NO. UMTA-MA-06-0052-78-7

LOW LIFE CYCLE COST PARATRANSIT VEHICLE DESIGN STUDY

Philip H. Schneider
David D. Norton

Dutcher Industries, Inc.
7617 Convoy Court
San Diego CA 92111

AUGUST 1978

FINAL REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
URBAN MASS TRANSPORTATION ADMINISTRATION
Office of Technology Development and Deployment
Washington DC 20590

Technical Report Documentation Page

1. Report No. UMTA-MA-06-0052-78-7	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle LOW LIFE CYCLE COST PARATRANSIT VEHICLE DESIGN STUDY		5. Report Date August 1978
		6. Performing Organization Code
7. Author(s) Philip H. Schneider and David D. Norton		8. Performing Organization Report No. DOT-TSC-UMTA-78-14
9. Performing Organization Name and Address Dutcher Industries, Inc.* 7617 Convoy Court San Diego CA 92111		10. Work Unit No. (TRAIS) UM844/R8749
		11. Contract or Grant No. DOT-TSC-1352
12. Sponsoring Agency Name and Address U.S. Department of Transportation Urban Mass Transportation Administration Office of Technology Development and Deployment Washington DC 20590		13. Type of Report and Period Covered Final Report April 1977-November 1977
		14. Sponsoring Agency Code

15. Supplementary Notes
Under contract to: U.S. Department of Transportation
Research and Special Programs Administration
Transportation Systems Center
Cambridge MA 02142

16. Abstract

A preliminary design and cost study was performed for a low life cycle cost paratransit vehicle. The manufacturing technique and cost analysis were based on limited production of 5000 units per year for a ten year period.

The vehicle configuration resembles a small van which will carry six passengers including a passenger confined to a wheelchair. A low floor is standard, and ramps can be provided to make wheelchair entry conventient.

It is estimated that these PTV's could be manufactured for $10,659.93 each. Operational costs would be lower than conventional taxi cabs for several reasons. Low vehicle weight and an efficient 4 cylinder engine provide good fuel mileage and low fuel costs. Durable front end components and excellent component accessibility provide reduced maintenance costs.

17. Key Words Paratransit Vehicle, Handicapped Passenger Vehicle, Jitney, Taxi, Dial-A-Ride	18. Distribution Statement DOCUMENT IS AVAILABLE TO THE U.S. PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	84	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

PREFACE

This final report summarizes the work performed on the Low Life Cycle Cost Paratransit Vehicle contract. The program was structured to provide a design of a vehicle suitable for taxi paratransit usage, optimized for low life cycle cost to the end user.

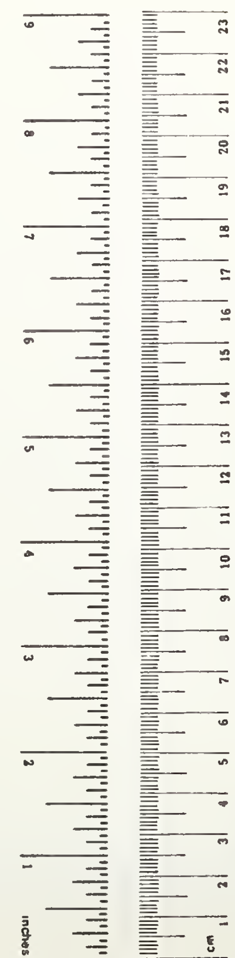
The program was conducted by Dutcher Industries, Inc. under contract DOT-TSC-1352 with the Transportation Systems Center (TSC) of Cambridge, Massachusetts for the Urban Mass Transportation Administration. Technical management of the contract was provided by Mr. J. Kakatsakis and Mr. J. Picardi.

The opinions and findings expressed in this report are those of the authors and not necessarily those of the Government.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

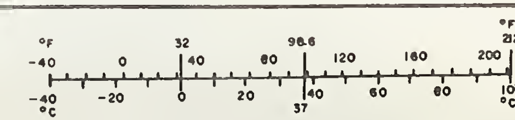


TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

0.1 INTRODUCTION

The purpose of this project is to complete the next logical step in the continuing program to develop a practical paratransit vehicle (PTV). In early 1975, UMTA issued contracts for design, fabrication, and development of two prototype PTV's. These original vehicles, produced by Dutcher Industries (formerly Steam Power Systems, Inc.) and AMF Corporation, were designed with low pollution Rankine cycle (steam) engines. The test results on these vehicles demonstrated the potential for very low exhaust emissions, but the fuel mileage and reliability of the experimental powerplants were not satisfactory. After spending the summer of 1976 on display in the taxi design show at the New York Museum of Modern Art, the steam engines were removed, and conventional spark ignition internal combustion engines were installed. During early 1977, the PTV's were tested for handling characteristics, ride quality, noise, accelleration, and fuel mileage. These tests were performed by Dynamic Sciences, Inc. of Phoenix.

Due to the need for this type of specialty vehicle and the large amount of interest shown by both taxi operators and transit districts, UMTA elected to proceed with this low cost design study. Contracts were issued by the Transportation Systems Center (TSC) of DOT in early 1977. The design study project was broken down into six specific tasks, and each task is discussed in a section of this report. The entire design study project covered only six months, and the objective was to carry the vehicle design only as far as necessary to allow production cost estimates to be made. It is understood that further engineering design effort is required prior to fabrication of preproduction prototype vehicles.

Figure 0-1 is a rendering of the PTV designed during this program.

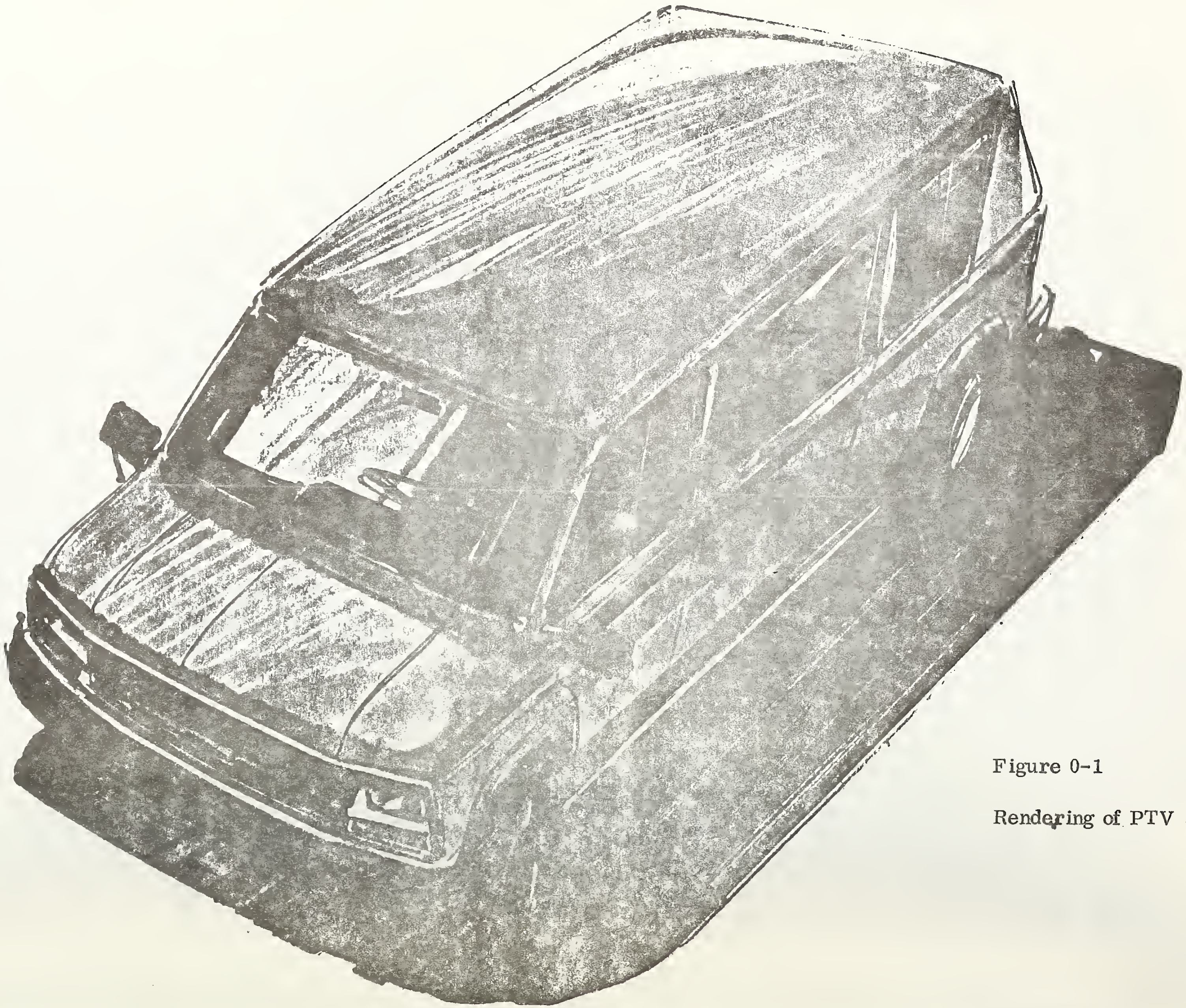


Figure 0-1

Rendering of PTV

1.0 TASK 1 - PROGRAM PLAN

The program plan was submitted after two weeks of the project, and consisted of: a detailed description of all work to be performed, a schedule of all significant milestones, and a description of methodology for the design, cost, maintainability, performance and other analyses to be performed.

Table 1-1 is a comprehensive list of all the tasks which were anticipated during this design study. By considering the relative magnitude of each task and realizing the limited scope of the total effort, a specific number of man weeks was allotted for each task. On the copies internal to Dutcher Industries, Inc. an estimate of the time spent on each task by each member of the staff was made. Of the 104 man weeks total, 38 man weeks were assigned to the primary consultants, Transportation Design and Technology (TDT). TDT has personnel experienced in estimating costs of production designs and had primary responsibility for the cost study, as well as supplying some design effort.

The schedule for each task and the milestone points are illustrated in Figure 1-1. The program reviews shown are the two listed in the contract - at completion of Task 4 and 5. Actually the reviews were held after Tasks 2 and 5, with published interim reports after Tasks 2, 3, and 4.

The description and method used to accomplish each major task is discussed in the section of this report relating to the task.

TABLE 1-1

TASK DESCRIPTION

Task	Description			Man Weeks
1.	Program Plan			1.5
		Prepare detailed program plan		1.5
2.	Prototype Review & Parametric Study			12.0
	a.	Identify design requirements and goals		1.0
	b.	Identify shortcomings of prototype		1.0
	c.	Identify suitable powerplant and drivetrain		1.0
	d.	Identify all design-related factors influencing LCC		1.0
	e.	Prepare parametric study flowchart		2.0
	f.	Determine $/lb tradeoff point		1.0
	g.	Determine drive layout concept of min LCC		2.0
	h.	Prepare preliminary performance calcs		0.5
	i.	Prepare reports to TSC		0.5
3.	System Component Assessment			21.0
	a.	Select powerplant and drivetrain components		2.0
	b.	Perform parametric studies of the following:		
		1.	Suspension system, front	1.5
		2.	Suspension system, rear	0.9
		3.	Brake system	0.2
		4.	Passenger doors	1.5
		5.	Steering system	0.8
		6.	Window materials	0.2
		7.	Climate control system	0.2
		8.	Bumper system	0.1
		9.	Seating configuration	0.5
		10.	Driver enclosure	0.2
		11.	Passenger restraints	0.2
		12.	Wheelchair restraints	0.5

		13. Wheelchair selection	0.2
		14. Ramp configuration	0.5
	c.	Exterior styling concept	1.5
	d.	Interior styling concept	1.0
	e.	Human factors evaluation	1.0
	f.	Vehicle conceptual layout	3.5
	g.	Front suspension conceptual layout	1.5
	h.	Rear suspension/drivetrain conceptual layout	3.5
	i.	Prepare reports to TSC	.5
4.	Repair and Maintenance Assessment		1.1
	a.	Engine and drivetrain R & M assessment	0.2
	b.	Other major component R & M assessment	0.2
	c.	Typical R & M cost estimates	0.2
	d.	Prepare reports to TSC	0.5
5.	Design Data Package		39.8
	a.	Body design layout	6.0
	b.	Chassis design layout	6.0
	c.	Front suspension design layout	2.0
	d.	Rear suspension/drivetrain design layout	3.0
	e.	Passenger restraint system design layout	1.5
	f.	Wheelchair restraint design layout	1.5
	g.	Ramp system design layout	1.0
	h.	Driver enclosure layout	1.0
	i.	Driver controls layout	1.0
	j.	Chassis stress analysis	2.0
	k.	Electrical system schematic	1.5
	l.	Fuel system schematic	0.5
	m.	Cooling system schematic	0.5
	n.	Climate control system schematic	1.0
	o.	Brake system schematic	0.5
	p.	Body panel detail drawings	2.0

	q.	Glazing detail drawings	1.0
	r.	Interior panel detail drawings	2.0
	s.	Suspension detail drawings	1.0
	t.	Drivetrain detail drawings	0.8
	u.	Seating detail drawings	0.5
	v.	Bumper detail drawings	0.5
	w.	Vehicle weight calcs	1.0
	x.	Performance/emissions	1.0
	z.	Prepare reports to TSC	1.0
6.	Manufacturing Cost Estimate		24.6
	a.	Prepare cost estimates for the following:	
		1. Chassis system	3.0
		2. Body system	17.6
		3. Powerplant/drivetrain system	1.0
		4. Optional systems	2.0
	b.	Prepare reports to TSC	1.0
7.	Final Report		4.0
		Prepare final report	4.0
	CONTRACT TOTAL MAN-WEEKS		104.0

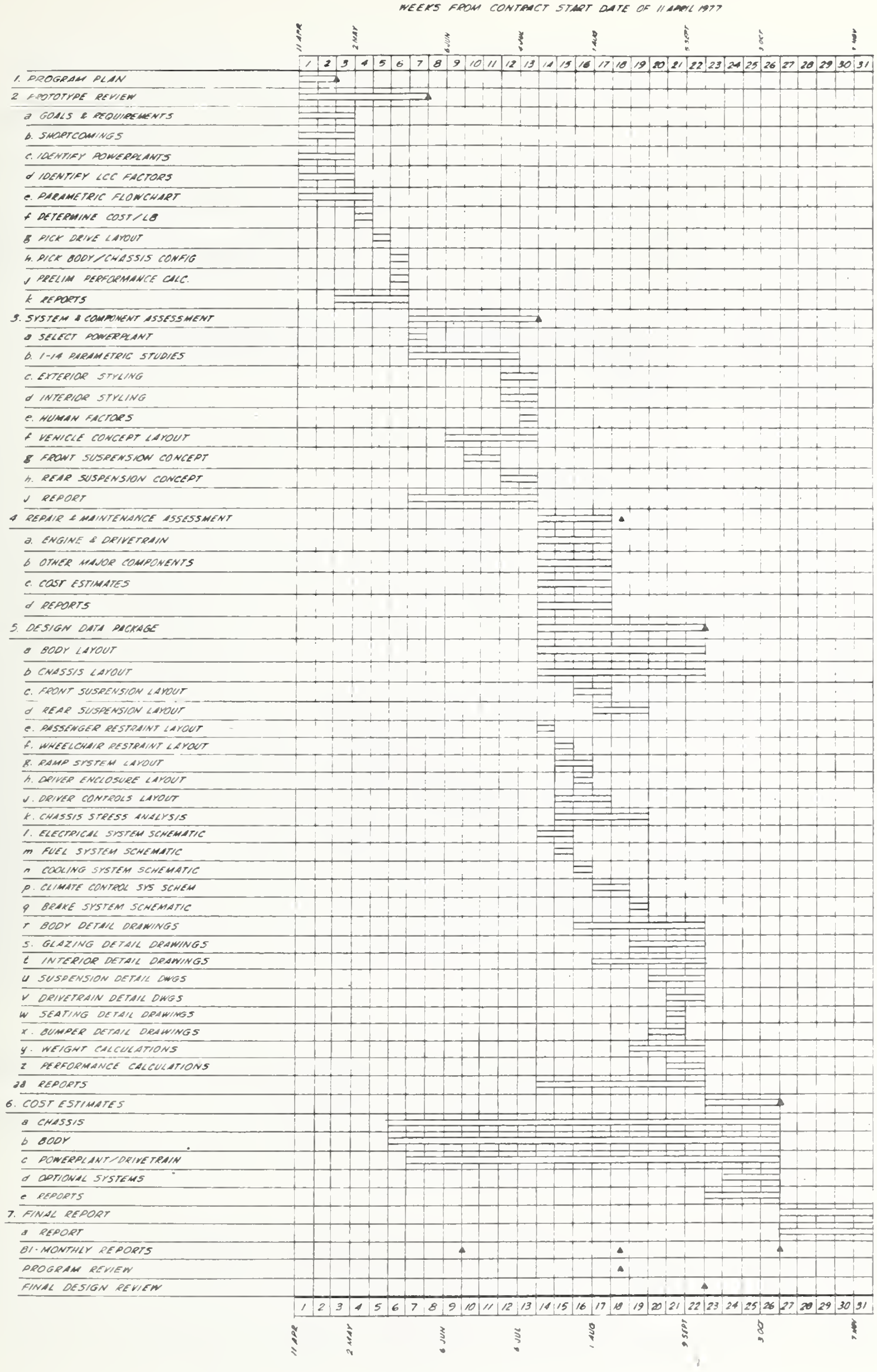


Figure 1-1. LLCC PTV Task Schedule

2.0 TASK 2 - PROTOTYPE DESIGN REVIEW AND PARAMETRIC STUDY

The effort during this task was to review the original prototype design and original criteria to identify areas where cost effective changes could be made, and to make a study of the parameters effecting life cycle cost as they would relate to taxi paratransit applications. At the end of this task, a review was held by DOT representatives at the contractor's facility, and the results of Task 2 were documented (Report No. DOT-TSC-1352-1) in June 1977. Consequently, only a summary of the results of Task 2 are presented herein.

2.1 Prototype Design Review

Three primary sources were used to identify areas where improvements to the original prototype design should be made. The first was our own experience with the design, fabrication, and development test phase. The second was the written evaluation of the vehicle by the International Taxicab Association (ITA) available in "Evaluation of Paratransit Prototype Vehicles", Final Report May 1977, prepared by ITA for UMTA, Project No. IL-06-0037. The third source was the preliminary results of the dynamic tests conducted on the PTV's by Dynamic Sciences, Inc. of Phoenix. A fourth source of information, which became available at the review, was a summary of a report on the human factors evaluation made by DOT. Table 2-1 is a list of shortcomings of the original PTV based on inputs from the four above mentioned sources. All of these problem areas received attention during the redesign phase and will be rectified on any subsequent vehicles.

A few of the original design criteria were also changed based on the various evaluations and on the new requirement of minimizing the cost of the vehicle over its useful life cycle. These criteria changes are listed in Table 2-2.

After evaluation of the shortcomings of the original PTV and the design criteria changes, it was decided to make numerous design changes during the low cost PTV redesign. Changes made for cost effectiveness reasons are listed in Table 2-3, and changes made to improve

TABLE 2-1

SHORTCOMINGS OF ORIGINAL PTV

The front inside wheel lifts off on hard cornering.

The interior noise level is excessive.

The ventilation and air conditioning system is marginal.

The passenger door system is complex and has experienced some reliability problems.

The suspension system is too soft and/or the wrong geometry. The passenger loading condition has an excessive effect on ground clearance and wheel camber.

The steering box has excessive free play.

The front hood is difficult to use.

The passenger - driver communication system is inadequate.

The discontinuity on the passenger compartment floor limits wheelchair maneuverability.

Brake pedal pressure is on the high side.

The 30" passenger doors are too narrow.

The thresholds onto the ramp and into the passenger compartment were too steep for some wheelchair passengers.

No vertical gard rails were provided on the ramp sides.

The jump seat frames had sharp corners.

The seatbelts for the jump seat and wheelchair passengers were not convenient.

The driver's openable window was not large enough, and was difficult to use.

TABLE 2-2

DESIGN CRITERIA CHANGES

Maximum curb weight is not limited to 3000 pounds.

The wheelchair ramp and the driver's partition may be considered optional equipment.

The passenger doors and the wheelchair ramp need not be automated.

It is not necessary for the primary seats to have two arm rests if three abreast seating is utilized.

The maximum turning circle diameter was increased from 35 to 38 feet.

The maximum height of the passenger chair seat may be 17 inches instead of 13.5 inches.

The bumpers must meet the FMVSS requirements of 16 to 20 inches above ground instead of 12 to 20 inches.

The maximum exterior width was increased from 72 to 76 inches.

TABLE 2-3

COST EFFECTIVE DESIGN CHANGES

Change chassis structure design for mass production.

Simplify passenger doors and eliminate automatic controls.

Provide an optional manually deployed ramp.

Use less expensive, mass produceable and easily replaceable body panels.

Use current production automotive hardware wherever possible (driveline, suspension, steering, brakes, etc.).

Change to more durable, vandal resistant and lower maintenance interior materials.

Design bumpers for low cost production and added dent resistance. Purchase stock bumpers if possible.

Use same tire and wheel diameters front and rear.

Eliminate passenger step (lower floor if possible).

Lower roof to specified minimum interior dimension.

Minimize passenger compartment floor area consistemt with wheelchair maneuvering requirements.

Improve access to engine and transmission maintenance items.

Air conditioning will be made optional, not standard equipment.

Driver security partition will be made optional.

Change to one piece windshield.

the functionality of the vehicle are listed in Table 2-4. A third group of changes that were suggested and would be evaluated during the redesign task is listed in Table 2-5.

2.2 Parameters Affecting Life Cycle Cost

The basic parameters that affect life cycle cost are relatively easy to identify, but very difficult to evaluate quantitatively prior to actually producing and operating a given vehicle.

Based on the Voorhees Report ("Study of Future Paratransit Requirements", for UMTA by Voorhees, January 1977) the largest expense is fuel and oil at 5.7¢/mile. The other specified items are the maintenance at 4.5¢/mile, the insurance at 3.6¢/mile, and depreciation at 2.5¢/mile. There is also a category called "other" at 5.2¢/mile which apparently includes taxes, license, interest, and other miscellaneous items. These are tabulated in Table 2-6.

Starting with fuel and oil expenses, a major item that influences fuel mileage (for a given driving cycle) is the vehicle weight. Figure 2-1 illustrates the Federal Driving Cycle fuel mileage vs inertia weight for the 1977 passenger cars. The sales weighted average mileage for a 4000 pound car is 18.2 miles per gallon and the average for a 3000 pound car is 24.4 miles per gallon. Thus the fuel mileage is inversely proportional to vehicle weight, or the fuel cost in cents per mile is directly proportional to vehicle weight. Another major factor in fuel mileage is the proper matching of the powerplant and transmission to the vehicle. The figure illustrates that the fuel mileage of a 3000 pound car varied from 17.0 to 30.0 miles per gallon. It is well known that operating a small displacement engine at a high mean effective cylinder pressure (throttle open) is more efficient than operating a large displacement engine at low mean effective pressure (throttle closed) to produce a given power. Thus a small displacement or low horsepower engine will provide better fuel mileage in a given vehicle. On the other hand, operating a small engine at a high specific output will decrease the engine life compared to a larger engine running at a lower percentage of its rated power. The additional maintenance costs

TABLE 2-4

DESIGN CHANGES FOR IMPROVED FUNCTION

Use production steering gear (to eliminate free play).

Redesign front suspension to prevent early wheel lift off.

Use vacuum assisted brakes to reduce required pedal effort.

Improve acoustic insulation and isolation between engine and passenger compartment.

Provide openable windows in passenger and drivers compartments to reduce "couped up" feeling.

Decrease rear wheel camber change with passenger load.

Improve body finish work.

Improve comfort of primary passenger, folding jump, and driver seats.

Improve weather seals around doors.

Increase side intrusion protection in doors.

Improve climate control system.

Relocate driver's shoulder belt.

Increase departure angle.

Use curved body panels for integral rigidity.

Widen passenger door openings to approximately 36 inches.

Eliminate ramp thresholds and provide side guard rails.

Provide for an optional spare wheel.

Increase length of grab straps.

Improve threshold illumination.

Provide rubber floor mat with markings on floor to assist wheelchair passengers in locating themselves properly to use the restraint devices.

Improve driver's door lock.

Increase dimension between driver's seat and right hand interior partition to five inches.

TABLE 2-5

SUGGESTED CHANGES TO BE EVALUATED DURING THE DESIGN PHASE

Provide multi-directional adjustment for driver's seat.

Add audio-visual signal above door to aid partially sighted and blind passengers.

Make the rear passenger seat fold when not in use to increase usable space.

Make luggage compartment accessible from passenger compartment.

Install 4 wheel disc brakes which can be inspected without wheel removal.

Install power assist steering as an option.

Incorporate a large powerplant access hatch which provides excellent maintenance accessibility.

Provide OEM installation of a tune up and trouble shooting electrical harness.

Offer a diesel powerplant as an option.

Make some body components identical from right to left or front to rear, to reduce the number of different components.

TABLE 2-6

TAXI COSTS - FROM "STUDY OF FUTURE PARATRANSIT REQUIREMENTS"

FOR UMTA BY VOORHEES - JAN 1977

Cost Component	1976 Standard-Size Automobile[1]	1975 Company-Operated Vanpool[2]	1975 Taxi[3]	1974 General DRT Haddonfield[4]	1974 Conventional Bus[5]
	Cents/Vehicle-Mile				
Vehicle Depreciation	4.9	8.4	2.5	10.0	10.4
Operating Costs					
Maintenance (labor, parts, tires)	4.2	2.0	4.5	23.1	24.2
Fuel and oil	4.2	7.0	5.7	5.3	7.3
Insurance	1.7	4.0	3.6	4.5	6.2
Taxes and license	0.7	0.6	--	--	5.5
Garage, parking, tolls	2.2	--	--	--	--
Other	--	--	5.2	40.0	53.1
Subtotal	13.0	13.6	19.0	72.9	96.3
Drivers, helpers	0.0	0.0	21.0	82.5	61.3
Total Operating	13.0	13.6	40.0	155.4	157.6
Vehicle Depreciation + Operating Costs	17.9	22.0	42.5	165.4	168.0

Cost Component	1976 Standard-Size Automobile[1]	1975 Company-Operated Vanpool[2]	1975 Taxi[3]	1974 General DRT Haddonfield[4]	1974 Conventional Bus[5]
	Percent of Vehicle Depreciation + Operating Costs				
Vehicle Depreciation	27	38	6	6	6
Operating Costs					
Maintenance (labor, parts, tires)	23	9	11	14	14
Fuel and oil	23	32	13	3	4
Insurance	10	18	8	3	4
Taxes and license	4	3	--	--	3
Garage, parking, tolls	12	--	--	--	--
Other	--	--	12	24	32
Subtotal	73	62	45	44	57
Drivers, helpers	0	0	49	50	37
Total Operating	73	62	94	94	94
Vehicle Depreciation + Operating Costs	100	100	100	100	100

[1] Federal Highway Administration, "Cost of Owning and Operating an Automobile 1976".

[2] Urban Institute, "Guidelines for the Organization of Commuter Van Programs", report prepared for DOT/UMTA (February, 1976).

[3] Glassman, M. L., "Operational Issues for Paratransit--Operators Prospective", paper presented at Transportation Research Board's Paratransit Workshop (November 9-12, 1975).

[4] The MITRE Corporation, "Summary Evaluation of the Haddonfield, Dial-a-Ride Demonstration", report prepared for DOT/UMTA (May, 1975).

[5] Advanced Management Systems Incorporated, "Life Cycle Costing for Current Rohr and AM General Buses and General Motors RTS-II Bus", report prepared for DOT/UMTA (July, 1976).

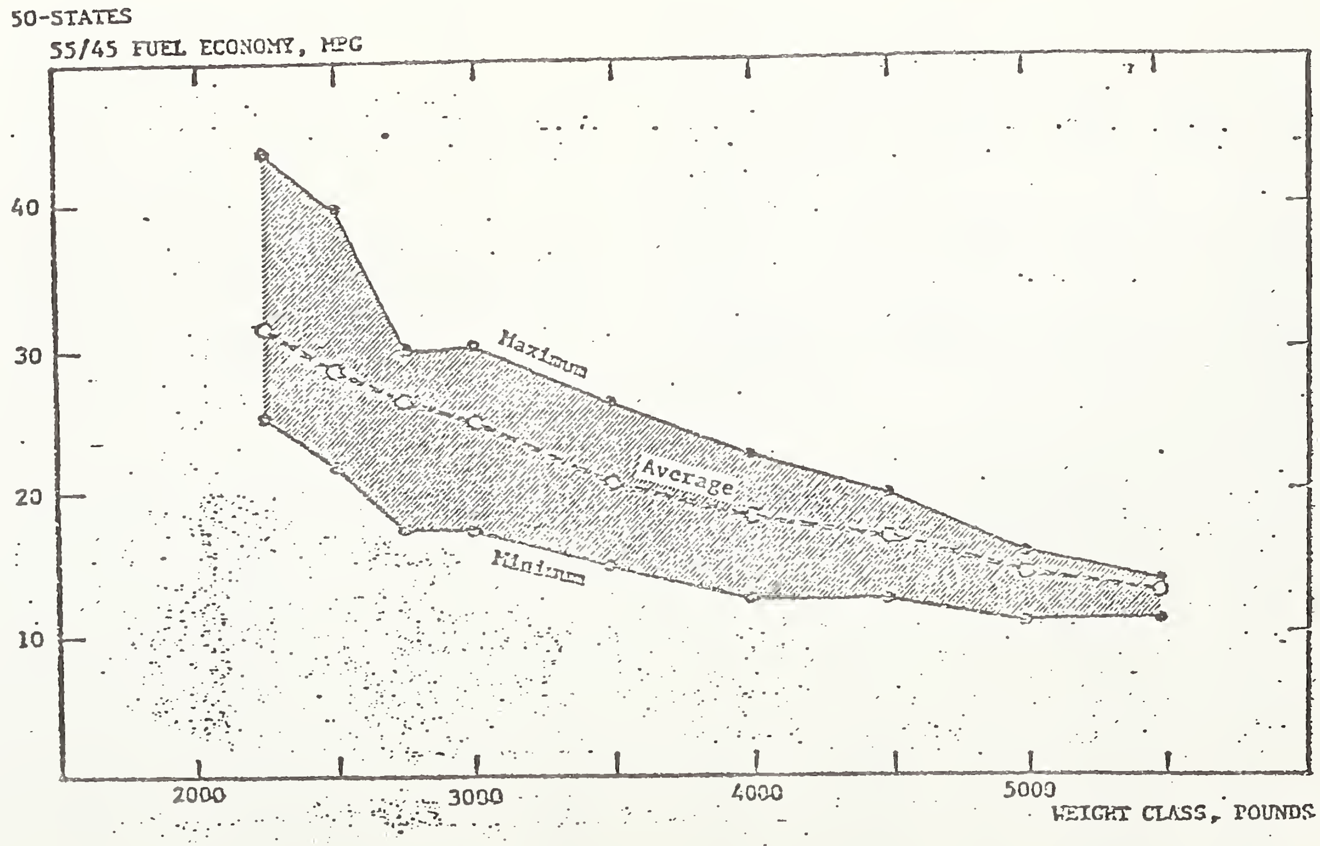


Figure 2-1. 1977 Passenger Car Fuel Economy, by Inertia Weight

Source: SAE #750795
Light Duty Automotive Fuel Economy
Trends through 1977 by Murrell, Pace, Service, and
Yeager of EPA

of running the small engine may out weight the fuel savings. This is one area where making the numerical tradeoff cannot be done until specific maintenance cost data is available.

It is also very important for fuel mileage that the transmission and differential have the proper gear ratios to allow the engine to run in its most economical speed range for the given vehicle duty cycle. If a vehicle will have a maximum speed of 55 or 60 mph, the final drive ratio should be such that the engine speed is proper for peak efficiency at that road load horsepower. In general, this will be at a low engine speed, which will also reduce maintenance costs by keeping piston ring speed and resulting wear as low as practical.

Another item which definitely affects fuel mileage, but is impossible to control, is the driver's driving habits.

If it is assumed that 5¢ of this 5.7¢ fuel and oil cost is for fuel, a 20% improvement in fuel mileage will save 1¢/mile, or 2.4% of the operating costs. Another way to look at this is -- how much additional initial cost is justified if a 20% fuel mileage improvement can be made. According to the Voorhees Report, the useful life of a taxi is between 120,000 and 250,000 miles. Using an average of 185,000 miles, times 1¢/mile, the initial cost could be as much as $1,850 higher if a 20% fuel mileage improvement were obtained.

This 20% improvement can be realized easily, if the vehicle weight can be reduced 20%. Assuming the average taxi in the study weighed 4000 pounds, a reduction to 3200 pounds would be worth up to an additional $1,850. Thus the allowed additional cost for a one pound weight reduction is $\frac{1850}{800} = \$2.31$.

Further fuel mileage improvement may be obtained by proper engine and drivetrain selection is discussed above.

Similarly if a vehicle design were such that maintenance costs could be reduced by 20%, then a 0.9¢/mile saving would be realized, which is 2.1% of the total operating cost. Based on the comments in the ITA evaluation, a significant decrease in maintenance costs could be realized if engine and transmission accessibility were improved. Another major maintenance cost item is brake servicing. This is why ITA recommended disc brakes that could be checked without removing the wheel. Tire replacement is another costly maintenance item. Tire replacement costs will be lower for lighter weight vehicles due to extended tire life and less expensive tires. Unfortunately, the study did not give the relative costs of the various maintenance items.

Other items that could reduce maintenance costs would be: having a protective strip along the sides of the vehicle to prevent minor scrapes, having easily replaced body panels to decrease the labor involved in repairing dented fenders, and making the vulnerable door and lower body panels out of a more dent resistant material.

Excellent driver visibility (having the driver's eyes high enough to see over standard automobiles), improved vehicle maneuverability, as well as high visibility, taxi identification, and abundant lighting (for braking and turning) will reduce the potential of accident involvement, and thereby reduce the maintenance and repair costs.

The interior fabrics and trim must be as durable as possible to decrease the maintenance costs involved with replacing interiors.

If various design features of a new vehicle could reduce the maintenance costs 20%, the initial vehicle cost could increase as much as $1,665 (0.9¢/mile x 185,000 miles) for the same life cycle cost.

Insurance costs could only be reduced after a considerable time period during which vehicle repair and passenger liability costs were reduced. Items such as a passenger restraint bar to prevent passengers from being thrown forward during a sudden deceleration and head restraints for the primary passengers should significantly reduce passenger injuries and consequently the liability insurance costs. Collision insurance costs would decrease for the same reasons that body repair costs would, i.e., protective side strip, dent resistant panels, easibly replaceable panels, good driver visibility, good vehicle maneuverability, and abudant lighting.

On the negative side, a lighter weight vehicle will not be as protective of the passengers in a high speed collision or a collision with a heavier vehicle.

If the insurance costs could be reduced by 20% the savings would be 0.72¢/mile or $1,332 over the 185,000 mile life of the taxi.

It is assumed that nothing regarding vehicle design can be done to reduce taxi and license costs, to the 5.2¢/mile for "other" costs remains the same. These items are primarily functions of local and state regulations.

Combining the potential savings in all three areas, if a vehicle could be constructed that increased fuel mileage by 20%, decreased maintenance by 20%, and decreased insurance costs by 20%, then the initial cost could be up to $4,847 (1850+1665+1332) more than a current taxi.

Obviously if the useful service life of the vehicle could be increased, the life cycle cost would decrease. The depreciation cost is directly porportional to the initial cost of the vehicle and inversely proportional to the service life of the vehicle. If the service life of the vehicle were increased by 20%, the initial cost could be increased by the same percentage for the same life cycle cost.

The life cycle cost of a taxi or PTV is not important as an absolute number, but only how it relates to life cycle revenue. Currently taxis log only 50% of their mileage with passengers and the average passenger load is 1.35 people. (Ref: "Para-Transit" by Kirby et al of the Urban Institute for UMTA and FHA). With a vehicle that can carry five or six passengers and employing a taxi meter capable of calculating six separate fares, the potential for the increased life cycle revenue is very substantial. It is quite conceivable that life cycle revenues could more than double in shared ride applications.

2.3 Parametric Study

The method used to arrive at the optimum design for low life cycle cost required numerous tradeoff studies carried out in a systematic manner. Figure 2-2 is the parametric study flowchart, which illustrates the major decisions that had to be made, and lists for each the alternatives considered and the criteria evaluated.

The first two studies, (drive layout, and engine/drivetrain selection) are very much interrelated and actually were answered simultaneously. The results of this tradeoff study are discussed in sections 3 and 5.

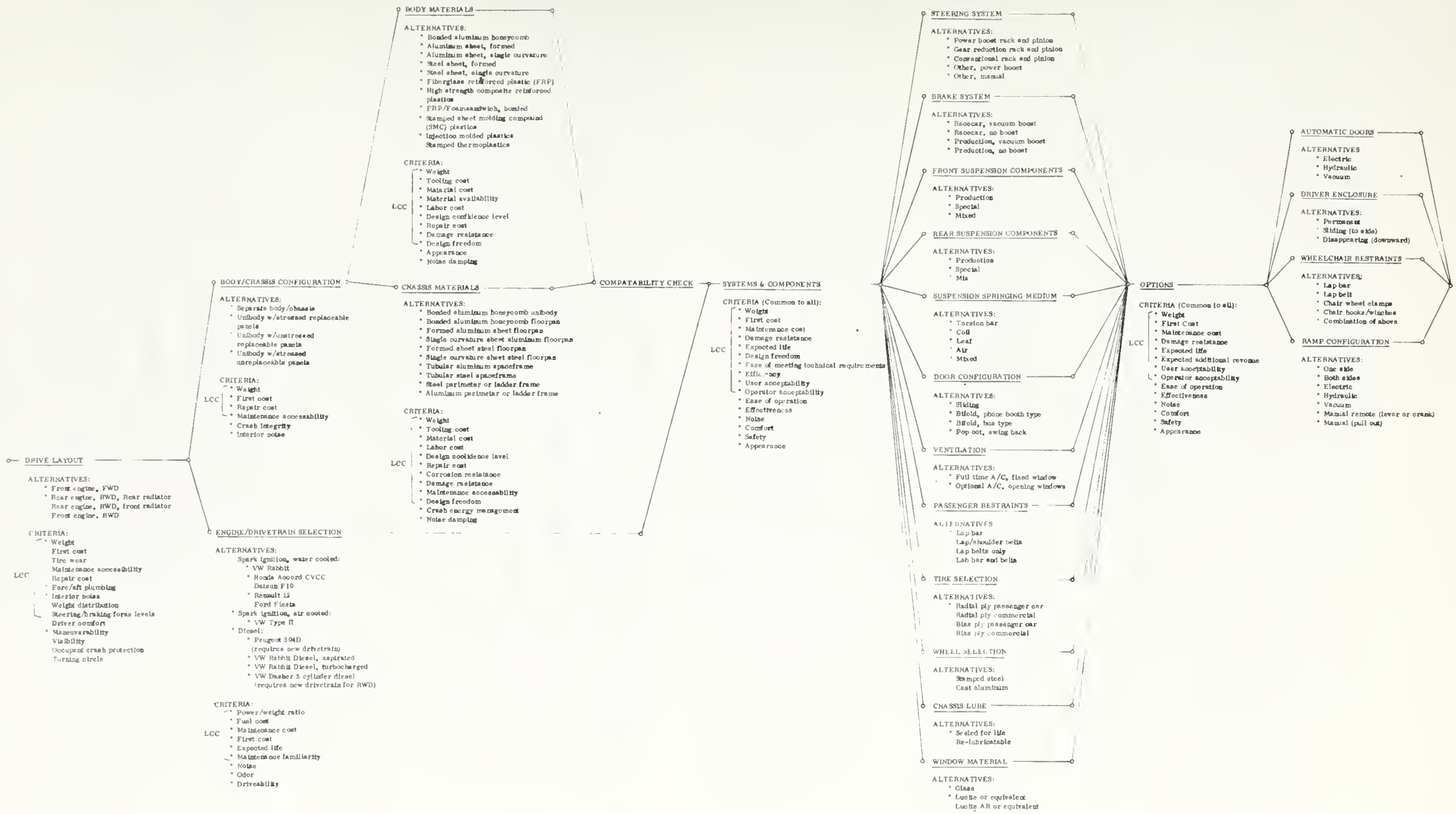


Figure 2-2. Tradeoff Study LLCC PTV Proposal

3.0 TASK 3 - SYSTEM AND COMPONENT ASSESSMENT

Task 3 consisted of selecting the appropriate designs, systems, and components for the redesigned PTV and listing the optional equipment to be offered. The systems and components were selected from those of proven design in taxi service or those that show promise of improving operation, reliability, or maintainability. This task was completed after three months of the program and was documented in Report No. DOT-TSC-1352-3.

3.1 Selection of Vehicle, System, and Component Designs

During this task decisions were made in each category of the tradeoff study flowchart (Figure 2-2).

A. Drive Layout

One on the major decisions that had to be made was what the basic vehicle configuration should be. This includes engine and driveline configuration as well as passenger seating arrangement.

Many various potential configurations of the PTV were laid out and critically evaluated. Three major categories were considered: front engine-front drive, front engine-rear drive, and rear engine-rear drive. In each major category there were several powerplants and driveline configurations as well as two basic driver stations (forward of the axle or behind the axle).

Several of the prime candidates were reviewed in some detail with the aid of detail drawings and some of the general tradeoffs are discussed very briefly in the following paragraphs.

Front engine-front wheel drive has good features such as even weight distribution, low passenger compartment noise, and good driver protection in a frontal collision. It has bad features such as: no American made hardware available at this time except for the very heavy Oldsmobile-Cadillac hardware, no European hardware available for 3000 pound plus vehicles, limited turing circle diameter, limited option on powerplants, limited engine accessibility, and the need to run an ex' aust system through or under a low floor.

Front engine-rear drive has good features such as plenty of available driveline hardware, but has an overriding bad feature of eliminating the possibility of a low flat floor if a conventional driveshaft and differential is utilized. If the engine is located beside the driver, as in a conventional van, the engine and transmission accessibility is very bad. In a front hood housed engine, the vehicle gets very long. The possibility of running a front engine and rear transaxle was considered, but the lack of a low price production transaxle made this choice unattractive.

Rear engine-rear drive has advantages such as several powerplant options, excellent engine and transmission accessibility, and no need to route an exhaust system under the floor. The bad features are: some driveline hardware has to be custom made, the weight distribution is less ideal, and the passenger compartment noise level may be higher, and a front radiator (and auxiliary water pump if necessary) is needed for proper cooling.

The forward control driver position provides a good weight distribution and a shorter wheelbase which decreases the turning circle diameter, but it provides less driver protection in a frontal collision, and in general drivers may not care for the forward control driving position.

The more normal driver station (behind axle) is more convenient and safer, but forces the wheelbase and turning circle to be larger.

In order to evaluate the configurations as objectively as possible and to include the important life cycle cost aspect, each criterion was listed and given a weighting factor. The weighting factors had to be based on somewhat subjective opinions, but were thoroughly discussed and arrived at by consensus of all the involved engineering personnel. Then each configuration being considered was rated based on a scale of how it met the criterion being evaluated. The high numbered weighting factors are the most important, and the high numerical ratings meet the criterion the best.

Figure 3-1 is a copy of the tradeoff evaluation martix for the configuration study. It illustrates that the rear engine-rear drive using an American engine and automatic transmission scored the highest rating. Thus it was selected as the design to pursue.

For our own reference, three additional vehicle configurations were also evaluated using the same martix and weighting factors. These vehicles were the Volvo, Alfa Romeo, and Volkswagen taxi prototypes as presented during the New York Museum of Modern Art taxi display. The three scored 95%, 56% and 20% of the most highly rated configurations evaluated. However, since none of the three meet the wheelchair and able-bodied passenger capacity criteria, they were not studied further. In addition, the VW and Alfa Romeo vehicles utilize flat opposed 4 cylinder engines and drivetrain components either not currently available in the U.S. (the Alfa) or near the end of their production life (the VW). The Volvo utilized an experimental diesel not commercially available anywhere.

B. Body Chassis Configuration

The body chassis configuration will be a unibody with unstressed replaceable panels. This combination is lighter than a separate chassis and body, and allows exterior panels to be produced and installed easily in the event of collision damage. Consequently, the weight and initial cost will be nearly as low as a unibody with stressed panels and maintenance will be less.

C. Engine Driveline Selection

The standard engine and transmission will be the 2.3L (140 in^3), 4 cylinder Ford engine coupled with the Ford C-3 automatic transmission, This combination will provide low initial cost American hardware with plenty of power (approximately 100HP) for acceleration and maneuvering, and good fuel mileage. Since it is

CONFIGURATION NUMBER	ENGINE LOCATION		DRIVEN WHEELS		ENGINE ORIENTATION		ENGINE RELATION TO AXLE		TRANSMISSION & DIFFERENTIAL		TRANSFER CASE REQD		DRIVER POSITION		TOTAL SCORE	% OF BEST	RANK	REMARKS
	FRONT	REAR	FRONT	REAR	TRANSVERSE	LONGITUDINAL	AHEAD	BEHIND	SEPARATE	UNIT	YES	NO	FORWARD CONTROL	CONVENTIONAL				
1	X		X			X	X			X		X		X	530	75	9	LCT-7113 PRESENT ASL PROTOTYPE (PRESENTED FOR REFERENCE ONLY)
2	X		X			X		X		X		X	X		642	91	3	LCT-7132 PINTO ENGINE, AUDI TRANS-AXLE. POOR ACCESS
3	X		X			X		X	X		X			X	680	96	2	LCT-7133 PINTO ENGINE/TRANS, NEW DIFF, POOR ACCESS
4	X		X		X		X			X		X		X	558	79	7	LCT-7112 RABBIT PACKAGE, STOCK FINAL DRIVE RATIO
5	X			X		X	X			X	X			X	611	87	4	LCT-7120 PINTO FRONT ENGINE, AUDI REAR TRANSAXLE, POOR ACCESS
6		X		X	X		X			X		X	X		542	77	8	LCT-7110 STOCK RABBIT. POOR ACCESS, STOCK FINAL DRIVE RATIO.
7		X		X	X			X	X		X			X	705	100	1	LCT-7134 REQUIRES NEW DIFFERENTIAL. PINTO ENGINE/TRANS.
8		X		X	X			X		X		X		X	610	87	5	LCT-7128 REQUIRES NEW DIFFERENTIAL HOUSING ADDED TO VW RABBIT UNIT
9		X		X		X		X		X		X		X	565	80	6	PRESENT DUTCHER PROTOTYPE

R = RATING, MAX OF 10 POINTS
R·F = RATING MULTIPLIED BY WEIGHTING FACTOR

CONFIGURATION NUMBER		FIRST COST: LOW COST POWERTRAIN	FIRST COST: LOW COST CHASSIS	FIRST COST: US-MADE POWERTRAIN	FIRST COST: LACK OF SPECIAL COMPONENTS	MAINT. COST: DURABLE POWERTRAIN	MAINT. COST: ACCESSABLE POWERTRAIN	MAINT. COST: DURABLE SUSPENSION	OPER. COST: LOW VEHICLE WEIGHT	DEVELOP. COST: WILL ACCEPT ALTERNATE POWERPLANT	DEVELOP. COST: GOOD WEIGHT DISTRIBUTION (RE HANDLING)	DEVELOP. COST: CAN ALTER FINAL DRIVE RATIO	SAFETY: DRIVER WELL PROTECTED IN CRASH	SAFETY: PASSENGERS WELL PROTECTED IN CRASH	OVERALL SUITABILITY: SHORT OVERALL LENGTH	OVERALL SUITABILITY: SMALL TURNING CIRCLE	OVERALL SUITABILITY: CONVENIENT DRIVER ENTRY/EXIT	OVERALL SUITABILITY: LARGE LUGGAGE CAPACITY	OVERALL SUITABILITY: LARGE PASSENGER CAPACITY	OVERALL SUITABILITY: LOW INTERIOR NOISE	OVERALL SUITABILITY: HIGH POWER/WEIGHT RATIO
1	R	0	5	0	10	4	3	0	2	8	8	0	10	10	0	3	8	7	0	10	2
	R·F =	0	25	0	60	40	27	0	20	48	40	0	60	80	0	15	48	21	0	40	6
2	R	4	10	4	8	4	0	0	10	8	4	0	0	10	8	10	0	3	10	8	10
	R·F =	24	50	16	48	40	0	0	100	48	20	0	0	80	24	50	0	30	50	32	30
3	R	10	6	10	1	8	4	0	8	7	4	10	3	8	10	3	6	7	5	5	9
	R·F =	60	30	40	6	80	36	0	80	42	20	30	18	64	30	15	36	21	25	20	27
4	R	6	8	0	10	0	8	0	8	2	10	0	3	5	10	0	6	8	5	8	1
	R·F =	36	40	0	60	0	72	0	80	12	50	0	18	40	30	0	36	24	25	32	3
5	R	4	0	5	2	3	4	8	4	9	7	10	3	10	5	0	6	10	10	4	7
	R·F =	24	0	20	12	30	36	64	40	54	35	30	18	80	15	0	36	30	50	16	21
6	R	7	8	0	10	0	5	10	9	2	8	0	0	2	0	7	0	7	10	2	1
	R·F =	42	40	0	60	0	45	80	90	12	40	0	0	16	0	35	0	21	50	8	3
7	R	10	3	10	0	8	10	10	6	9	0	10	4	3	9	3	6	8	5	0	7
	R·F =	60	15	40	0	80	90	80	60	54	0	30	24	24	27	15	36	24	25	0	21
8	R	7	5	1	6	0	10	10	7	8	2	10	4	3	9	3	6	8	5	0	0
	R·F =	42	25	4	36	0	90	80	70	48	10	30	24	24	27	15	36	24	25	0	0
9	R	0	0	0	10	10	7	8	8	0	2	0	3	4	5	7	6	6	5	0	3
	R·F =	0	0	0	60	100	63	64	80	0	10	0	18	32	15	35	36	18	25	0	9
WEIGHTING FACTOR (F)		6	5	4	6	10	9	8	10	6	5	3	6	8	3	5	6	3	5	4	3
		21				27			10	14			14		29						

VEHICLE CONFIGURATION TRADEOFF STUDY

FIGURE 3-1

Figure 3-1. Vehicle Configuration Tradeoff Study very common hardware (over 350,000 engines sold in 1976) parts and service costs will be minimal. Although the actual quote has not arrived yet, it is estimated that this engine and transmission will cost less that $1,000 per vehicle in quantities of 5,000 units per year. This is several hundred dollars less than lighter duty European hardware (VW Rabbit) which was considered.

The 2.3L Ford engine will provide a horsepower per pound ratio of approximately 0.03, which is the high end of the range requested in the contract. Optional engines of lower horsepower will be discussed in section 3.2.

The final drive set up between the output of the transmission and the rear axle must be custom made for this vehicle due to the non standard configuration. At the output of the transmission will be a chain drive transfer case using hardware very similar to that used on the Oldsmobile Toronado and the Cadillac ElDorado. This drives a shaft into a differential using Ford Granada differential gears and special ring and pinion gearing. Layout drawings of this special driveline hardware have been made so that production cost estimates can be obtained as rapidly as possible. It is anticipated that even with the special hardware, the overall cost of this system will be satisfactory for this application.

The differential as designed allows many optional final drive ratios, which provides the opportunity to tailor the vehicle for its intended purpose. An application where considerable expressway driving is done can have a low ratio final drive to provide optimum fuel mileage, and a stop and go type application can use a higher ratio for better acceleration.

D. Body Materials

Cost estimates indicate that fiberglass reinforced plastic exterior panels will have the lowest initial cost as well as low repair costs. Reaction Injection Molded (RIM) polyurethane structural foam was also evaluated.

1. Chassis Materials

Rolled sheet steel beams will be spot welded together to form the frame to which the body panels are fastened.

2. Systems and Components

Steering System - The standard steering system will be a manual unit as used on the Ford E-100 Van. This unit provides the low cost and heavy duty system needed in taxi service. An optional power steering system will be discussed in section 3.2.

Brake System - The standard brake system will utilize vacuum assist with the Ford Van disc brakes on the front and Ford Granada drum brakes on the rear. An optional 4 wheel disc brake system is discussed in section 3.2.

Front Suspension - In order to provide a very durable and readily available front suspension system, the Ford Twin I-Beam suspension will be used. Since the entire front end (steering, brakes, and suspension) is Ford truck hardware, the initial cost and maintenance will be low, and the durability should be better than any in taxi use today. This will be a significant factor in overall life cycle cost of a commercial vehicle.

Rear Suspension - Since the rear engine-rear drive configuration is unusual, a special rear suspension system must be used as well. The suspension system is a deDion type, which is a simple configuration which can be made very durable and is not expected to be costly. Basically there is a large tube which holds the rear wheels parallel to each other in a manner similar to a conventional beam axle.

Suspension Springs - The front springs are coils, the rear leaf, both are specially made but not significantly more costly than standard Ford Van components.

Door Configuration - After considerable evaluation, it was decided to install conventional swing out doors on the PTV. The conventional door provides several advantages over either a sliding door or a bi-fold door. It is lighter and less expensive to produce and to maintain, it is more obvious to passengers how to operate it, and it takes lower force levels to open or close manually. The only disadvantage is that the conventional door will swing a wider arc, which could interfere with traffic on the left or sign posts on the right. It is felt, however, that life cycle cost factors strongly outweigh these disadvantages. Sliding or bi-fold doors could be offered as an option later to those who require them.

Ventilation - Windows that slide open and closed will be installed in the driver's door, and adjacent to the rear seat passengers. This will allow variation in the ventilation to suit various tastes. Also, the heater system fan can be used to force outside air through the vehicle. An optional air conditioning system will be discussed in section 3.2.

Passenger Restraints - The standard passenger restraints will consist of standard lap belts with retractors for the passengers, and a three point system for the driver. An optional passenger restraint bar will be discussed in section 3.2.

Tire Selection - The PTV is being designed for radial ply tires. It is anticipated that the increased tire mileage will more than compensate for the initial cost premium.

Wheel Selection - Stamped steel wheels will be provided on the PTV at least until stamped aluminum wheels can compete on a cost basis.

Chassis Lubrication - A "sealed for life" chassis lubrication system was considered, but since the Ford suspension has been chosen, the chassis will require periodic lubrication. It is also questionable whether a system that is sealed for the life of a passenger car could actually survive in taxi service for 200,000 miles.

Window Material - Until Lucite or some other plastic material is approved for passenger car glazing, glass will be used in the PTV. Eventually a plastic may be cost effective since it is lighter weight and does not break as easily.

3.2 Optional Equipment Available on the PTV

Engines - At the present time, the most suitable diesel engine to offer as an option is the Peugeot 4.9 This is a 4 cylinder diesel rated at 62 HP. It will fit in the same space as the Ford engine and will provide approximately 0.02 HP per pound. The weight increase is approximately 50 pounds and the initial cost premium is estimated to be $800. If fuel costs drop from approximately 4¢/mile to 3¢/mile, the diesel engine will pay for itself in 80,000 miles. Hence it will very likely be a cost effective option for taxi service. In addition, the engine life should be longer and the maintenance costs lower than for the standard spark ignition gasoline engine.

At a later time, the Volkswagen turbocharged diesel engine may also be a good candidate for an optional engine.

Wheelchair Passenger Capability - This option will include wheelchair ramps that the driver sets up manually, positive wheelchair restraints, and floor markings to assist in properly locating the wheelchair.

If the capability of carring two wheelchairs is desired, only two jump seats will be installed, and two wheelchair restraints will be provided.

Final Drive Ratio - Due to the nature of the differential design, several gear set combinations will be made available such that the final drive ratio can be made anywhere between approximately 2.8 and 4.4. This will allow the operator to optimize the gearing for the engine selected and the type of route or service the vehicle will run.

Power Steering and 4 Wheel Disc Brakes - Ford has available a power steering unit combined with a hydraulic brake booster for their 4 wheel disc brakes. This system will be adapted to the PTV and made available as an option. This option may not be cost effective but may be desired in some cases as a driver convenience.

Self Leveling Rear Suspension - Gabriel SL self leveling shock absorbers are offered as an option, to maintain a constant ride height independent of passenger load.

Air Conditioning - A standard after market air conditioning system similar to that installed in VW Vans will be made available as an option. This will be a roof mounted unit such that minimal interior changes are required for the installation.

Passenger Restraint Bar - An optional rear seat passenger restraint bar will be offered as "short stop" protection. It is believed that passengers will be more likely to use the restraint bar than they are to use the lap belts. Although crash tests have not been made with the restraint bar, it is anticipated that with the proper development testing it would be a very effective device. If liability insurance costs can be reduced, it could also be cost effective.

Protective Partition - A bullet resistant Lexan partition between the driver and the passengers can be ordered if desired. The partition will have a perforated section for driver-passenger communications, and a device for making fare transactions.

Spare Wheel, Tire and Jack - The spare wheel, tire, and jack will be available for those fleets or uses where the driver is expected to change his own flat tires. This probably will not be cost effective in fleets where a maintenance man is sent out to change flats.

Taxi Meter - An electronic, multiple fare, taxi meter like the one installed in the prototype will be made available as an option. Some fleets will have their own meters that are passed on from taxi to taxi.

Radios - The standard list of radios - AM, FM, and/or CB will be made available as well as an optional stereo tape player for those fleets that wish to provide driver conveniences or even music to the passenger compartments.

In addition, a selection of commercial band transceivers will be offered for fleet use.

Interior and Exterior Colors - Various interior and exterior color schemes could be made available, and possible variations in interior material quality.

4.0 TASK 4 - REPAIR AND MAINTENANCE ASSESSMENT

4.1 Vehicle Maintainability Features

A primary criterion for the low life cycle cost paratransit vehicle design study is to make the vehicle inexpensive to maintain. This criterion is largely responsible for the configuration selected and the powerplant and driveline layout. The components which are most costly to maintain on a motor vehicle are the powerplant, the transmission, the brakes, the front suspension, and the cooling system. The Dutcher Industries' design is intended to minimize the required maintenance of these items and to make the components as accessible as possible to simplify maintenance when it is required.

Areas that normally require considerable maintenance when standard sedans are used as commercial taxis are front suspension, steering, and brakes. For this reason, it was decided to use the heavy duty Ford Van Twin I-Beam suspension on the PTV. The springs will be lightened as required to provide the proper ride for a lighter vehicle, but the suspension arms and bushings, the steering mechanism, and the disc brake system are all standard components from vehicles heavier than the PTV. This will provide for less frequent maintenance of the front end components. When front end maintenance or repair is required, it will be accomplished more easily because there are no engine components up forward to inhibit accessibility to the steering mechanism or the suspension attach points.

The battery, and the radiator for the engine cooling system are located under a hood forward of the windshield. Since there is no engine directly behind the radiator, the radiator and the fan will be easily accessible for repair or replacement.

As shown in Figure 4-1, the entire engine enclosure can be tilted up to provide convenient access to the engine and driveline components. The engine is completely exposed on the front, top, left side, rear, and bottom. This feature exposes such items as the water pump, the distributor, the carburetor, the intake manifold, the emission control valves, the alternator, the power steering pump, the freon compressor, the dip

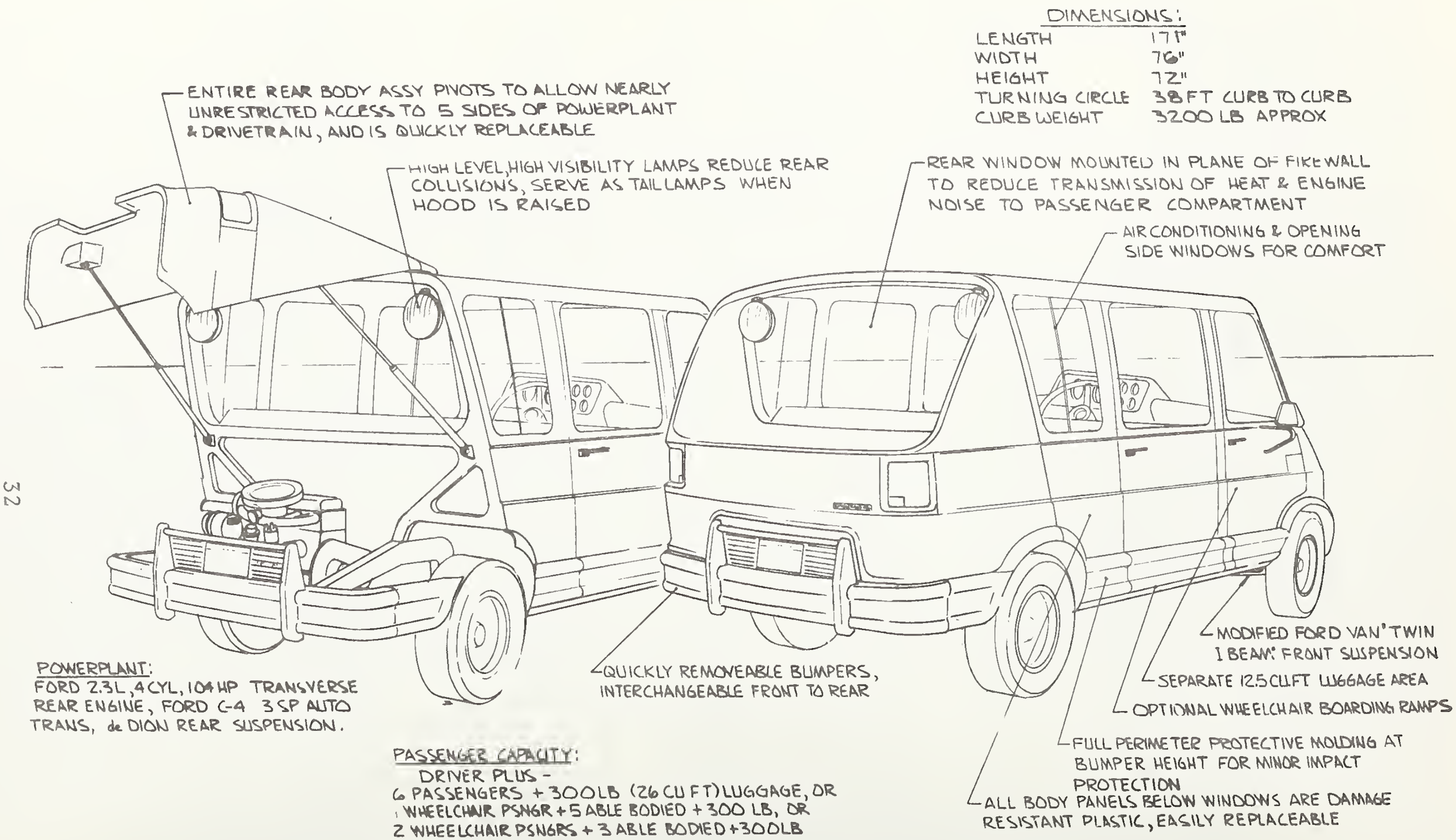


Figure 4-1. Dutcher Industries Paratransit Vehicle

sticks, and the exhaust system such that they can be easily repaired or replaced. Only the air pump and the spark plugs are on the right side of the engine, away from the door. These items are still very easy to reach by comparison with modern vans or sedans.

A particular advantage of this vehicle is the accessibility of the automatic transmission. In a standard van or sedan, the transmission is buried behind the engine and beneath the vehicle floor. In the Dutcher Industries' PTV it is readily accessible in the engine compartment. This configuration should allow the ITA's goal of being able to exchange the transmission in one man hour to be met. It will certainly greatly reduce the time required compared to standard vehicles.

The differential and the drive axles are located conventionally, but the axles contain universal joints like those on vehicles with independent rear suspension. The non standard driveline components are being designed conservatively and are not anticipated to be a maintenance problem.

The rear suspension is also non standard, a deDion system utilizing leaf springs for wheel suspension and location. Again, these components are being designed as heavy duty, low maintenance items readily accessible for replacement.

The PTV body panels will be attached to the structural frame with fasteners that allow for quick replacement of a single panel in the event of minor exterior damage. It is anticipated that a considerable amount of vehicle down time for body work can be eliminated this way.

All exterior body and trim panels will be molded with the color impregnated into the parent material. While this practice places practical limits on the selection of colors and adds somewhat to the cost of the individual pieces, it should greatly reduce the extent of final finishing and later cosmetic repair operations. This does not preclude the use of multi-colored paint schemes or self-adhesive vinyl trim accents should the customer desire a less utilitarian appearance.

The interior will be made as durable and vandal resistant as practical to reduce interior maintenance costs. Heavy gage vinyl over foam plastic is used as the "soft" upholstery material. Rubber floor mats are used throughout, and all non upholstered interior areas are covered by semi-rigid molded Kydex plastic, color impregnated. Both vinyl and Kydex materials are easy to clean, and resistant to cuts, punctures, tears, and graffiti.

4.2 Parts Availability and Cost

As many of the components as possible will be purchased from Ford. This includes engine, transmission, front suspension, brakes, differential gears, steering system and driver controls. Although we are unable to guarantee these components will be available for the next ten years, the parts are from current models which we expect will be continued through the forseeable future.

Wherever possible, all other components are used on current model production American automobiles. This will assure reasonable cost and supply of parts for several years.

Components which must be fabricated specifically for the PTV will be kept available as required to supply the PTV market. Depending on the component fabrication technique, these components may be more costly due to the relatively small production quantity involved.

An effort was made to determine the costs of the various maintenance items on existing taxi cabs. The question was discussed with Mr. Richard Gallagher of the International Taxicab Association. He indicated that there were no numbers available on maintenance costs of individual components. All taxi fleets have different costs depending on make, model, and year of vehicle, annual mileage, type of environment, and whether they do inhouse mechanical work, or contract it out. Even within most fleets they have vehicles from several model years and even from different manufacturers. Mr. Gallagher said that items such as engines or transmissions may last anywhere from 55,000 to 175,000 miles between overhauls. For this reason it is not practical to place a numerical value on the benefit of component accessibility or on component durability.

In the first interim report (DOT-TSC-1352-1) there was a discussion on life cycle cost which related the percentage of maintenance costs to total operating costs. Since a breakdown of maintenance costs for various components is not avaialble, the previous discussion is difficult to elaborate on, and it is not repeated here.

4.3 Estimated Labor Time

In order to make some sort of comparison in the case of maintaining the Dutcher Industries taxi, the labor required to perform various maintenance and repair tasks was estimated by the mechanics at Dutcher Industries, and compared to the Mitchell Manual for estimating repair tasks on 1977 American sedans. These items are tabulated in Table 4-1 for Dodge 6 and 8 cylinder cars, for Ford 4, 6, and 8 cylinder cars and for the Dutcher Industries PTV. It is assumed that the mechanic is familiar with the PTV and the time differences are due to either the relative simplicity or accessibility of the tasks. The estimates show signficantly reduced replacement times for many of the engine, transmission, and suspension related components. These numbers are estimates, of course, and must be confirmed later after the hardware has been built.

4.4 Special Tools and Equipment Requirements

At this stage of the design study we forsee no need for any special tools or equipment for maintaining the Dutcher PTV. Further, because of direct accessibility to the engine and transmission, several service operations normally requiring a hoist or pit can be done on a flat floor.

TABLE 4-1

COMPONENT REPAIR AND MAINTENANCE LABOR ESTIMATES IN WORKHOURS

COMPONENT	TASK	DODGE 6 cyl	DODGE 8 cyl	FORD 4 cyl	FORD 6 cyl	FORD 8 cyl	DI PTV
Air Pump	Remove and Replace	1.1	1.0	0.8	0.6	0.6	0.8
Alternator	" " " " "	0.8	0.8	0.6	0.7	0.7	0.6
Brake Pads, Front	" " " " "	1.2			1.2		1.2
Brake Shoes, Rear	" " " " "	1.5			1.9		1.9
Brake Pads, 4	" " " " "	-			2.0		2.0
Brake Pads and Cyls	Overhaul	4.3			4.4		4.4
Carburetor	Adjust	0.5			0.5		0.5
Carburetor	Remove and Replace	1.1			0.9		0.9
Differential	" " " " "	5.6			5.3		2.0
Engine	" " " " "	7.5	9.1	9.2	8.4	8.4	6.0
Cyl Heads	" " " " "	4.3	6.4	5.8	4.5	6.9	5.0
Engine	Tune Up, Minor	1.2	1.6	1.0	1.1	1.4	1.0
Engine	" " ", Major	3.7	4.1	3.2	3.9	4.5	3.2
Front Suspension	Align	1.5			1.5		0.3*
Steering Knuckles	Remove and Replace	2.5			1.5		1.5
Ball Joints, Top	" " " " "	1.5			1.8		0.8 [KING PIN]
Ball Joints, Bottom	" " " " "	2.3			1.8		
Fuel Pump	" " " " "	0.6		0.6	0.5	0.7	0.4
Water Pump	" " " "	1.3		2.0	1.3	1.5	1.0
Radiator	" " " " "	1.2		1.2	0.9	1.1	1.0
Rear Springs	" ' " " "	2.2		1.9	2.1	0.6	2.0
Rear Shocks	" " " " "	1.0		1.0	0.9	0.9	1.0
Timing Chain	" " " " "	2.6	3.1	2.0	3.8	3.9	1.0
Transmission	" " " " "	3.4		4.0	3.4	3.6	2.5
Transmission	Overhaul	6.6			5.3		5.3
Universal Joints	Remove and Replace	1.3(for 2)			1.3(for 2)		2.6(for 4)

*The Twin I-Beam suspension requires toe adjustment only.

COMPONENT	TASK	DODGE 6 cyl	DODGE 8 cyl	FORD 4 cyl	FORD 6 cyl	FORD 8 cyl	DI PTV
Battery	Test	0.3			0.3		0.3
Battery	Remove and Replace	0.5			0.5		0.5
Battery Cables	" " " " "	0.3			0.5		0.5
Belts 1st	" " " " "	0.3			0.3		0.2
2nd	" " " " "	0.5			0.5		0.4
3rd	" " " " "	0.8			0.8		0.6
4th	" " " " "	1.0			1.0		0.8
Brakes	Minor Adjust	0.5			0.5		0.5
Gas Filter	Remove and Replace	0.5			0.3		0.3
Oil and Filter	" " " " "	0.3			0.3		0.3
Radiator Hoses	" " " " "	0.8			0.8		1.2
Rear Axle	Drain and Refill	0.6			0.3		0.5
Spark Plugs	Remove and Replace	0.6	0.7	0.5	0.6	0.8	0.5
Thermostat	" " " " "	0.7		0.8	0.6	0.6	0.6
Transmission	" " " " "	0.8			0.8		0.6
Wheel Bearings	Repack	1.4			1.4		1.4
Headlight	Remove and Replace	0.3			0.3		0.3

5.0 TASK 5 - DESIGN DATA PACKAGE

5.1 Vehicle Design

A. Selection of Optimum Design

Overall vehicle design and designs of the various systems were chosen with the intent to provide the lowest life cycle costs for specific uses as a ride sharing paratransit vehicle. At the outset of the program, numerous different vehicle and powerplant combinations were evaluated to determine which overall configuration offered the potential to provide the lowest life cycle cost. This procedure and its results were discussed in section 3. The outcome of this study was the selection of a rear engine-rear drive vehicle. This configuration provides features such as: use of a heavy duty van front end, use of a production American engine and transmission, excellent engine and transmission accessibility, and the option of a diesel engine installation.

B. Overall Vehicle Configuration

The configuration of the PTV is illustrated in Figure 5-1. This drawing shows the passenger seating arrangement and the basic vehicle dimensions. The PTV seats up to six passengers in comfort, including one wheelchair confined passenger if desired. A low (12 inch) floor and large doors provide ease of entry for the elderly and handicapped.

The PTV wheelbase is 114 inches, which allows a 38 foot curb to curb turn circle diameter. This compares favorably to the 41 foot circle provided by a standard Checker taxi. The overall length is only 177 inches, which is 31 inches shorter than a Checker. These features make the PTV easy to handle in city traffic while providing a large payload.

A separate luggage or package compartment is provided to the right of the driver with its own convenient right side door.

Optional features such as wheelchair ramps and restraints, a diesel engine, a

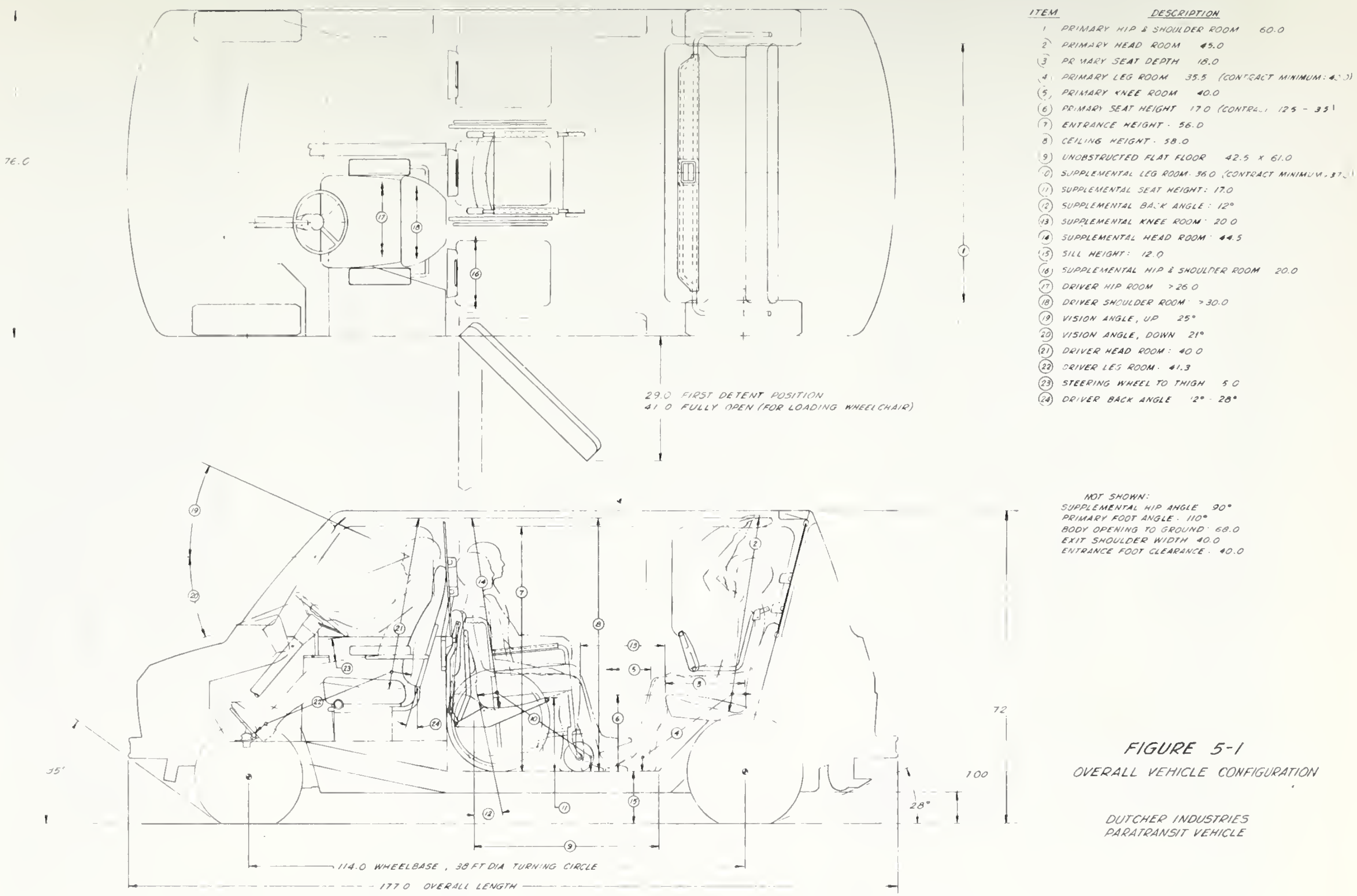


Figure 5-1. Overall Vehicle Configuration

bullet resistant partition to provide driver security, short stop restraint bar, air conditioning, power steering, and 4 wheel disc brakes are available and their designs are discussed later in this report.

C. Structural Chassis

The chassis structural concept drawing is shown in Figure 5-2, and the details of the various sections are shown in Appendix A. It was decided to design the chassis members out of rolled steel parts that could be welded together. Steel is less expensive than the aluminum that was used in the prototype. The all welded unit frame provides a very stiff and strong structure without being excessively heavy.

A finite element computer model of the PTV structure was set up. The material thicknesses were initially chosen based on vehicle fabrication experience. The model was then subjected to the various tests specified in the Federal Motor Vehicle Safety Standards (FMVSS). These tests included the five mile per hour front and rear impact (FMVSS #215), the roof crush test (FMVSS #216), the three 'g' vertical bumps, and chassis torsional loads.

Initially the results indicated high stresses in certain chassis members, so the material thicknesses of the sections were changed as required. The model now indicates stresses for all members that are significantly below the yield stress level. The entire stress analysis report is included as Appendix B.

D. Body

The basic body styling and the exterior body concepts are illustrated in Figure 5-3. Exterior body panels are designed to be made of fiberglass reinforced plastic which are individually fastened to the frame with sheet metal screws and flexible sealant. The details of the panels and attachment are included in Appendix A. This method of attachment is expected to save a considerable amount of repair effort after minor collisions.

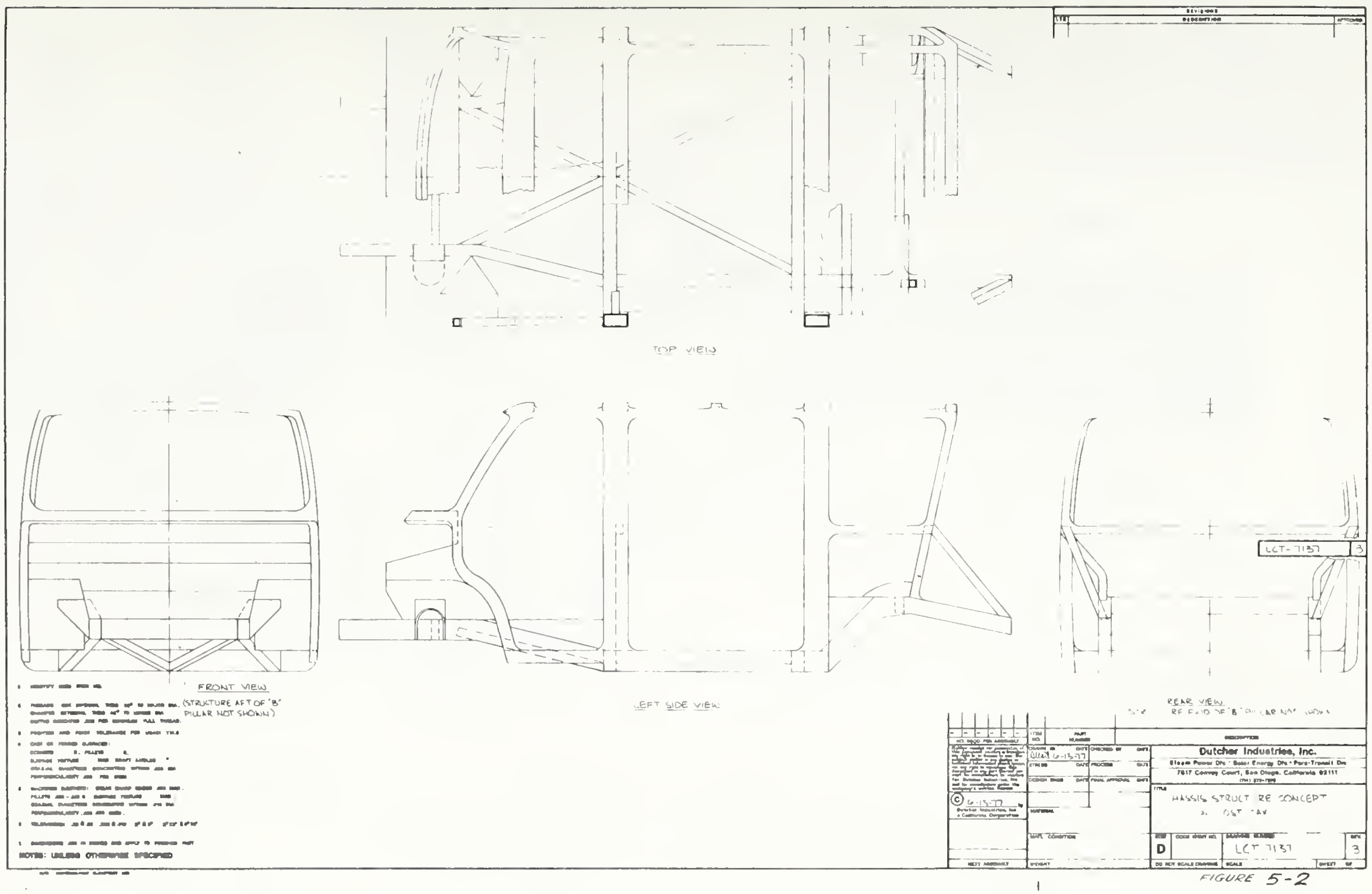


Figure 5-2. Chassis Structure Concept

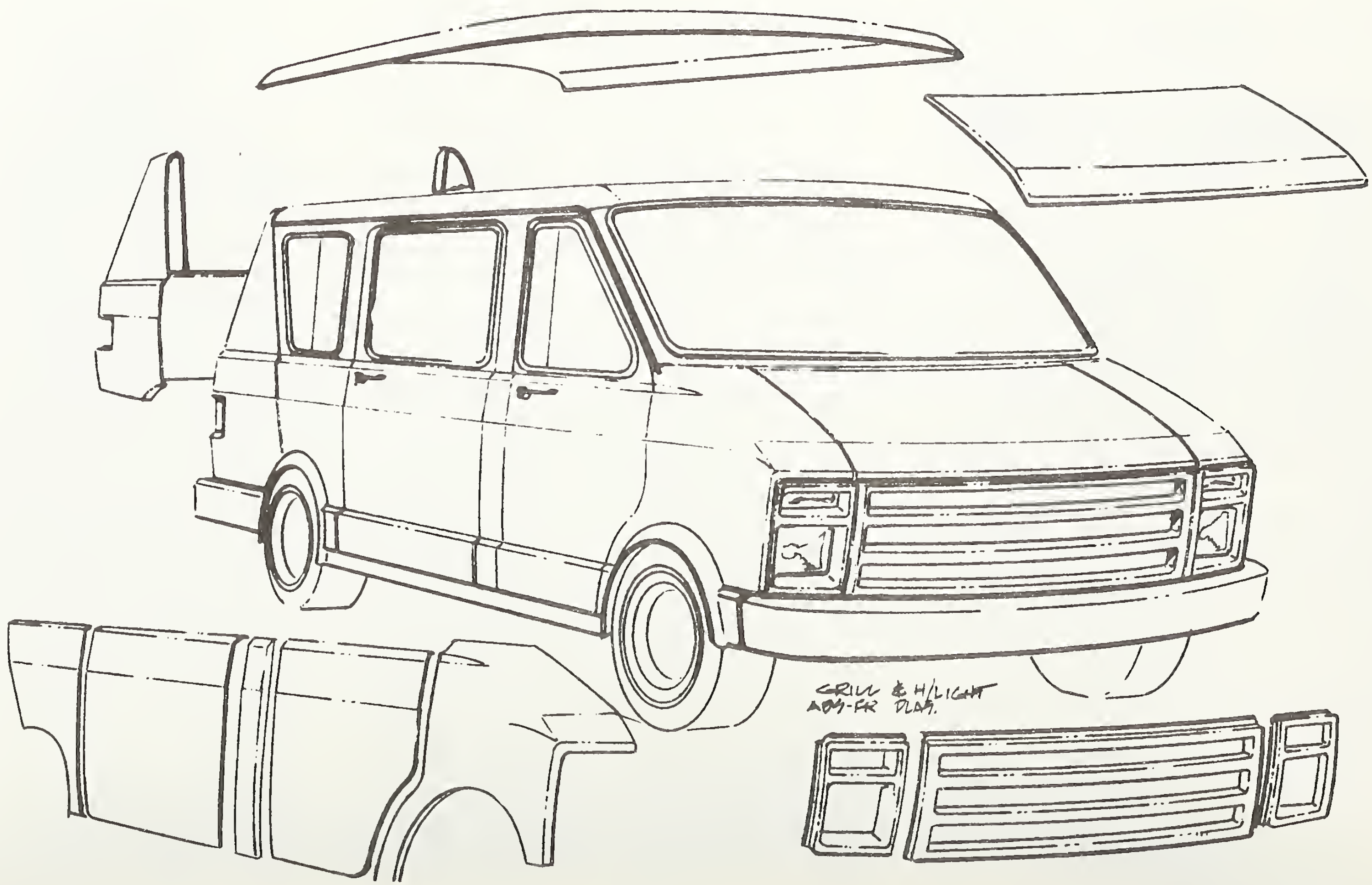


Figure 5-3. Exterior "NON METAL" Body Panels

The windshield area is designed using a Ford Econoline Van windshield. This saves on tooling required to make a custom glass shape. The grill is made in three pieces of thermo-formed ABS plastic.

The driver's door has a sliding glass window for ease of paying tolls and for simple ventilation. The sliding window is less expensive to build and maintain than a roll down type. The two passenger doors are very wide (42 inches) to provide generous room for loading wheelchairs or other bulky items. The passenger doors have fixed glass windows, but there are sliding windows adjacent to the rear seat passengers to provide ventilation. There is a separate luggage compartment door forward on the right side.

The entire rear body panel is a large door which provides excellent access to the engine and transmission area when the door is raised. The rear window is fixed to the "D" pillar and does not lift with the door. There is a small hood in front which provides access to the radiator, the battery, and the spare tire.

E. Passenger Compartment

As shown in Figure 5-1, the passenger compartment seats six adults comfortably, including a wheelchair passenger. Primary seating is for two passengers facing forward with a large arm rest between them. The rear seats are 21 inches wide in this configuration. When necessary, the arm rest can be folded up to provide a 60 inch wide bench seat.

Secondary seating is provided by three rear facing fold down jump seats, with the outboard seats 18 inches wide, and the center seat 16 inches wide. A wheelchair confined passenger can be located in the center, facing aft, by raising the jump seats to allow for the wheelchair to enter and be properly located. The outboard jump seats can again be lowered if desired.

The jump seat design has been improved over that used in the Prototype PTV. The seats are made of durable and easy to maintain molded plastic covers over a steel tubular frame. No support cables are required and positive spring clips to hold the seats in the raised position are provided. In either position, the jump seats have no protruding steel members which might be hazardous in a sudden stop. The jump seats have high backs for increased comfort and safety and are provided with head restraints. The jump seats are illustrated in Figure 5-4.

The primary seat is made of foam with a heavy vinyl cover to provide good comfort and vandalism resistance as well.

An optional short stop restraint bar is available which can be pulled down in front of the rear seat passengers to limit their forward travel in the event of a sudden stop. The design is such that the molded plastic pad with semi rigid foam inside and the tubular side supports will absorb energy during a frontal collision. A positive latch is installed to retain the bar in the raised position when not in use.

Head restraints for the primary passengers are horizontal bars with molded self skinning urethane foam attached between the "D" pillars.

All six seats are provided with late model retracting lap belts which comply with FMVSS #209.

Figures 5-5 and 5-6 illustrate the interior trim parts. Interior panels are made of a tough thermally formed plastic and are individually replaceable. The panels adjacent to the rear seat include arm rests and ash trays. The lower portion of the forward bulkhead and beneath the rear seat are carpeted because that is the most durable covering for those areas. The floor covering is a heavy duty rubber mat which provides sure footing, ease of maintenance, and acoustic and thermal insulation.

The door latch release handles are Dodge parts and soft passenger assist handles

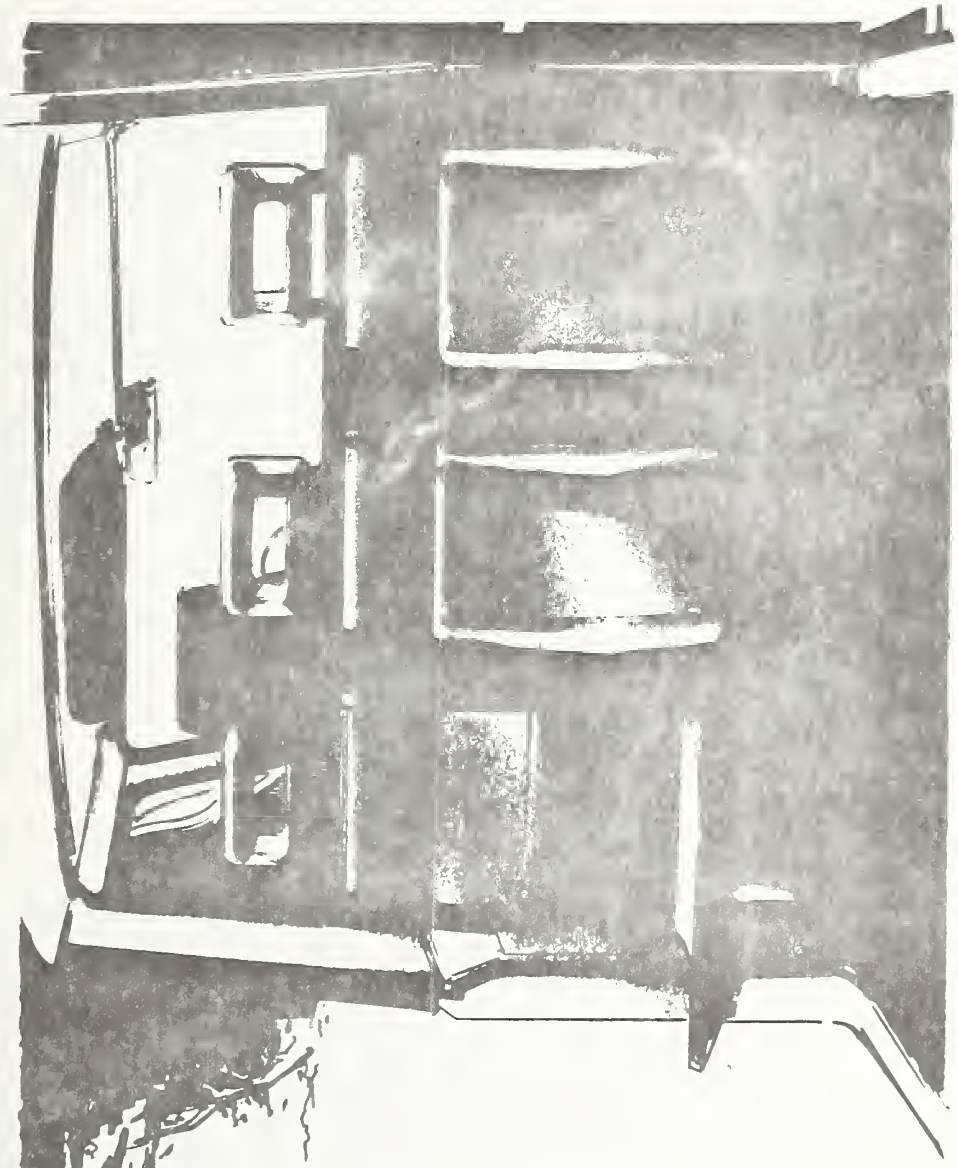


Figure 5-4. Jump Seats

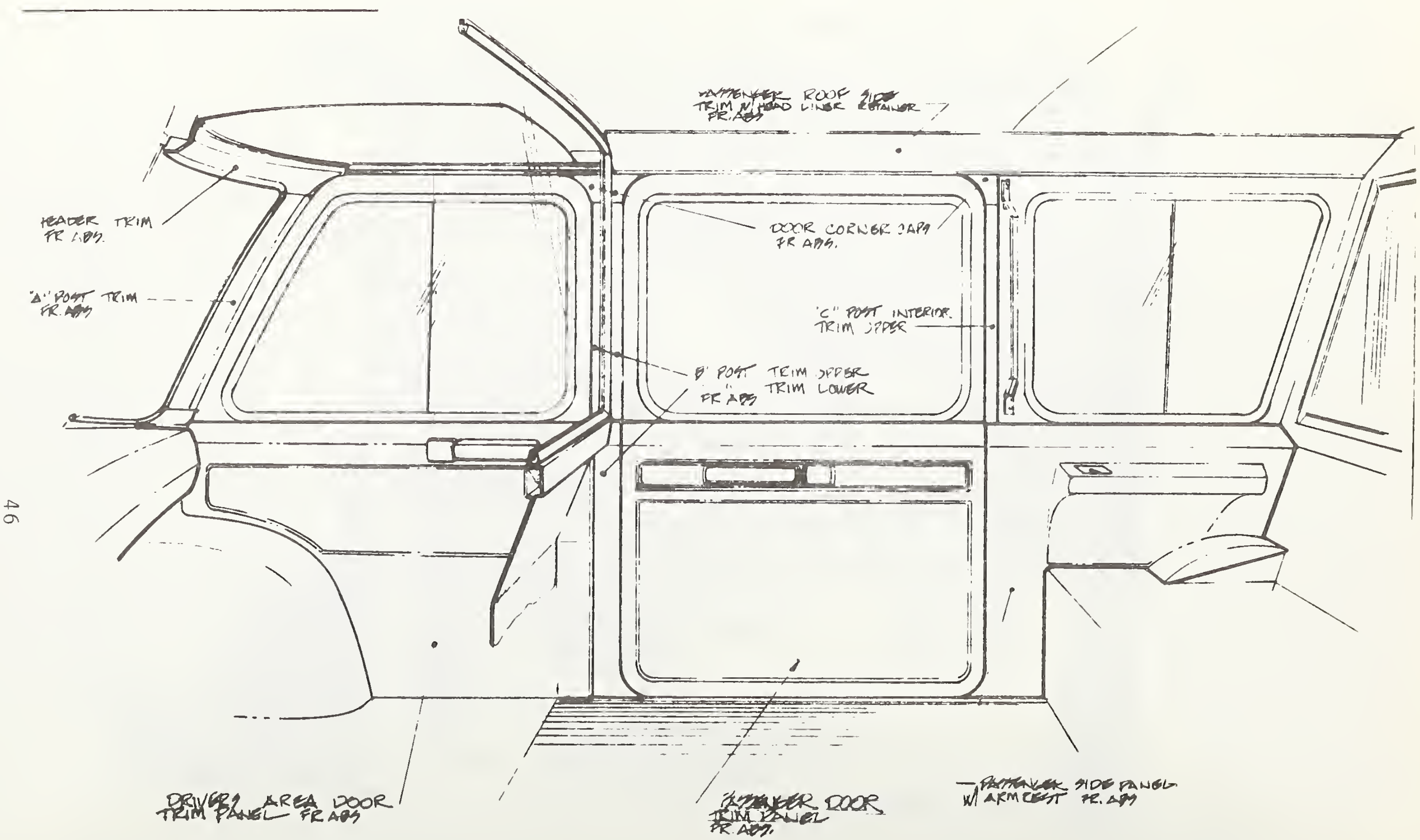


Figure 5-5. Interior Trim Parts

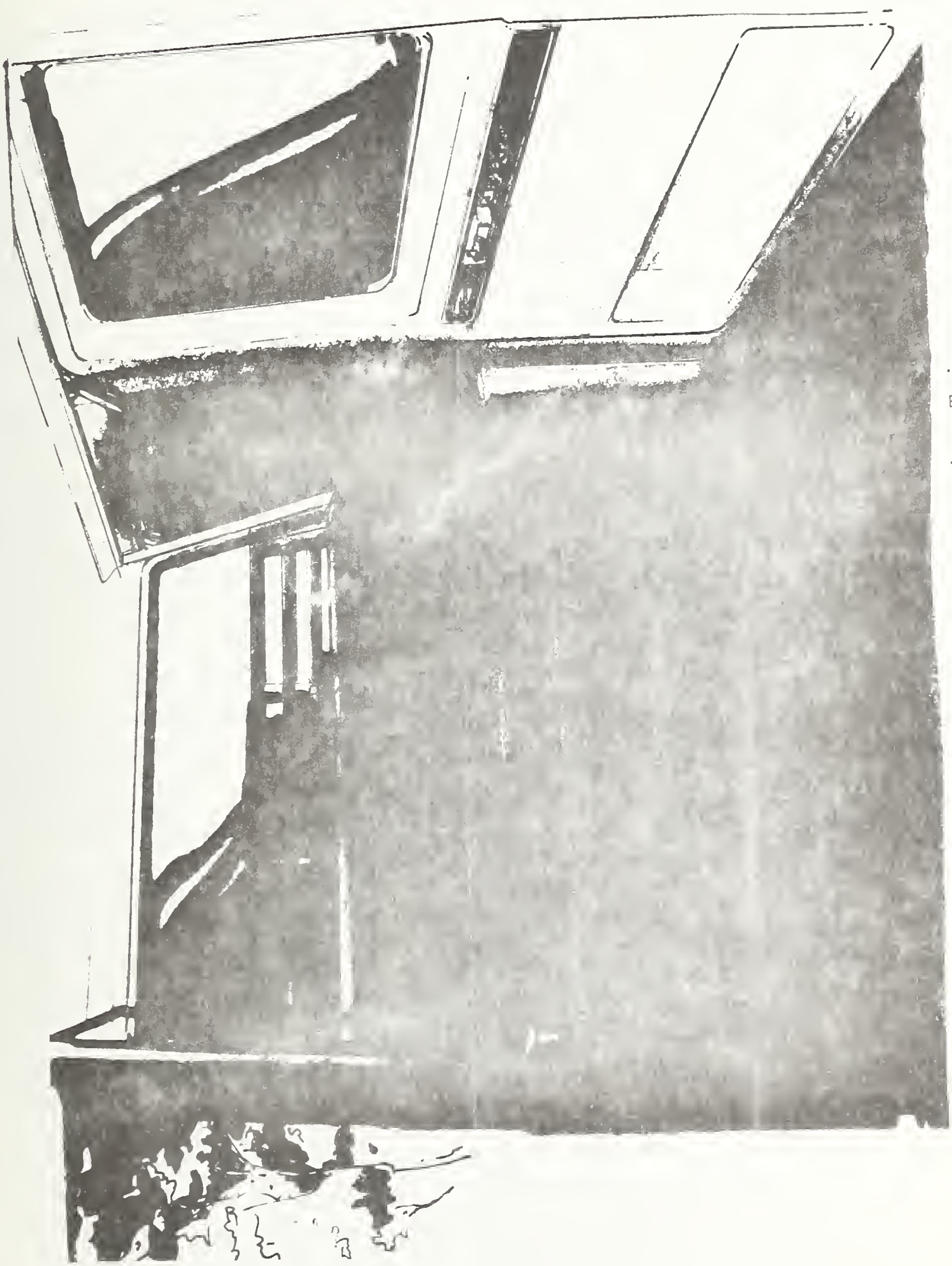


Figure 5-6. Interior Trim

are fastened to the "C" pillars. The interior is illuminated with both overhead and door sill area lights.

F. Driver's Compartment

A sketch of the driver's compartment is shown in Figure 5-7 illustrates the interior trim panels. The driver's seat is manufactured by Royal Industries, is very comfortable, and can be adjusted fore and aft, up and down, and for seat back angle with arm rests and head restraint included. The steering column is from a Ford Van, and the instrument cluster is made by Teleflex Corporation. All the standard instruments are provided.

The dash board is all padded to comply with FMVSS, and a locking glove box is provided to the left of the instrument panel.

Control pedals, gear select lever, and heater controls are all located conventionally. The flat surface to the right of the driver is used for optional radio and taxi meter as it was in the prototype.

G. Steering and Front Suspension

One of the desirable features of this vehicle is the heavy duty front end. Use of the Ford Van Twin I-Beam suspension, power disc brakes, and steering gear provides an exceptionally rugged and durable system which will require very little maintenance. The suspension, brake, and steering geometry is illustrated in Figure 5-8. This suspension uses long lever arms such that the reaction loads are very low. Springs and shock absorbers are standard Ford components. Also, the caster and chamber angles are set on assembly, and never need adjustment. Since there is no powerplant in the front, the suspension attach points are easily reachable in the event that maintenance is necessary.

The steering geometry (in conjunction with 114 inch wheelbase) allows for a 38 foot curb to curb turning circle diameter. An optional power steering unit using production Ford hardware is available.

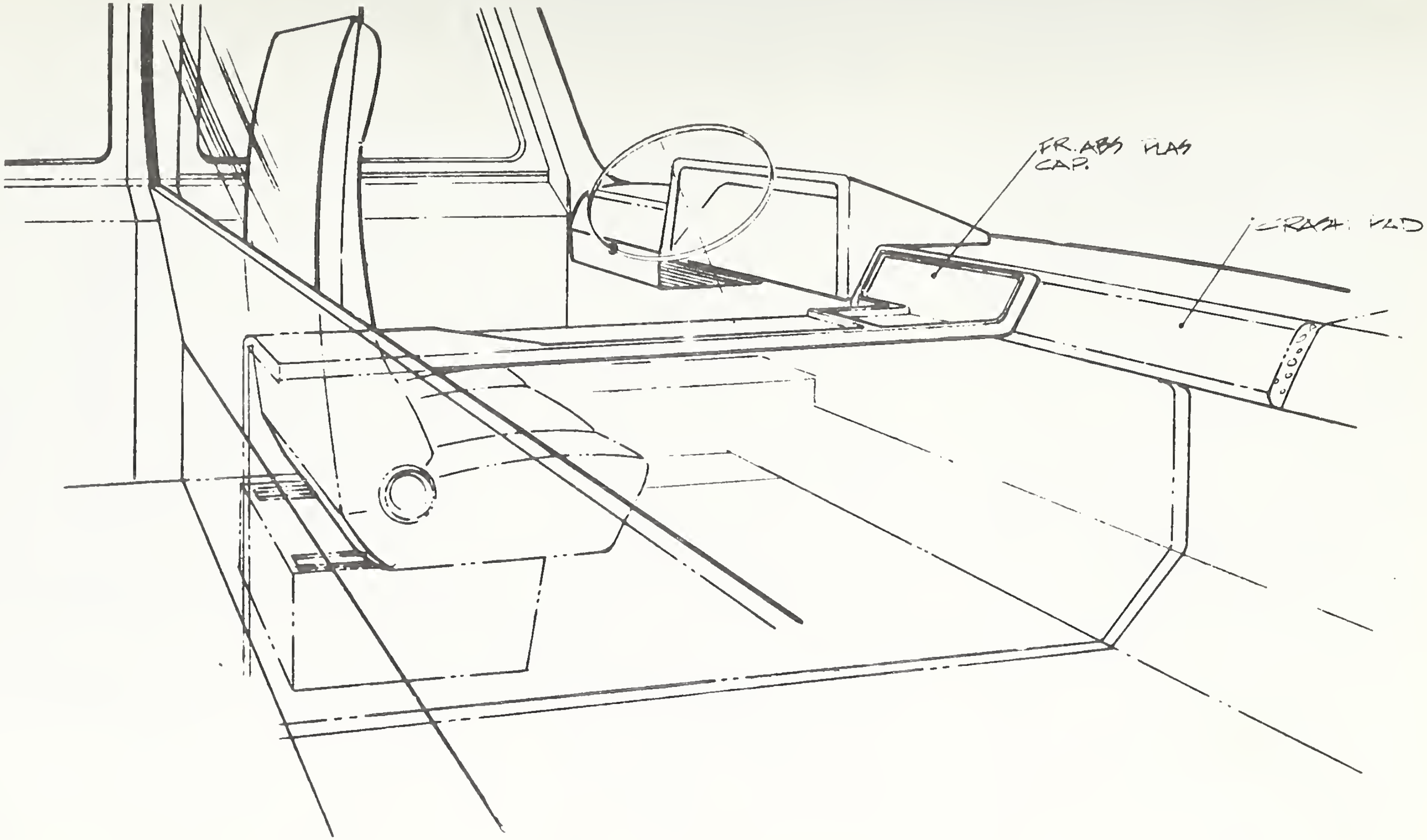


Figure 5-7. Driver's Area

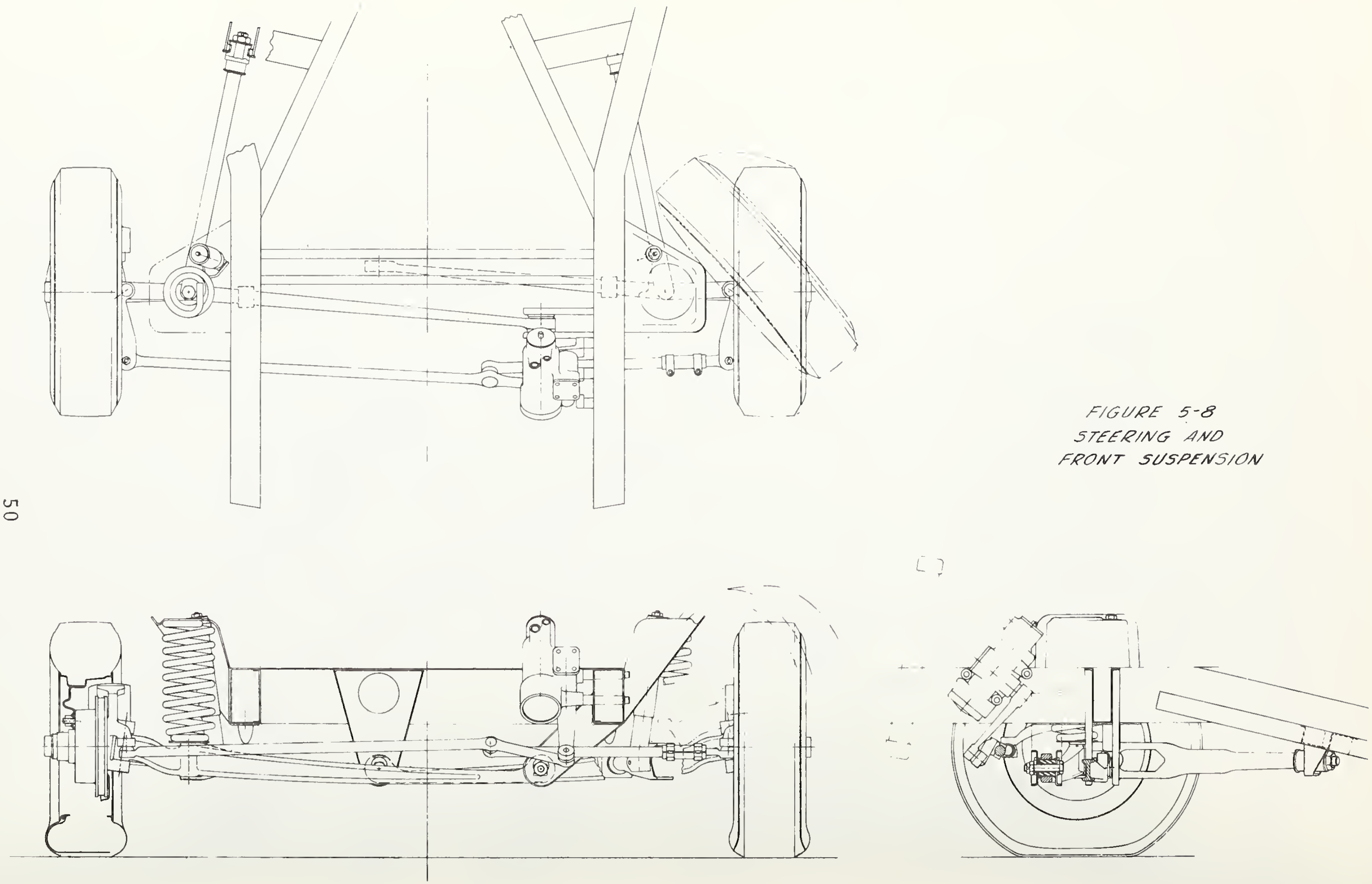


Figure 5-8. Steering and Front Suspension

H. Powerplants

The standard engine supplied with the Dutcher PTV is the 2.3 liter (140 cubic inch) 4 cylinder Ford engine. This engine is currently produced in quantities in excess of 300,000 units per year, is expected to remain in production for a long time, is considered to be a very reliable powerplant, and is obtainable at a reasonable cost (approximately $700). For 1978, the horsepower is being increased to 104 BHP at 5400 RPM. The horsepower and torque curves of this engine are shown in Figure 5-9. Unfortunately, a brake specific fuel consumption map for this engine could not yet be obtained. Figure 5-10 illustrates the engine installation in the rear of the PTV, and shows the excellent accessibility it has for maintenance.

A diesel, the Peugeot XDP 4-90, is offered as an option. This engine is approximately the same dimensionally as the Ford engine and has the maintainable items on the exposed side of the engine, so it makes a good diesel alternative. The horsepower, of course, is lower (68 compared to 104) which results in less acceleration (see vehicle performance section), the cost is higher (by approximately $700), and the weight is increased by 100 pounds. The fuel mileage is up to 40% better, however, as discussed in the vehicle performance section. The technical data on this engine is attached as Appendix C.

The cooling system for either engine consists of a cross flow radiator 20 inches high, 24 inches wide (core), and 2 1/2 inches deep (four row) designed and fabricated by Eskimo Radiator of Los Angeles. This radiator has excess capacity for heavy loads, hot days, and air conditioning. The radiator fan and electric drive motor are a package put together by Flex-a-Lite Corporation of Tacoma, Washington. The fan is a 12 inch model made by Flex-a-Lite, and the motor is made in Europe for Flex-a-Lite. The fan motor is thermostatically controlled so it only runs when there isn't sufficient vehicle velocity to supply the necessary cooling air. The motor draws nine amps when running.

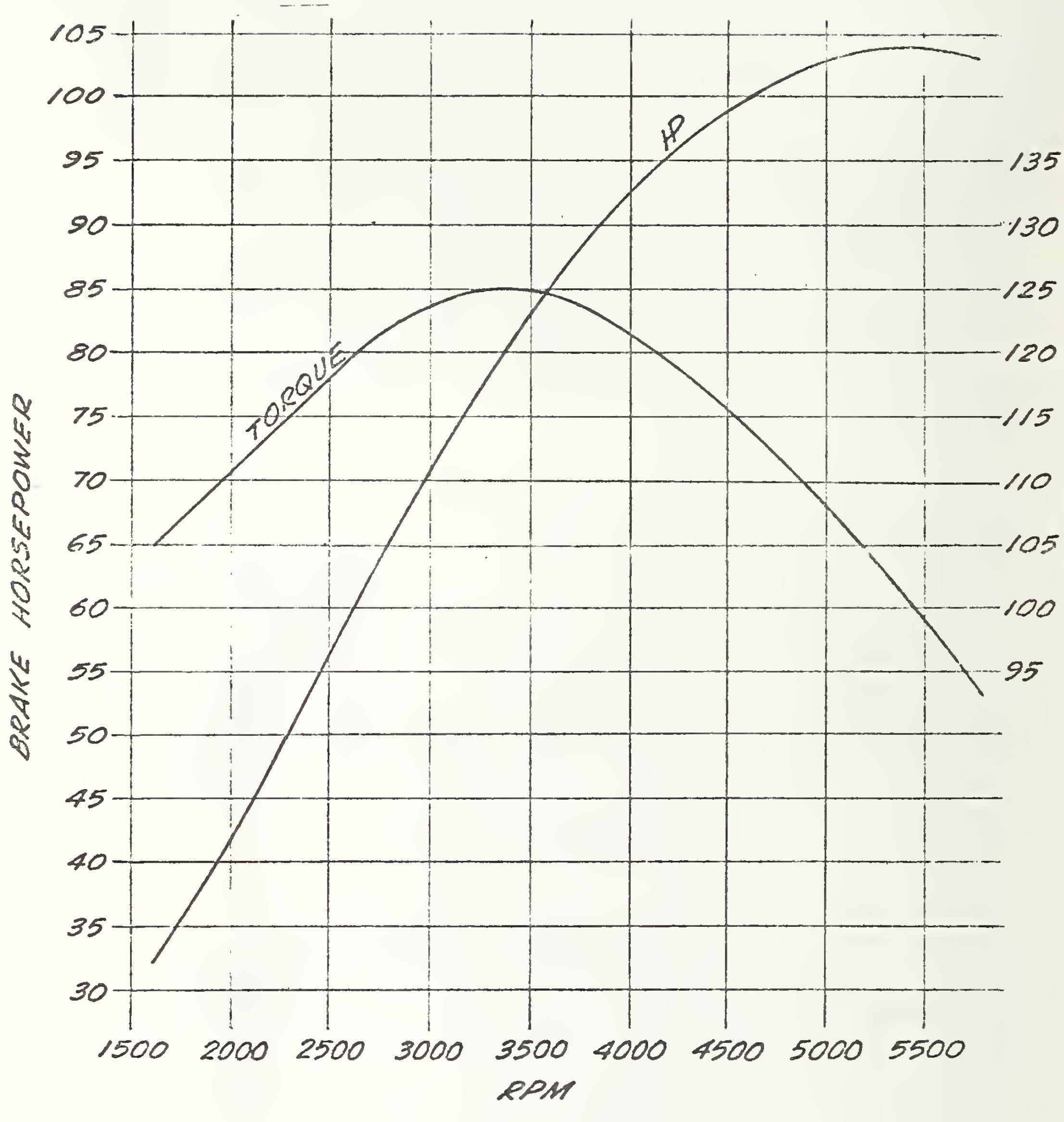


FIGURE 5-9. FORD 2.3L ENGINE PERFORMANCE

I. Driveline and Rear Suspension

The driveline and rear suspension systems are the two areas where components had to be specifically designed for this application because no standard automotive components were suitable. Figure 5-10 illustrates the layout of the drivetrain components. The production Ford C-3 automatic transmission is attached to the engine bell housing in the conventional manner. The transmission tailshaft is removed and a shortened tailshaft drives into a transfer case containing a Morse chain drive similar to that used in the Oldsmobile Toronado. The sprocket and chain sizes were calculated by engineers at Morse based on the engine torque curve supplied by Ford and taking into account the torque multiplications in the torque converter and transmission. The sprockets are on short shafts supported with heavy duty bearings, and the reliability of this transfer drive is expected to be excellent.

From the transfer case there is a short drive shaft with two universal joints leading into the differential. This unit utilizes helical gearing for the ring and pinion instead of the conventional spiral bevel gearing required when the drive shaft is perpendicular to the axles. The differential gearing itself and the carrier are standard Ford Granada parts. The Granada differential is designed to handle the output of a V-8 engine rated at nearly twice the output of the 4 cylinder PTV engine, so it will be very durable in this application. The housing for the differential assembly will be manufactured specifically for the PTV.

The rear axle shafts are to be supplied by Spicer, as is the drive shaft, and are designed with heavy duty universal joints to provide long life. Timken tapered roller bearings and Chicago Rawhide seals are used in this assembly.

The rear suspension system is illustrated in Figure 5-10. The larger curved tube (deDion) holds the two rear wheels parallel to each other, and carries the cornering, braking, and suspension loads from the wheels back into the leaf springs. The ends of the leaf springs are attached to the chassis and provide location of the rear axle in the horizontal plane.

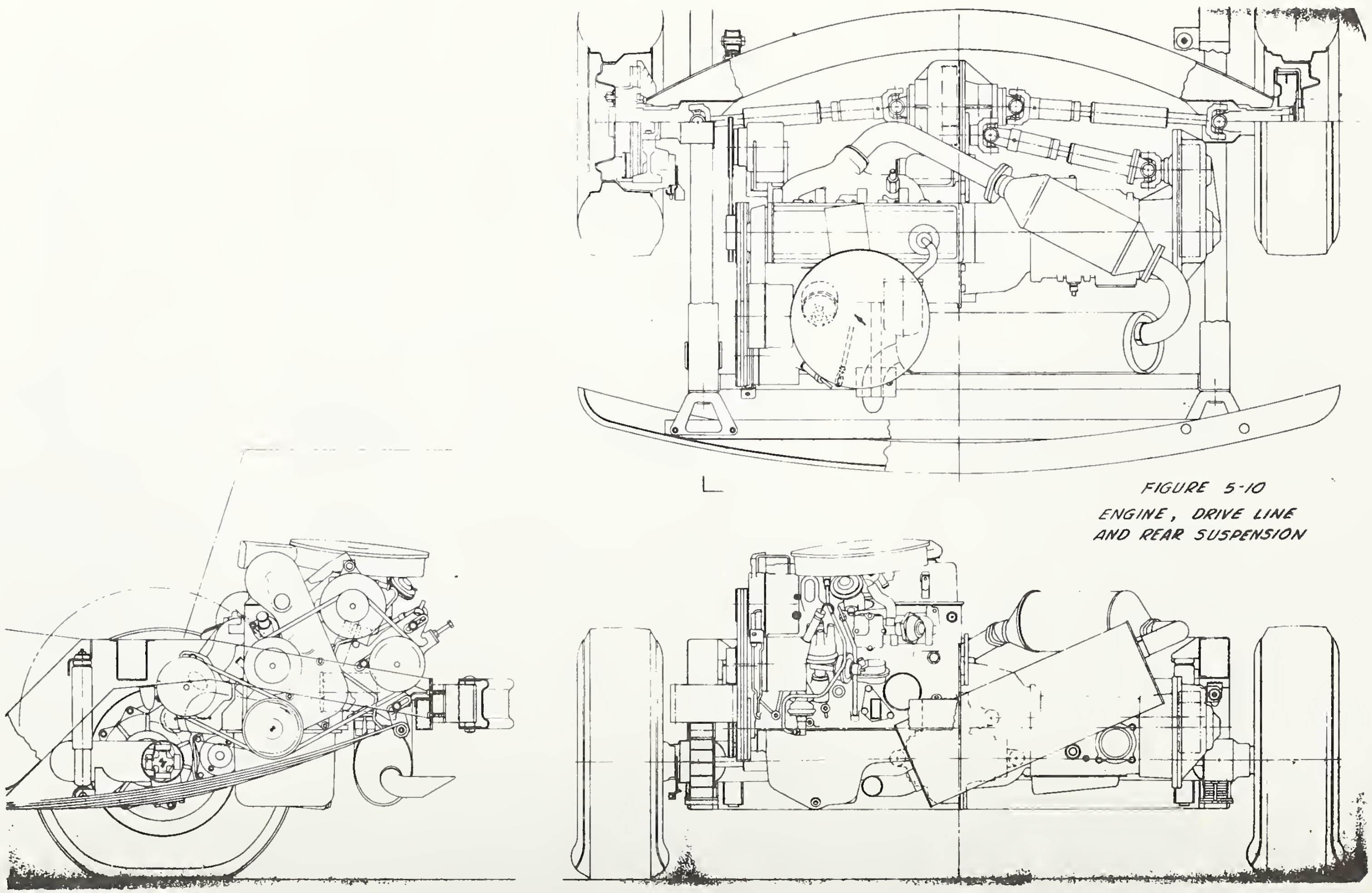


Figure 5-10. Engine, Driveline and Rear Suspension

The deDion suspension system was selected due to the following considerations:

- Increase sprung/unsprung weight ratio for improved ride quality over conventional live rear axle.
- Suspension geometry identical to live rear axle.
- Lower cost, less maintenance, and longer life than independent rear suspension systems.

J. Energy Absorbing Bumper System

In order to meet the five mile per hour bumper impact criterion (FMVSS #215) without incurring a severe weight penalty, a Dunlop Mark II bumper mounting system was selected. The detail of the bumper mount unit is shown in Figure 5-11. The mount deforms elastically during collision up to five miles per hour and immediately returns to its original condition. This device is manufactured by the Polymer Engineering Division of Dunlop in Leicester, England. The model APG 083 is designed to absorb 17,700 IN LBS of energy, so two of these are suitable for vehicle curb weights up to 3500 pounds. The test data sent by Dunlop shows that the mounts actually pass the FMVSS #215 test at vehicle weights as high as 4375 pounds (25% over design) without permanent deformation to the mount.

The bumper mount allows the use of bumper jacks and bumper towing, yet weighs only five pounds per pair.

No suitable production bumper was found, so a simple rolled steel bumper is being used.

K. Heating and Air Conditioning

The heating and defrosting system consists of a standard Ford Van unit mounted in the front of the vehicle. In addition, an additional heater core and blower is located immediately forward of the partition below the luggage compartment. This

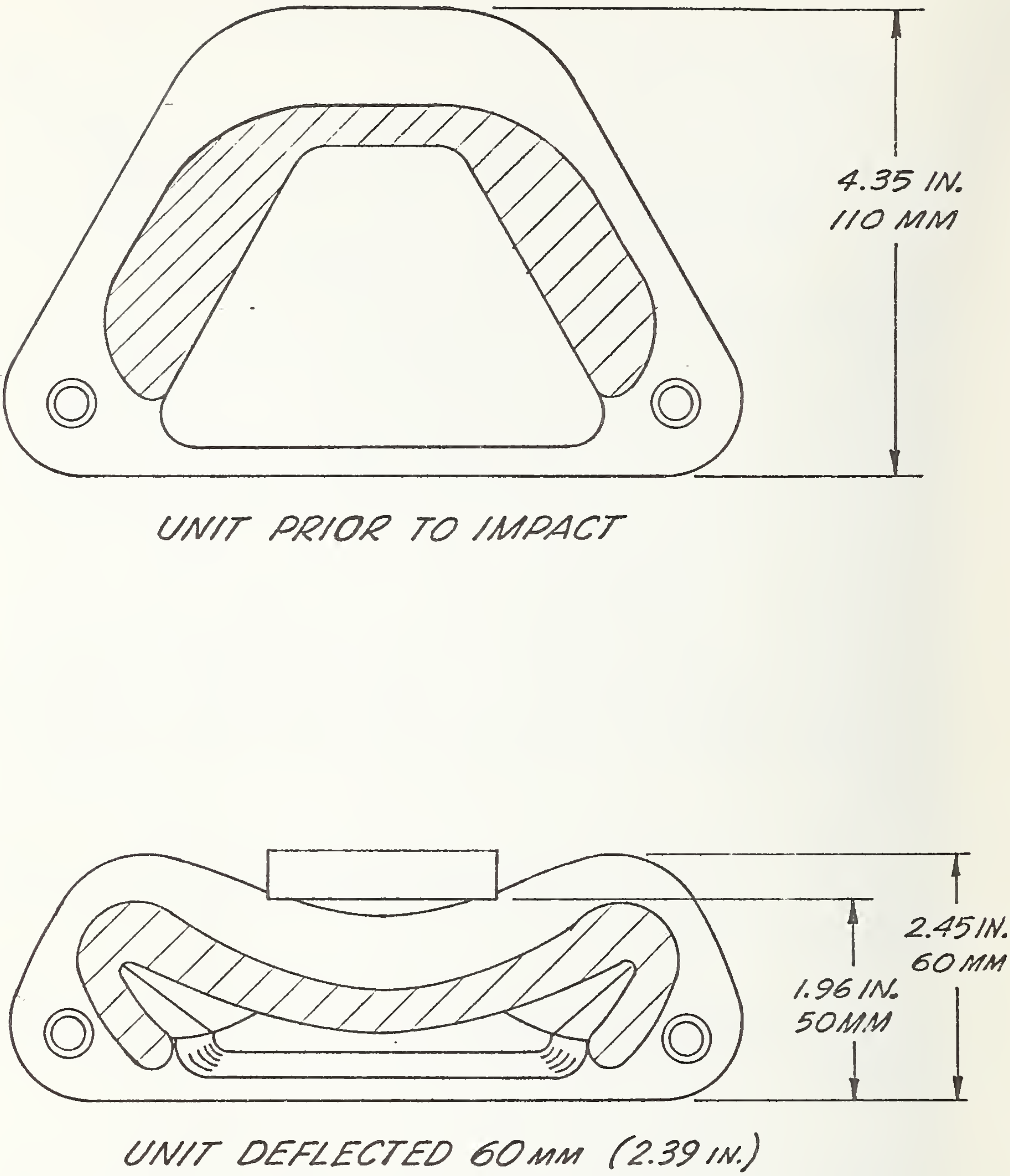


FIGURE 5-11. DUNLOP MARK II IMPACT MOUNTING

system supplies warm air to the passenger compartment when it is necessary. The driver controls both heaters. A preliminary layout of this system is shown in Figure 5-12

An optional air conditioning system is available from dpd Manufacturing Company of San Antonio. This unit employs hardware similar to the unit they make for the VW Microbus market. The air conditioning system includes a 9.2 cubic inch York freon compressor with magnetic clutch, a large evaporator core with two sets of blowers, and a condenser mounted forward of the radiator. A preliminary layout of this system is shown in Figure 5-12 as well. The driver controls the unit for both compartments, and the passengers can close or redirect the louvered outlets if they so desire.

L. Wheelchair Related options

One of the potential uses for the PTV is carrying wheelchair passengers. The optional wheelchair package includes the following items: wheelchair ramps with locating points in the floor, a wheelchair restraint mechanism, a different seat belt for the center jump seat, and yellow lines painted on the floor to assist in the proper entry and exit procedures.

Due to cost and safety considerations, it was decided not to offer the automatic doors or ramp as options. The driver or some other able bodied person is required to open the door, insert the ramps, and help load the wheelchair passenger.

The ramps are aluminum channels dipped in rubber to provide good traction, protection from sharp edges, and silent handling. Normally the ramps are stowed beneath the jump seats. When needed, the ramps are set up by inserting the tabs on the ramp end into slots in the door sill such that the ramps are properly located and secured. With the wheelchair passenger on board, the ramps are nested and placed upside down beneath the chair, where they will serve as wheel chocks. Figure 5-13 illustrates the ramps and their use.

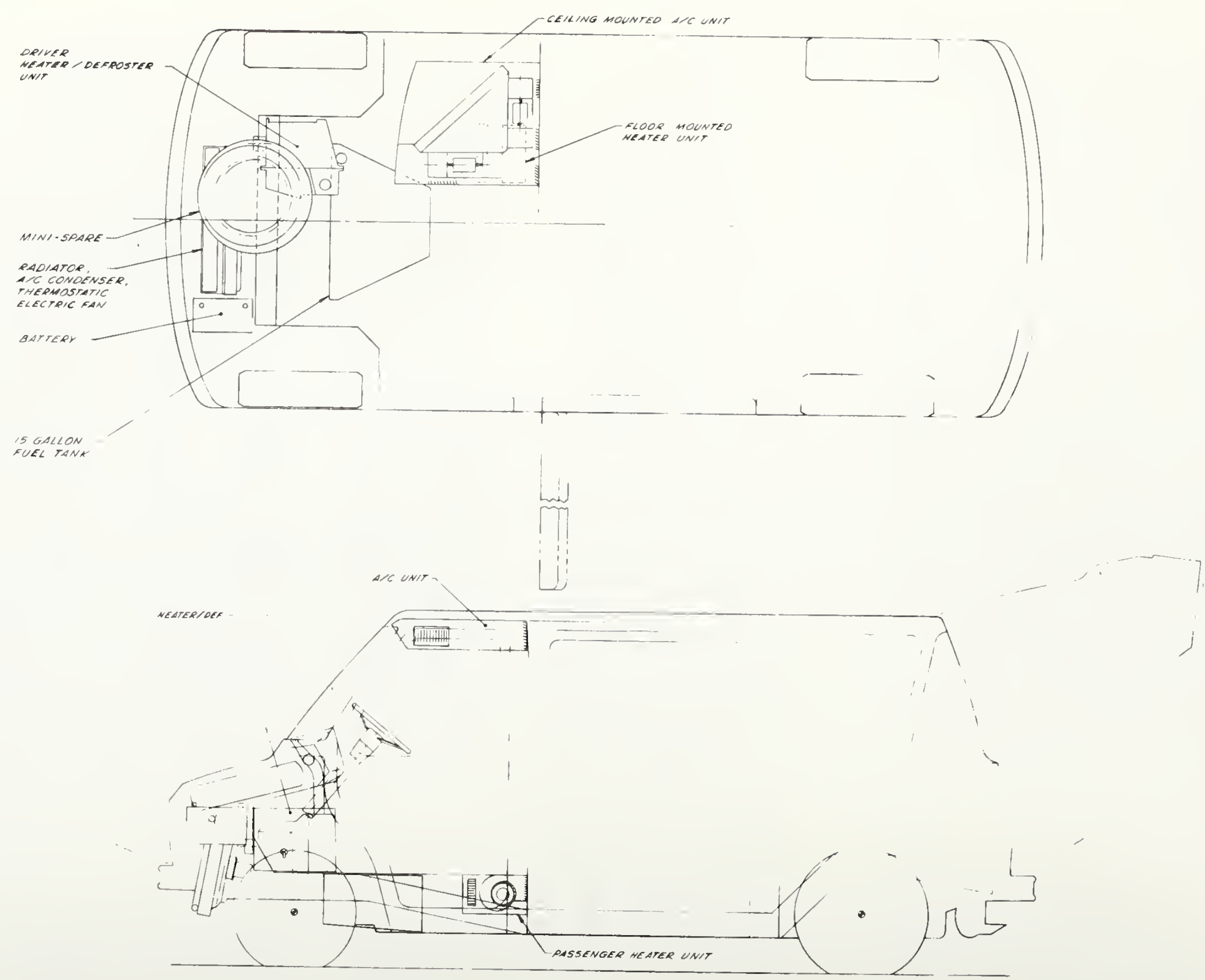


Figure 5-12. Heating and Air Conditioning System Layout

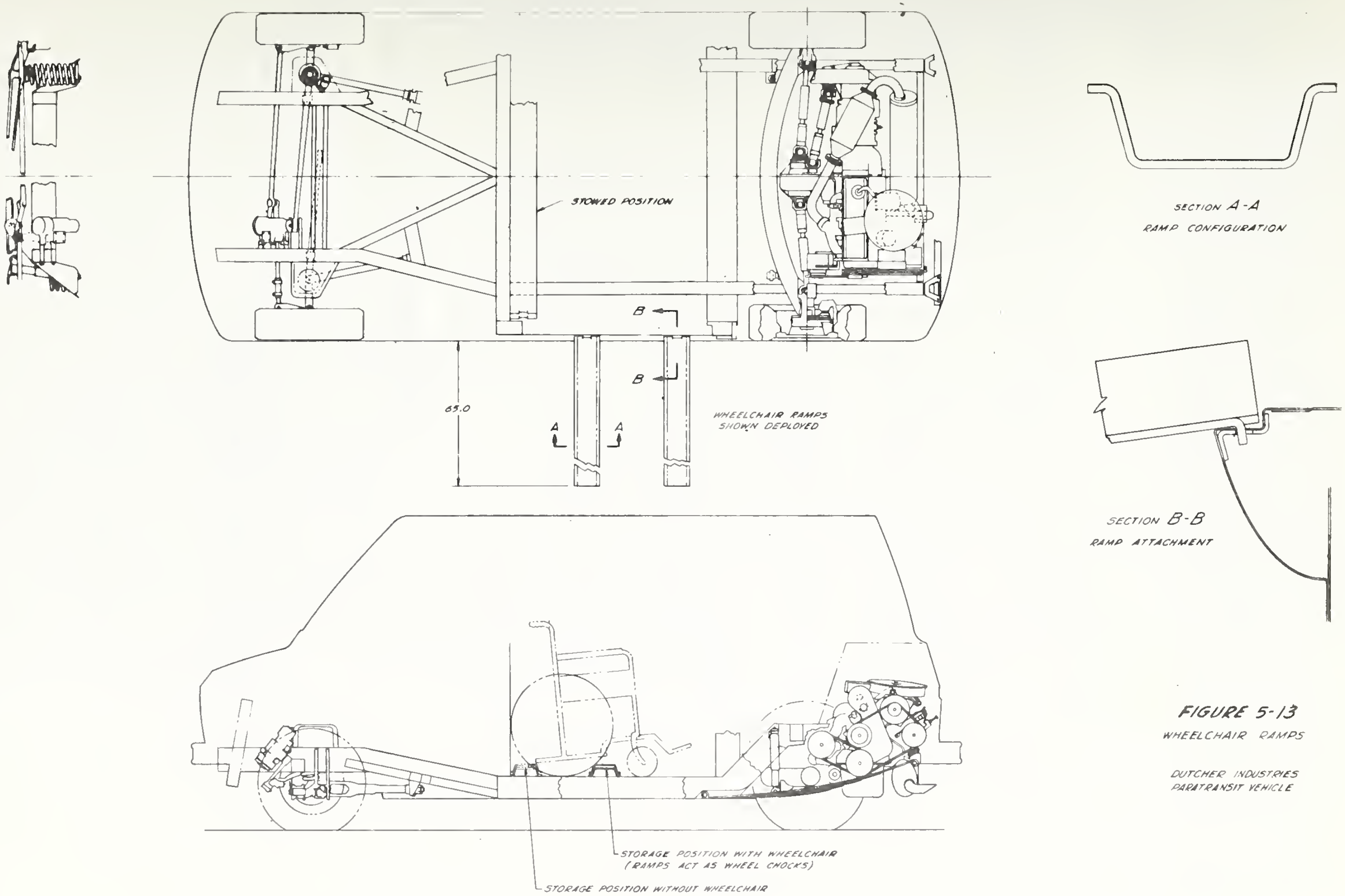


Figure 5-13. Wheelchair Ramps

The wheelchair restraint mechanism consists of two aluminum hooks that are spring loaded against the sides of the wheels and limit the wheelchair motion to a fraction of an inch in either a rear end or side collision. The passenger lap belt and the parking brake on the chair are expected to preclude whellchair motion due to normal vehicle maneuvering forces.

M. Other Optional Equipment

Four Wheel Disc Brakes - The Ford Granada four wheel disc brake package is offered as an option, but is only available if the power steering option is taken as well. The reason for this is that the brakes are hydraulically boosted instead of vacuum boosted as are most automotive brakes. The brake and power steering systems share the hydraulic system.

Bullet Resistant Partition - A Lexan partition can be installed between the driver and passengers to provide the driver with maximum security. This option includes a means of passing money through the partition, and a means of communicating with the driver. Both the money pass-through and the communications method will be improved over those used in the prototype. The money pass-through will be a pivoting tray which is spring loaded toward the driver and is flush with the passenger side of the partition. When a transaction is required, the driver can pivot the tray so it is open to the passenger compartment.

A simple heavy mesh stainless steel screen will be installed in the Lexan partition to provide direct passenger - driver communications.

Taxi Meters - Two types of taxi meters are offered as options. A single fare electronic unit by Argo is available and a multiple fare (up to five) meter is available from Bru-der Instruments.

N. Parts List

A comprehensice parts list was made up in order to identify all the components that go into the vehicle assembly. The parts list is included as Appendix D, and includes part number, supplier, quantity, and unit cost assuming production of 5000 units per year.

5.2 Vehicle Weights

A. Weight Analysis

The weight numbers tabulated on the parts list in Appendix G are only approximate, since detailed drawings and purchase components must be available to obtain actual weights. The weight of each chassis piece was calculated, however, based on the section drawings shown in Appendix A.

Currently, the projected curb weight of the baseline vehicle is 3250 pounds. Estimated weights of the various options are listed below:

Air Conditioning	71 pounds
Driver Partition	32 pounds
Power Steering	32 pounds
4 Wheel Disc Brakes	36 pounds
Wheelchair Hardware	27 pounds
Short Stop Restraint Bar	24 pounds

B. Dynamic Performance

A small computer model was set up in order to project the vehicle acceleration, top speed, and steady state fuel mileage for the proposed PTV design. As inputs the program requires vehicle characteristics such as weight, frontal area, drag coefficient, rolling resistance, tire size, transmission and differential gear ratios, drive line and accessory power losses, and the engine horsepower and brake specific fuel consumption curves.

The drag coefficient and the driveline power losses are not known accurately, and these variables were adjusted until reasonably good correlation was obtained between the computed performance and the actual test data from the prototype PTV with the Porsche engine. This correlation is illustrated in Figures 5-14 and 5-15.

It may be seen that the model is slightly optimistic on high speed acceleration, and pessimistic on high speed cruise fuel mileage. The cause of this minor discrepancy is not currently understood, and will have to be considered a characteristic of the analytical model.

The characteristics of the proposed PTV and powerplants were then inserted into the model. The acceleration and fuel mileage were calculated for four different cases - two engines (gasoline and diesel), and two loads (driver only and fully loaded). The projected results are tabulated in Table 5-1 and plotted in Figures 5-16 and 5-17.

As a second check on the model, the characteristics of a Pinto with the 2.3 liter Ford gasoline engine were inserted. The result indicated a cruise fuel mileage at 55 miles per hour of 24.2 miles per gallon. The EPA chassis dynamometer tests on the 1977 Pinto with automatic transmission yielded 32 miles per gallon for the highway cycle and 23 miles per gallon for the urban cycle. This also indicates that the computer model provides pessimistic or conservative fuel mileage projections.

The fuel mileage on the EPA highway driving cycle test is expected to be somewhat higher than the projected 50 miles per hour cruise mileage. The reason for this is that the EPA test is a chassis dynamometer test where the dyno is loaded to a value based only on vehicle weight. Consequently, the PTV will not be penalized

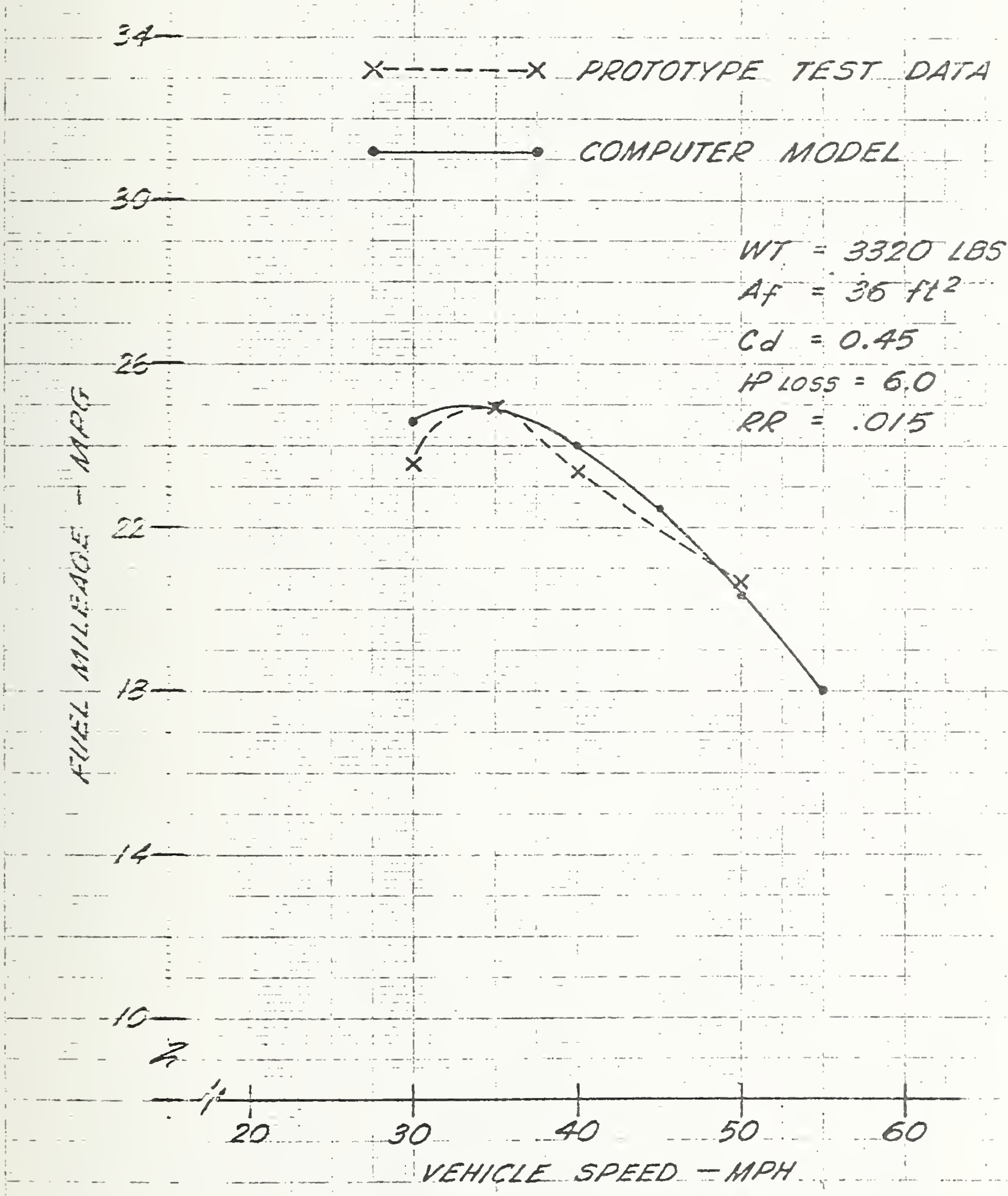


Figure 5-14. Prototype Steady State Fuel Mileage

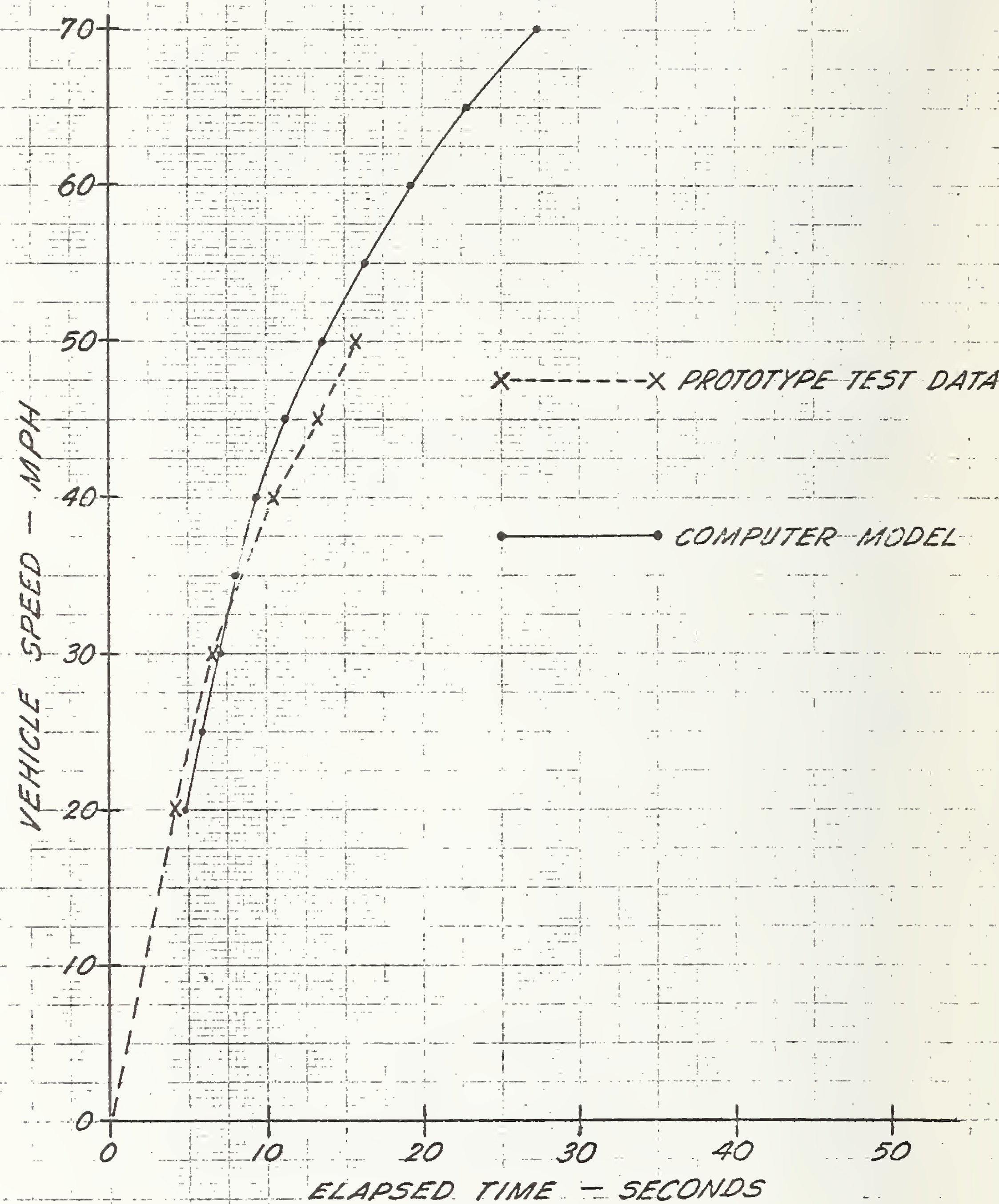


Figure 5-15. Prototype Vehicle Acceleration

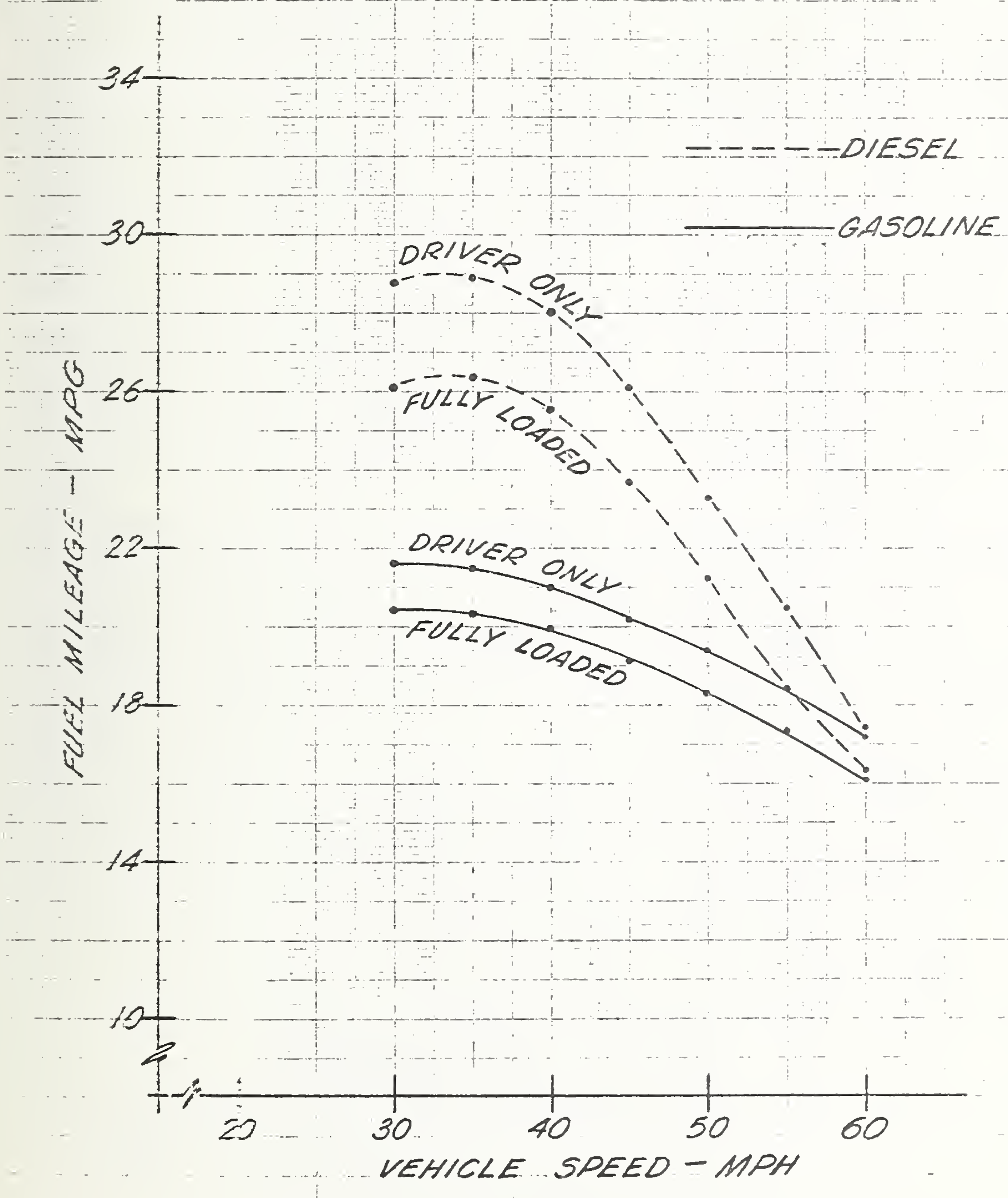


Figure 5-16. Projected Steady State Fuel Mileage

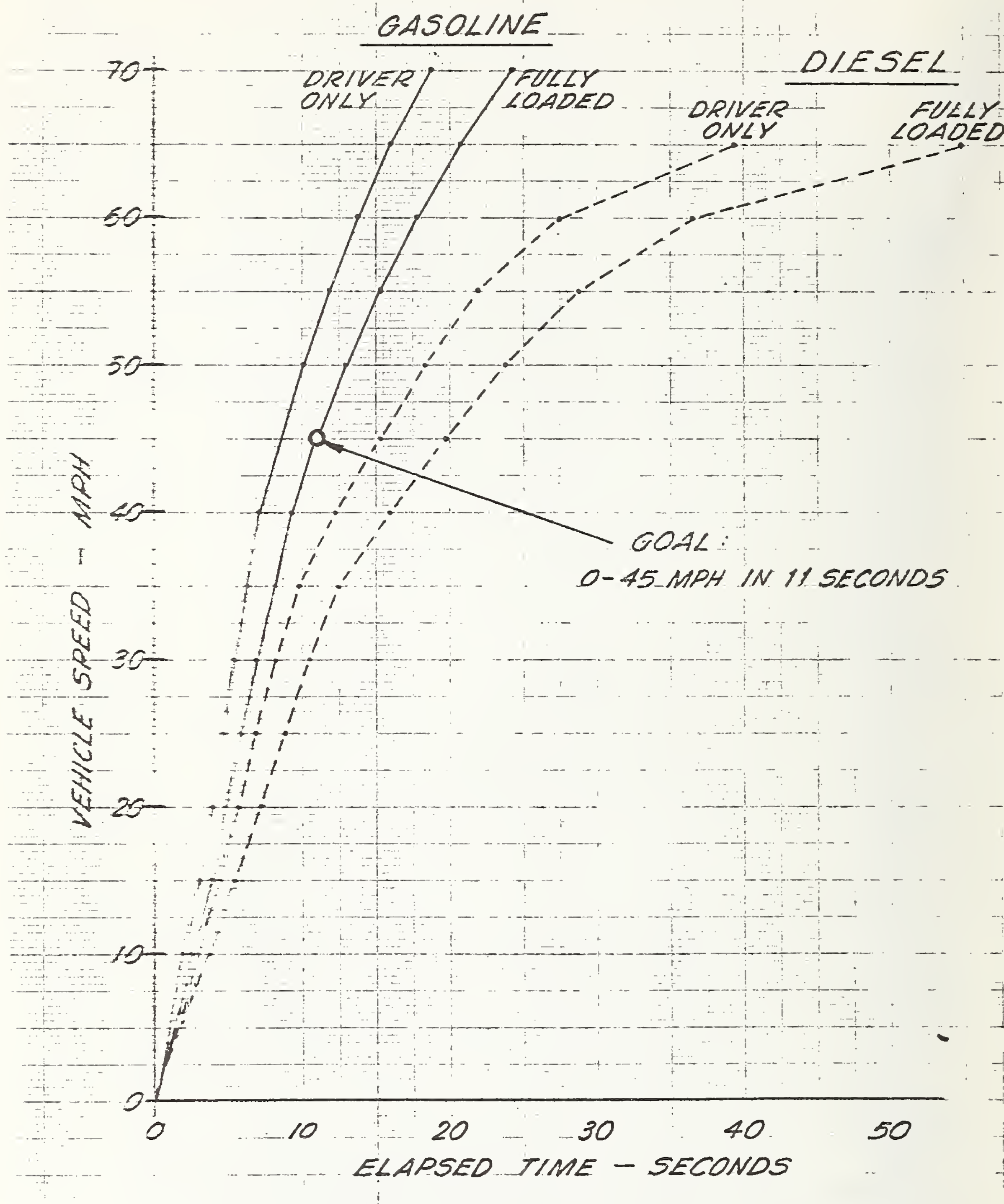


Figure 5-17. Projected Vehicle Acceleration

for its high frontal area which causes wind resistance and higher fuel consumption on actual highway driving. The projected EPA test cycle fuel mileages listed in Table 5-1 for the gasoline engine were based on 1977 Pinto test results and correcting for the inertia test weight difference. As shown in reference (1) the combined fuel mileage is inversely proportional to the inertia weight. The EPA urban and highway mileages for the 1977 Pinto with automatic transmission were 23 to 32 miles per gallon respectively. This would project to 18 to 25 miles per gallon for the PTV at 3500 pounds inertia weight.

The EPA driving cycle fuel mileage with the diesel engine will be the same as those for the Peugeot 504D since it is the same engine in the same weight vehicle. The 1977 Peugeot achieved 35 miles per gallon on the highway test and 28 miles per gallon on the urban test.

Exhaust emissions are impossible to calculate and can only be projected based on adjusting the Pinto test data for the increased inertia weight of the PTV. Since the Federal exhaust emissions limits will continue to decrease for the next few years, the exhaust cleanup devices will continue to be developed also. Therefore it is not meaningful to use 1977 model exhaust emissions to project PTV emissions in the early 1980's. At this point we can only state that we are confident that the PTV will meet the Federal exhaust emission requirements even though it will use an engine from a lighter vehicle. If need be, a California engine can be used, which typically has lower emissions than a 49 states engine.

(1) SAE #750957, "Passenger Car Fuel Economy Trends Through 1976", by Austin, Michael, and Service of EPA.

TABLE 5-1

PROJECTED VEHICLE PERFORMANCE

	GASOLINE ENGINE		DIESEL ENGINE	
	DRIVER ONLY	FULLY LOADED	DRIVER ONLY	FULLY LOADED
ACCELERATION				
(time in seconds)				
0-45 mph	8.5	10.9	15.2	19.7
0-55 mph	11.9	15.3	21.9	28.7
TOP SPEED				
(miles per hour)	91.5	90.5	73.5	71.5
FUEL MILEAGE				
(miles per gallon)				
35 mph cruise	21.5	20.4	28.9	26.4
45 mph cruise	20.2	19.2	26.1	23.7
55 mph cruise	18.4	17.4	20.2	18.4
EPA Highway Cycle	- 25	-	- 35	-
EPA Urban Cycle	- 18	-	- 28	-
TAXI SERVICE				
Range (miles) at				
55 mph	276	261	303	276
Urban (estimate)	180	160	240	220

6.0 TASK 6 - MANUFACTURING COST ESTIMATES

Based on the design discussed in section 5, a manufacturing cost estimate was made for the limited production quantity of 5000 units per year. For each fabricated part, a drawing was sent to one or more potential suppliers for cost projections. As many of the purchased components as possible were priced directly from manufacturers and suppliers to the automotive industry. The individual component costs are tabulated in Appendix D.

In order to arrive at assembly labor costs, the time required to perform each assembly and component installation task was estimated and multiplied by the appropriate labor rate. These details are included in Appendix E. Cost of all tooling fixtures was estimated based on design, material, and labor estimates. The tooling breakdown is included in Appendix F. The tooling costs were amortized over five years or 25,000 units.

The cost of the manufacturing facility was estimated by determining the size of the production line (how many vehicles were in work at one time), and adding the space required for component and material storage, some component assembly areas, paint shops, and office space. An estimate was made for management and clerical help as well as overhead costs. A figure of 3% was added for producing spare parts under the warranty agreement of 12 months or 12,000 miles. In addition, an estimate was made on taxes, interest, and return on investment for the invested capitol. All these figures are tabulated and summed in Table 6-1.

The botton line shows a selling price per baseline vehicle of $10,659.93 plus shipping from the factory. Optional equipment and the additional costs are listed in Table 6-2.

TABLE 6-1

VEHICLE COST BREAKDOWN - PER VEHICLE

BODY FABRICATION	
Underbody assembly	$ 398.50
Body side frame (2 x 210.47)	420.94
Cowl and firewall	31.82
Rear compartment closeout	15.09
Hood sub assembly	15.06
Front door assemblies (2 x 42.57)	85.14
Rear door assemblies (2 x 49.76)	99.52
Engine compartment door	31.63
Body in white	242.69
Body fabrication sub total	$1,340.39
COMPONENT INSTALLATION	
Accessory installation	$ 32.94
Powerplant and suspension installation	12.06
Interior trim installation	15.80
Painting	200.00
Inspection and quality control	19.00
Rework	50.00
Assembly sub total	$ 329.80

PURCHASED COMPONENTS

Body side frame	$ 163.89
Roof assembly	229.04
Underbody assembly	134.93
Cowl and firewall	65.19
Door assemblies	587.82
Hood assembly	15.63
Engine compartment door	109.81
Rear compartment closeout	67.37
Front end assembly	45.57
Interior and trim	564.70
Accessories & electrical	1,005.55
Undercoat and insulation	86.49
Engine	700.00
Transmission	300.00
Driveline	652.49
Rear suspension	219.64
Front suspension and steering	480.34
Brakes	312.48
Tires and wheels	185.37
Miscellaneous parts	113.05
Nuts, bolts, washers	200.00
Purchased parts sub total	$6,239.41
INBOUND FREIGHT (5% of parts cost)	311.97
DIRECT VEHICLE COST TOTAL	$8,221.57
TOOLING (amortized over 25,000 units)	20.69
OVERHEAD LABOR	352.00
FACILITY COSTS, TAXES	986.00

INSURANCE (product liability)	$ 287.41
WARRANTY	287.41
PROFIT	504.85
TOTAL VEHICLE PRICE (FOB Factory)	$10,659.93

TABLE 6-2

OPTIONAL EQUIPMENT COST

AIR CONDITIONING	$ 450.00
POWER STEERING	131.77 *
4 WHEEL DISC BRAKES	147.15
WHEELCHAIR CAPABILITY	53.50
SHORT STOP RESTRAINT	44.04
DRIVER PARTITION	72.63
TAXI METER	416.00
PEUGEOT DIESEL ENGINE	856.00 *
SELF LEVELING REAR SUSPENSION	50.00 *

*THESE COSTS ARE DIFFERENTIAL COSTS RELATIVE TO THE STANDARD EQUIPMENT.

7.0 REPORT OF INVENTIONS APPENDIX

After a thorough review of the work performed under this contract, no new inventions or discoveries were made or patents submitted. However, the program did result in an improved paratransit vehicle design for a low lift cycle cost vehicle in production quantities of 5000 units per year. The PTV has been designed to utilize as many current automotive production components as possible, and is deisgned for durability as well as east of maintenance and repairability. A low floor and wide doors are provided for ease of handling passengers confined to wheelchairs. Excellent driver visibility and short turning radius for maneuverability provide for safe and easy driving, while the spacious passenger compartment seats six passengers comfortably, with or without a wheelchair passenger. Options available include: power steering, air conditioning, isolated driver's compartment, short stop restraint bar, and four wheel disc brakes.

110 Copies

U.S. DEPARTMENT OF TRANSPORTATION
RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION
TRANSPORTATION SYSTEMS CENTER
KENDALL SQUARE, CAMBRIDGE, MA. 02142