your agency's patrol cars operated primarily in:
(a.) Urban Areas
(b.) Rural Areas
(c.) Other (Please specify)

(3.) Is the back seat of your agency's patrol cars used for purposes other than transportation of detainees?
(a.) Never
(b.) Rarely
(c.) Sometimes
(d.) Often

If affirmative, please specify:

(4.) Are the cars of your agency's fleet equipped with partitions?
(a.) Yes
(b.) Part of the fleet
(c.) No

(5.) What number of rear doors would be adequate for all or most of your agency's operations?
(a.) 0
(b.) 1 (at either side, or rear)
(c.) 2

(6.) Approximately how much of the total available trunk space is normally used for equipment storage in your fleet's cars?
(a.) 0-25%
(b.) 25-50%
(c.) More than 50%

(7.) About your agency's policy for changing tires on patrol cars during patrol duty

Is there a need for spare tires on your patrol cars, i.e., do your officers on patrol ever change the tires themselves, or do they always call for assistance?

(8.) Are there any special features you would like to see incorporated in a new police car body?

(8) Desired Features:

- Reinforced frame and door panels
- Additional ground clearance on the front cross member of the frame
- Built-in equipment box located in front portion of vehicle capable of being secured
- Reduced transmission hump in the front center
- Roll bars
- Hidden blue lights to come out of body or bumpers
- Better vision ahead and to the rear, possibly by elevating the driver
- Ability to see over the cars in parking lots and on the road
- Increased head room
- More comfortable seats

*Specified uses for back seat (other than transportation of detainees):

- Transportation of other police personnel, witnesses, citizens
- Stolen property
- Traffic units fill out forms with accident victims in patrol car
- Personalized cruiser program, family uses
- Ambulance runs

SUMMARY OF ANSWERS

QUESTION/ITEM	NUMBER	% OF AGENCIES	% OF CARS
Number of responses	9		
(1) Standard size cars	546		43
Intermediate size cars	708		56
Compacts	12		1
(Station wagon)	(3)		
Total	1269		
(2) Urban areas	7	78	96
Rural areas	2	22	4
(3) Never	0	0	0
Rarely *	4	44	40
Sometimes *	2	22	9
Often *	3	34	51
(4) Yes	4	45	18
Part of the fleet	4	45	77
No	1	10	5
(5) 0 rear doors	1	10	13
1 rear door	4	45	13
2 rear doors	4	45	74
(6) 0-25% of trunk space	2	22	12
25-50% of trunk space	4	44	31
More than 50% of trunk space	3	34	57
(7) Call for assistance	5	56	26
Change tires	4	44	74

3.0 INITIAL DESIGN APPROACHES

Initially, three different design concepts were explored to find out what each might offer as a possible solution. These were:

1. Minimum size
2. Modification of a compact sedan
3. Functional design

The first two concepts are presented with more details in the following two subsections. In addition, one approach to a functional design utilizing a front wheel drive system, is also presented.

3.1 MINIMUM SIZE CONCEPT

This concept is based on an existing design of an advanced lightweight sedan, Figure 3-1. A few features of this vehicle are short wheelbase (100 in) for good maneuverability and low weight (2400 lbs curb weight and 400 lbs police package) for good fuel economy. The vehicle's configuration affects power consumption primarily through weight and aerodynamic drag factors and of these weight predominates. Since minimum weight is a corollary of efficient, compact packaging, the approach taken was to enclose the occupant's riding and survival space, the mechanical components, and required crush space for safety with the minimum amount of sheet metal. This package was then given the best aerodynamic shape possible without increasing exterior dimensions or sacrificing interior room. Primarily, this included contouring the forward section of the car and keeping the exterior surface, including the underbody as free as possible from excrescences and abrupt depressions.

The car has a rear wheel drive with a fixed differential and independent rear suspension, resulting in a minimum size drive shaft tunnel and hump, thereby conserving interior space.

However, despite the promising features this concept proved to be impractical because of marginal space for the large amount of police equipment, both tactical and electronic. A major redesign of the vehicle would be required to eliminate this deficiency.

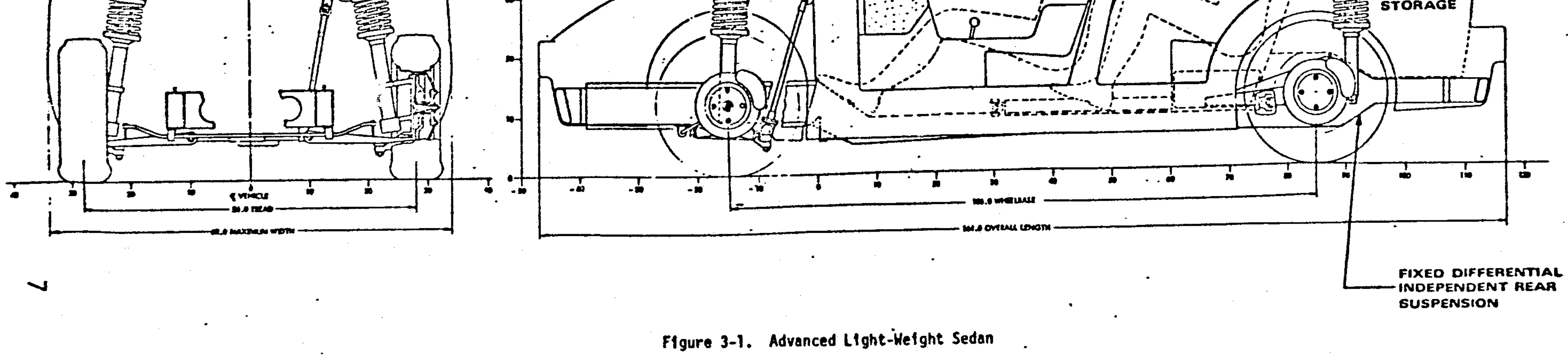


Figure 3-1. Advanced Light-Weight Sedan

3.2 MODIFICATION OF A COMPACT SEDAN

This compact is based on an existing compact sedan which is already in service in a number of law enforcement agencies. One of the major complaints about this newly introduced patrol car is the marginal or inadequate space in the rear seat area and access to it. An attempt was made to correct this deficiency by modifying the upper body around the rear seat compartment, and thus increase the usefulness of a compact sedan for police duty as shown in Figure 3-2. This was accomplished by moving the rear seat further back, above the rear axle and between the wheel wells. This then necessitated an elevated roof line, or hump in the rear. Such an arrangement allows for a considerably larger door and improves access. Trunk space remains virtually unchanged and is considered to be barely adequate for efficiently packaged equipment. Other views are shown in Figures 3-3 and 3-4.

This concept would provide police with an improved version of an existing compact patrol car, featuring the financial and operational advantages of a small vehicle but offering increased roominess for better utility.

However, despite the advantages mentioned above, this arrangement is still a less-than-ideal solution. Its biggest drawback is that there are no improvements possible in the front seat area. It was therefore concluded that the concept did not offer sufficient advantages to justify further development.

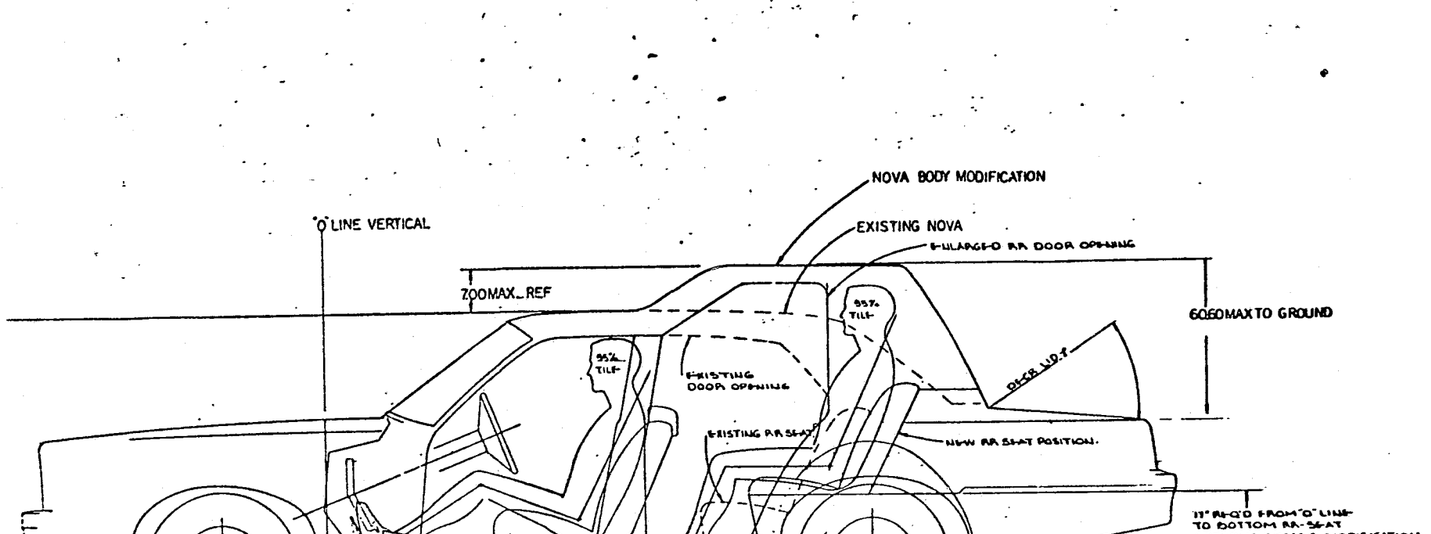


Figure 3-2 Compact Car Modification

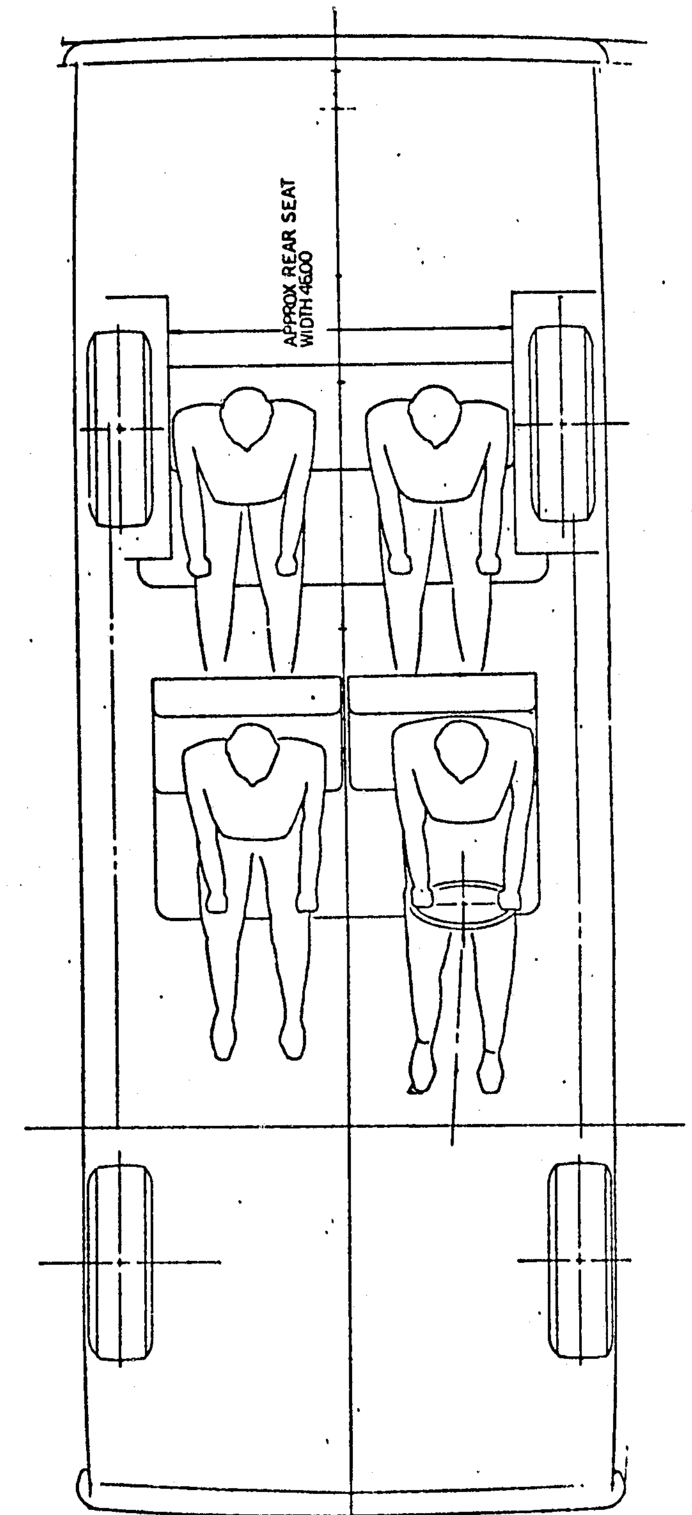


Figure 3-3 Compact Car Modification - Plan View

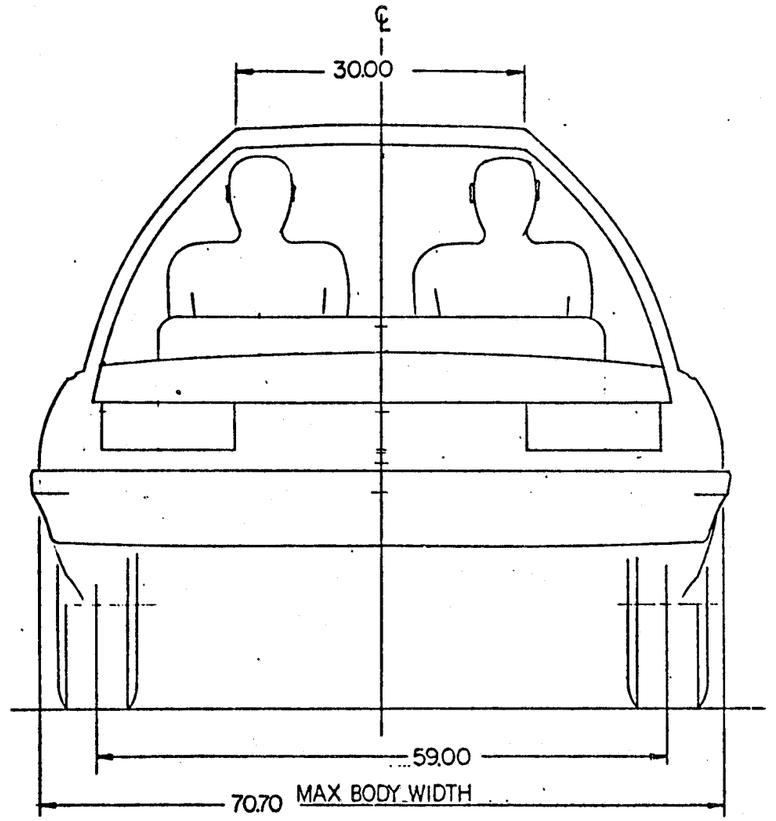


Figure 3-4 Compact Car Version

3.3 FUNCTIONAL DESIGN

This concept evolved from a thorough evaluation of current police patrol car deficiencies and possible ways to solve them. It lead to the conclusion that it is not feasible to satisfy all the requirements with a compact, 4-door sedan body style. For example, adequate access to both front and rear seat area calls for wide front and rear doors, a requirement in conflict with the vehicle's limited dimensions. Also, the conventional seating arrangement makes it difficult to provide more space in the front seat area.

Thus, the functional concept was the result of the effort to satisfy the requirements with a non-conventional approach:

1. Eliminate the rear doors and enlarge the front doors to improve access to the front.
2. Reduce the number of individual compartments from three to two (front seat area + equipment bay/rear seat area).
3. Provide adequate access to the rear seat area from the rear through an oversized hatch.

This concept has the following advantages:

1. As light as an existing compact car for more usable interior space.
2. Overall size is similar to a compact car.
3. Easy access to front seat through large front doors.
4. Easy access to rear seat through large back door (hatch).
5. Improved mass distribution (permanent equipment is stored near CG).
6. Only two side doors required.
7. All equipment easily accessible from the front.
8. More equipment space within the driver's reach.
9. Simple and short wiring for electronic equipment.
10. Rear area can accommodate occasional bulky luggage.

A drawing of the concept is shown in Figure 3-5.

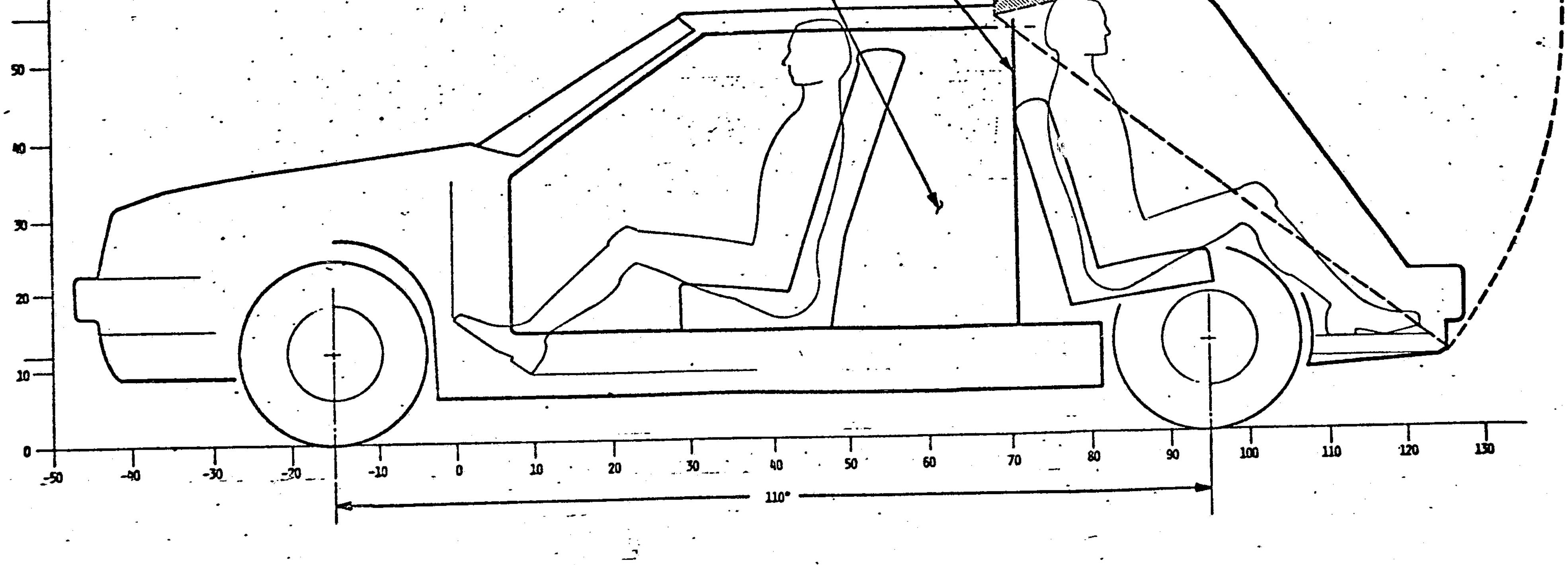


Figure 3-5 Functional Design Approach

3.3.1 Front Wheel Drive System

An idealized configuration was then developed for the Alternate Police Patrol Car Body Design. The factors that resulted in this evolution also led to consideration of a front wheel drive powertrain for the vehicle.

Evolution of the design concept took place as the design goals stated in the technical proposal were pursued. Briefly stated, these design goals are as follows:

- Improve utilization of interior space for police needs.
- Improve fuel economy by decreasing weight.

In a conventional automobile, the greatest impediment to efficient interior space utilization is the driveshaft hump and the "kickup" over the rear axle. Communications equipment and tactical gear can be housed only in the regions below the vehicle beltline, where they will not interfere with the driver's vision. Major driveline intrusions into the floor area of the passenger compartment and trunk make it difficult to efficiently house standard rectangular profile electronic units. The use of a front wheel drive powertrain can permit the floor in the passenger compartment and trunk to be flat. Front wheel drive can contribute toward meeting all three design goals stated above, provided suitable driveline and suspension components can be obtained.

Because of the overall attractiveness of front wheel drive for this specialized application, a design based on this configuration was carried forward in considerable detail. Interior layouts were made. Vehicle exterior dimensions were established and weight distributions were calculated. A styling rendering based on front wheel drive was completed. The design was checked out from an operational standpoint and from a performance standpoint. With the exception of component availability, all aspects of the design appeared favorable.

Following is a detailed description of the design.

Configuration

Preliminary engineering drawings (Figure 3-6) show the general layout and location of major subsystems of the vehicle. All seat positions were designed to accommodate 95th percentile males. Glass in the side doors can be lowered and raised; all other glazing is fixed. Bumper heights conform to Federal Motor Vehicle Safety Standards and ramp, departure angles and ground clearances exceed normal automotive practices.

This design is shown with 15" diameter wheels, principally because a Toronado front end was utilized for the point of departure. It is expected that the 14" wheel normally used with compact cars of this size would be worked into a finalized prototype design.

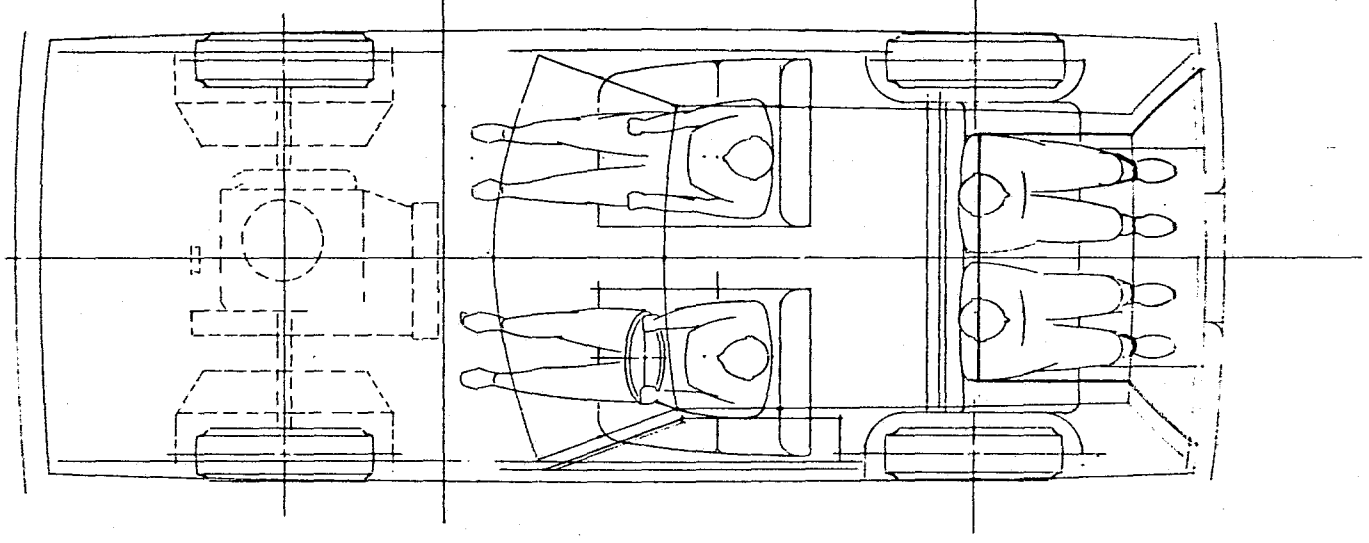
The rear door lid handle is just over 6 feet above ground level in the open position and readily reached. Should there be a requirement for having the emergency lights visible to the rear when the lid is open, this can be accomplished by adding a window opening in the roof part of the lid.

The fuel tank, sized for 20 gallons, is located just forward of the rear axle. A spare tire and tools are carried in the right hand side of the detainee area.

A 350 cubic inch displacement V-8 engine is shown as the power plant, together with a 3-speed automatic transmission. As discussed in the section on Performance, options exist for selecting a smaller V-8 engine or a 6-cylinder in-line or V-6. Final choice should be based on considerations of performance and economy.

Body

The concept for the body evolved from a balanced achievement of efficient use of interior space, a simple, light but rugged structure, good visibility and comfort for the driver, and best all-around access for officers, equipment and detainees. Aspects of safety and crashworthiness were also kept in mind. General configuration is shown in Figure 3-7.



DIMENSIONS

Wheelbase, in.	111.0
Track, front/rear	63.6
Length	194.0
Width	79.0
Height	59.0
Shoulder Room	63.7
Hip Room	57.6
Head Room	43.8

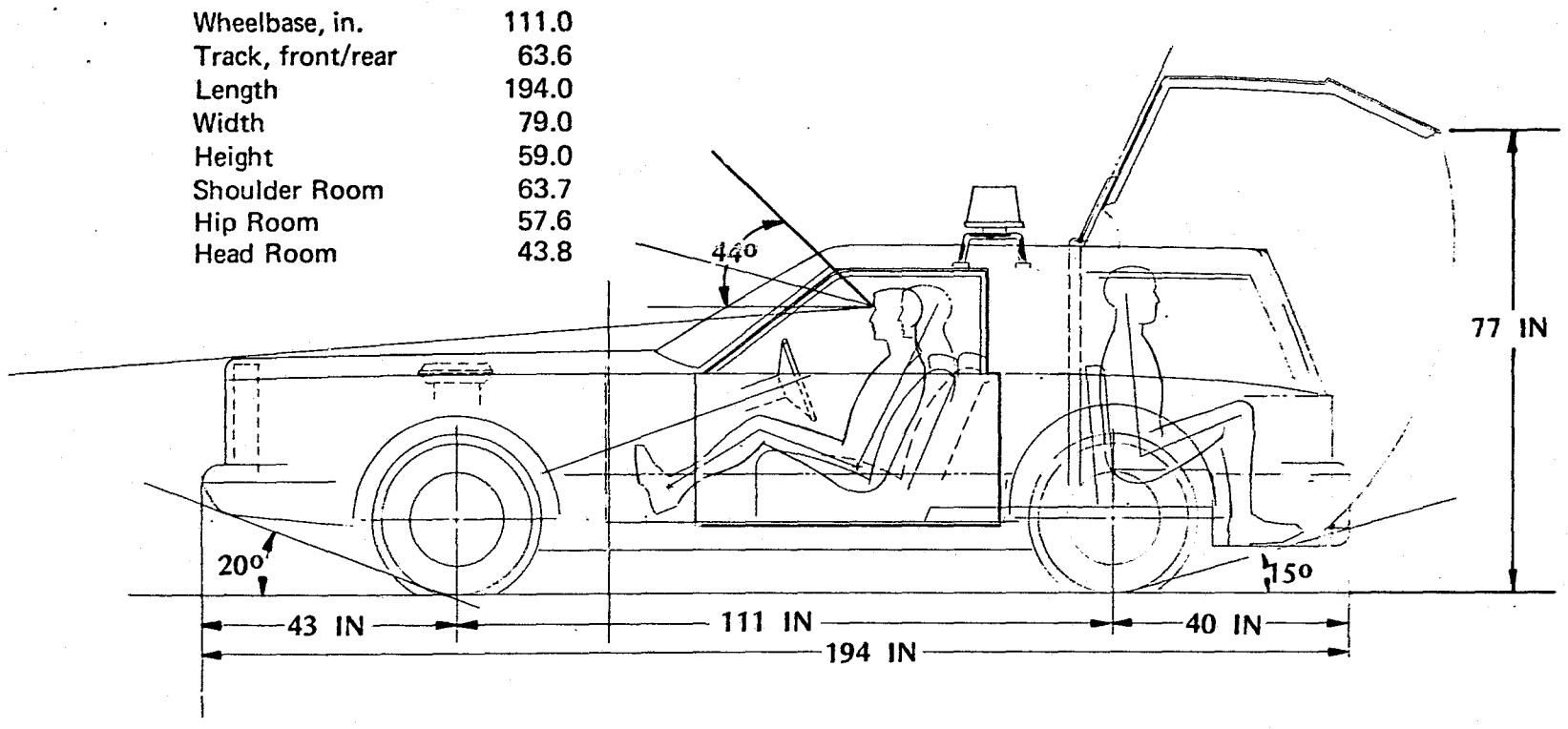


Figure 3-6 Front Wheel Drive Concept

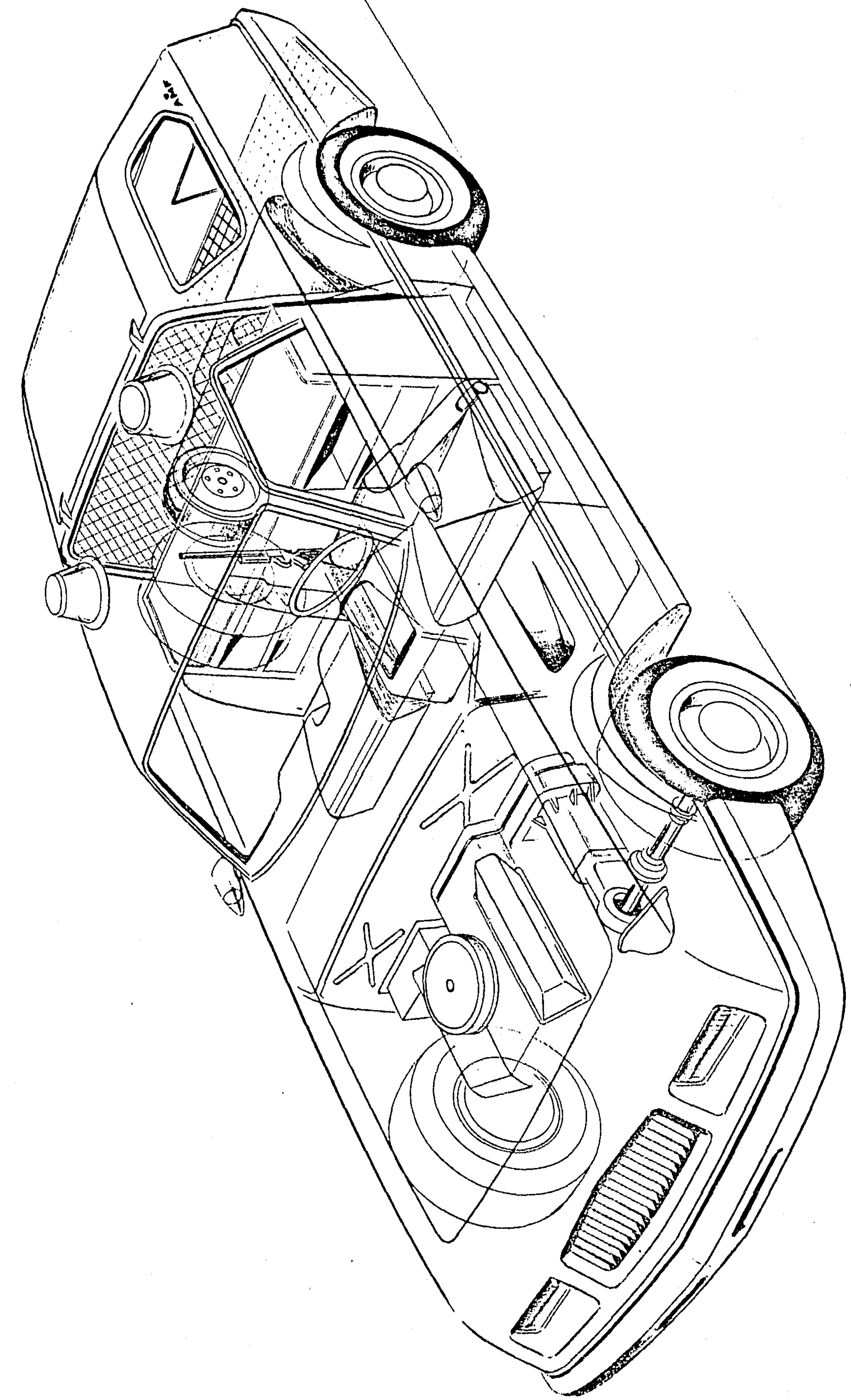


Figure 3-7 Front Wheel Drive Configuration

Chassis

The flat floor pan allows placement of communications and tactical equipment where it is readily usable or accessible to the patrol officers. With traction and steering both through the front wheels, control is better on slippery surfaces and with this arrangement, the vehicle has desirable understeer characteristics built in.

3.3.2 Domestic Front Wheel Drive Systems

It has been reported from time to time that the Toronado front wheel drive system will be scaled down to intermediate size or that American manufacturers will introduce new front wheel drive systems. An article in Motor Trend (May 1975) stated that GM will introduce a front wheel drive system in a line of mini-vans and that the driveline may be used later in A-body cars. The article also stated that it is likely that the engine to be used will be a 231 cu. in. V-6 or a 350 cu. in. V-8. A note in Car and Driver (March 1976) indicates that the GM F-body (Chevrolet Camaro; Pontiac Firebird) will be included in a front wheel drive conversion project, scheduled for introduction in 1979. These vehicles are presently in the weight and performance class of the alternate police patrol car. Business Week (February 16, 1976) reported that Chrysler Corporation has agreed to purchase from Volkswagen the engines and transaxles for a new front wheel drive vehicle. The Dana Corporation has been working for several years on a four wheel drive system with independent front wheel suspension. The Vemco Company presently is marketing this system on Chevrolet vans and pick-up trucks. These and other possible domestic front wheel drive projects were checked out to determine their potential for application to the alternate police patrol car. No source could be located that can provide reasonable assurance of supplying front wheel drive components for alternate police patrol cars within the next five years.

Front wheel drive activity at Chrysler Corporation appears to be limited to the imported subcompact units. Commitments to conventional drive in new vehicle projects seems to preclude any move into front wheel drive in compact and larger vehicles.

The Dana/Vemco four wheel drive system is designed for vehicles weighing up to 8,400 pounds. The physical layout of the components is such that they would intrude excessively into the passenger compartment of an automobile even if the rear drive components were removed. This system offers no advantages in the alternate police patrol car application.

American Motors performed an evaluation of available front wheel drive hardware and decided not to introduce this feature in any passenger car. They are using a heavy duty Toronado suspension in motorhome type chassis produded by the AM General division.

3.3.3 Foreign Front Wheel Drive Vehicles

Front wheel drive has been popular for a number of years in small European automobiles, (Citroen, Renault, Peugeot, Audi, Volkswagen and others). In 1970 Citroen introduced a front wheel drive vehicle (Model SM) that is the approximate weight and performance range of the alternate police patrol car. Model SM weighed 3,200 pounds and was powered by a 180 hp Maserati V-6 engine with 163 cu. in. displacement. Model SM was discontinued in 1973 and new engines and driveline components are no longer available.

Dealers and importers were contacted to determine if any other intermediate size front wheel drive vehicle is available or scheduled for introduction. None was found, due no doubt to the current popularity of compact and subcompact vehicles and concern with fuel economy. A review of automotive literature provided no indication that any front wheel drive vehicle larger than the Audi 100 LS (2,500 lb. curb weight, 115 hp engine) will be available in the near future.

AMF/ASL recently dismantled a new 1975 Audi 100 LS to obtain running gear for an experimental steam powered test vehicle. The engine, drive-train and front suspension from the Audi were examined to determine if any of the components could be adapted to a vehicle having 50% greater weight and twice as much horsepower. It was determined that the Audi parts were well designed for their function in a 2,500 lb. passenger car, but that little can be done that would permit their use in an alternate police patrol car. For example, the Audi engine has a high output for its size. It delivers a peak of 1.07 hp per cubic inch at 5,600 rpm. In comparison, a typical domestic V-8 engine delivers 0.5 hp per cubic inch at a more conservative 4,000 rpm. Likewise, drivetrain suspension components appear to be designed specifically for the present vehicle, with little or no allowance for future growth in model size, weight or performance.

3.4 CONCEPT EVALUATION

After developing the three basic approaches into preliminary design concepts a comparative evaluation was made to determine the preferred candidate. The factors considered and the ratings are shown in Table 3-1. Based on this appraisal it was decided to proceed with the functional approach.

3.5 FINAL DESIGN CONCEPT

After determining that the front wheel drive concept was ideal but not realistically attainable in the next few years, the study turned to ways of incorporating its desirable arrangement features on a conventional chassis. A survey of 1976 models led to the selection of the Dodge Aspen two-door sedan as a most promising candidate.

Three variations of the functional police car body, matched to an Aspen chassis, were prepared and are described in the final report. The options are similar in general arrangement, but differ in the amount of body redesign from the stock model. The increase in functional utility and the savings in weight are in proportion to the amount of body changes made, and of added cost. Estimates of cost for these three versions are presented in Section 4.

	Minimum Size	Compact Car Modification	Functional Design
Body Style	4-door sedan	4-door sedan	2-door hatchback
Estimated Weight Including Police Package (lbs)	2,800	4,000	3,900
Estimated Gas Mileage (mpg)	13	9.5	10
Wheelbase (inches)	100	111	111
Overall Length (inches)	170	195	195
Roominess, Front Seat	Inadequate	Marginal	Good
Roominess, Rear Seat	Marginal	Good	Good
Access, Front	Marginal	Fair	Good
Access, Rear	Marginal	Marginal	Good
Equipment Space	Inadequate	Limited	Good

Table 3-1

Evaluation Table

4.0 COSTS

In this section there are presented the detailed estimates for designing and building the several variations of the proposed design concept as well as a discussion of life cycle costs of current and proposed police patrol cars. Although the cost estimates are based on design concepts and on AMF's previous cost experience in designing and building other advanced types of specialized vehicles, they must still be considered as preliminary in nature.

4.1 DETAILED PROTOTYPE AND PRODUCTION ESTIMATES

Cost estimates for each of the final design concept options were prepared for the following order lots:

(a) One prototype only
(b) Twenty (20) prototypes
(c) Production run of 60,000 units per year.

These estimates were prepared on an individual basis, that is, without reference to each other. Each one, therefore, represents the cost of carrying out that option from the present design concept to the delivered vehicle(s).

Table 4-1.
One Prototype

	#1	#2A	#2B
DESIGN:			
Body Studies	41,600	20,000	25,000
Body Drawings	75,000	20,000	32,000
DEVELOPMENT:			
Rear Hatch	20,000	12,000	15,000
Seats	5,000	2,000	2,000
Other New Items	61,200	3,000	5,000
MATERIALS:			
Aspen	5,000	5,000	5,000
Other	17,000	3,000	3,000
TECHNICAL SUPPORT/ODC	74,000		40,000
PROTOTYPE BUILD	80,000	20,000	30,000
Subtotal	378,800	85,000	157,000
G&A and Fee	75,760	17,000	31,400
TOTAL	454,560	102,000	188,400

Table 4-2.

Twenty Prototypes

	#1	#2A	#2B
DESIGN:			
Body Studies	41,600	20,000	25,000
Body Drawings	75,000	20,000	32,000
DEVELOPMENT:			
Rear Hatch	20,000	12,000	15,000
Seats	5,000	2,000	2,000
Other New Items	58,400	3,000	6,000
TOOLING:	180,000	18,000	100,000
MATERIALS:			
20 Aspens	80,000	80,000	80,000
Other	60,000	20,000	30,000
TECHNICAL SUPPORT:	80,000	20,000	40,000
PROTOTYPE BUILD:	600,000	100,000	160,000
Subtotal	1,200,000	300,000	490,000
G&A and Fee	240,000	60,000	98,000
TOTAL	1,440,000	360,000	588,000
UNIT COST	$ 72,000	$ 18,000	$ 29,400

Table 4-3.

Production - 60,000/Year for 3 Years

	#1	#2A	#2B
PRODUCTION ENGINEERING	$10,000,000	$200,000	$3,000,000
NEW TOOLS AND DIES	50,000,000	6,000,000	15,000,000
ASSEMBLY FIXTURING	10,000,000	1,000,000	3,000,000
Subtotal	$70,000,000	7,200,000	21,000,000
AMORTIZED UNIT COST	389	40	117
LOW-VOLUME PENALTY	200	80	200
BASELINE ASPEN FACTORY COST	$3,583	$3,583	$3,583
TOTAL UNIT COST	$4,172	$3,703	$3,900

For concept #2A an assumption was made that an Aspen 2-door hatchback model, for which it is understood production engineering has been completed, but which is not in production, would be available. Based on this it would be reasonable to expect that remaining engineering required would be minimal and that the low-volume penalty would be reduced.

4.2 LIFE CYCLE COSTS

The true cost of ownership of any system is arrived at only by taking into account all of the cost factors associated with the procurement, operation, maintenance, and disposal of the system.. Use of this technique helps to overcome a common tendency to give undue weight to the "first cost" or initial purchase price of a system with consequent neglect of later costs.

This type of analysis was applied to police patrol cars to indicate the savings possible to law enforcement agencies when a more durable, as well as a functionally more suitable, vehicle is utilized. A comparison is made between an intermediate size patrol car (such as Coronet, Fury) and a compact size design such as developed in this study. Although the design goal for the latter was set for a useful life of 3 years and 200,000 miles, for the purposes of this illustrative example a more conservative 2-year, 120,000 mile life is used. Typical cost figures are then -

Intermediate Size

First Cost	$ 5,000
Resale (after 1 year, 60,000 miles)	- 600
Net cost	$ 4,400
Operation (gas, oil, tires) 60,000 x.057	3,420
Maintenance (service repairs) 60,000 x .059	3,540
Total cost for 1 year	$11,360

Functional Compact

First Cost	$ 4,400
Resale (after 2 yrs, 120,000 miles)	0
Net Cost	$ 4,400
Operation 120,000 x .055	6,600
Maintenance 120,000 x .065	7,800
Total cost for 2 years	$18,800
Total cost per year	$ 9,400

It is seen that, even taking a slightly higher maintenance cost and only a modest decrease in fuel consumption, the functional compact shows a savings of almost $2,000 per year over the conventional intermediate.

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