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RAIL CAR COST CONTAINMENT STUDY

AUGUST 1988
FINAL REPORT

Prepared by

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16. Abstract

This report describes a study of rail car procurements over the past 15 years to analyze cost growth and to determine whether deletion, reduction or modification of some procurement conditions (design, specifications, warranties, etc.) could be effective in the containment of future rail car costs. It was found that rail car cost has increased at an average annual rate of 9.4% per year and that, if unchecked, the average rail car will cost $2.4 million in 1995. Even with inflation removed, the average annual rate of growth has been over 5% per year.

The analysis points to many areas that should be considered for potential cost savings when rail cars are to be purchased. There are many potential savings methods available. The greatest cost savings identified in this study are from the use of negotiated procurements, existing designs, smaller car sizes, and large procurement order sizes. Significant initial cost savings have also been demonstrated from equitable escalation and monetary value clauses, but these add the risk of additional cost later in the contract.

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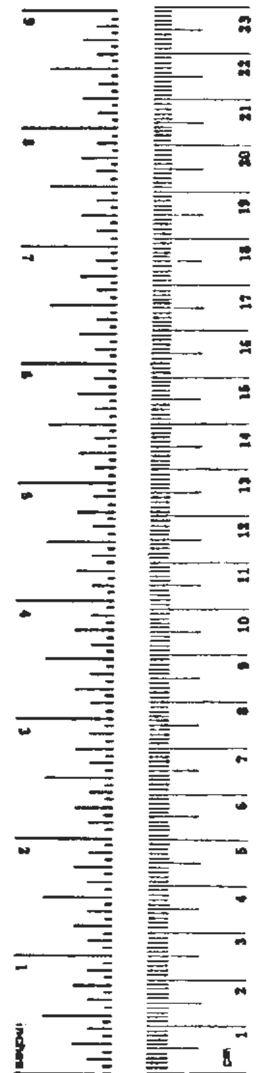
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

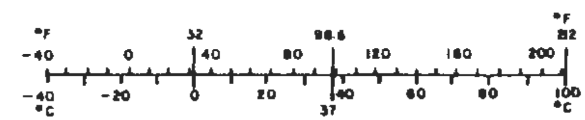
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



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	35	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



PREFACE

This report describes a study of rail car procurements over the past 15 years to determine whether deletion, reduction or modification of some procurement conditions (design, specifications, warranties, etc.) could be effective in the containment of future rail car costs.

This study was sponsored by the U. S. Department of Transportation, Urban Mass Transportation Administration (UMTA), through the Office of Technical Assistance and Safety. The work was performed by DYNATREND INCORPORATED under contract to the sponsor.

The assistance of Mr. Michael Burshtin at the Southeastern Pennsylvania Transportation Authority (SEPTA), Messrs. William Rhine and Joel Sandburgh at the Southern California Rapid Transit District (SCRTD), Mr. Chris Eichin at the Santa Clara County Transportation District (SCCTD), and Mr. Walter Keevil at the Chicago Transit Authority (CTA), was especially helpful in the collection and evaluation of data. Valuable input was also received from Mr. Peter Stetler at Westinghouse, Mr. Robert Halperin at Bombardier, and many others.

The study project manager also wishes to acknowledge the assistance of Mr. Jeffrey Mora of the UMTA Office of Technical Assistance and Safety who provided his insight and historical perspective, as well as encouragement and support, to the study team.

The results contained in this report follow directly from the data collected and analysis performed and present the technical observations made, and conclusions reached, by DYNATREND INCORPORATED.

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Acronyms

APTA	American Public Transit Association
ATC/ATO	Automatic Train Control/Automatic Train Operation
BART	Bay Area Rapid Transit District
BRRTS	Baltimore Region Rapid Transit System, now called MTA-Baltimore
CBS	Cost Breakdown Structure
CTA	Chicago Transit Authority
DOT	U.S. Department of Transportation
GCRTA	Greater Cleveland Regional Transit Authority
GNP	Gross National Product
LACTC	Los Angeles County Transportation Commission
MARTA	Metropolitan Atlanta Rapid Transit Authority
MBTA	Massachusetts Bay Transportation Authority
MDTA	Metro Dade County Transit Agency
MDMTA,	Maryland Mass Transit Administration
MTDB	Metropolitan Transit Development Board, San Diego, CA
MUCTC	Montreal Urban Community Transit Corporation
MUNI	San Francisco Municipal Railway
NFTA	Niagara Frontier Transportation Authority
NHSL	Norristown High Speed Line
NWA	Northwest Analytical, Inc.
NYCTA	New York City Transit Authority
PAAC	Port Authority of Allegheny County
PATCO	Port Authority Transit Corporation
PATH	Port Authority Trans-Hudson
PCC	Presidents Conference Committee
SCCTD	Santa Clara County Transportation District
SCRTD	Southern California Rapid Transit District
SEPTA	Southeastern Pennsylvania Transportation Authority
SLRV	Standard Light Rail Vehicle
SOTA	State-of-the-Art
SRTD	Sacramento Regional Transportation District
TRIMET	Tri-County Metropolitan Transit District (Portland, OR)
TTC	Toronto Transit Commission
UMTA	Urban Mass Transportation Administration
UTDC	Urban Transportation Development Corporation
WMATA	Washington Metropolitan Area Transit Authority

CHAPTER 1.0

EXECUTIVE SUMMARY

1.0 EXECUTIVE SUMMARY

A continuing trend of rising rail car prices is causing concern within the urban mass transit community. In the past 15 years average rail car prices have gone from $308,000 in 1973 to $1,391,000 in 1988, an increase of 452%. The components of this increase, and the estimated share of each are:

- o INFLATION - 46%
- o PERFORMANCE AND TECHNICAL REQUIREMENTS - 25%
- o NON-PERFORMANCE REQUIREMENTS - 29%

A historical review of trends shows that cost drivers have not increased uniformly. Transit authorities have used a wide variety of technical specifications, procurement approaches, and contractual terms. In some cases varying order sizes, warranty conditions, or other contractual terms, have significantly altered the effect of the various cost drivers.

The Urban Mass Transportation Administration has undertaken an aggressive Rail Car Cost Containment Program to bring costs under control and establish a process that will reduce or contain the capital costs of acquiring transit rolling stock. This report addresses the issue of the cost drivers and attempts to identify, and where possible quantifies potential cost savings areas.

1.1 Data Collection

An extensive amount of rail car procurement data was collected from transit authorities, carbuilders, industry suppliers and others. It covered identified purchases form 1973 through 1988. The information includes extensive technical descriptions of 55 car buys, their carbuilders and costs. It also includes data on contractual terms and conditions and requirements for deliverables such as reports, tests and analyses.

Four specific procurements were selected for detailed case studies. Information collection forms were developed and team members visited each of the four transit authorities listed below.

1. Southeastern Pennsylvania Transportation Authority (SEPTA) Norristown, High Speed Line Light Rail Car - 1987 procurement from ASEA-AMTRAK

2. Metropolitan Altanta Rapid Transit Authority (MARTA) Rapid Rail Car - 1982 procurement from Hitachi

3. Santa Clara County Transportation District (SCCTD) Light Rail Car - 1984 procurement from UTDC

4. Chicago Transit Authority (CTA) Rapid Rail Car - 1978 and 1981 (option) procurements from Budd

A reasonable amount of data was collected, however in some cases the level of detail desired was not available. For example, in all cases the cost per car was available but the breakdown to a significantly lower level was not in the carbuilders proposals, and therefore not a part of the record. This constrained the study to some degree. In some cases the team was forced to rely on data obtained from previous work, and through interpolation drew conclusions.

1.2 Data Analysis

The following percentage breakdown shows what each factor contributes to the total cost of a "typical" rail car.

FACTOR	SHARE
Car body	27.0%
Communications Equipment	0.5%
Electrical System	1.0%
Heating, Ventilating and Air Conditioning	4.5%
Propulsion System	22.0%

Train Control System	4.0%
Trucks	13.0%
Engineering	11.0%
Integration, Assembly, Test and Evaluation	4.0%
Guarantee, Warranty and Reliability	4.0%
Management, Data and Other Costs	9.0%
Total	100.0%

The data gathered during the course of the study is grouped into four principal cost driver categories:

- o Rail Car Cost Growth
- o Performance Growth and Technical Requirements
- o Terms and Conditions Growth
- o Non-Performance Requirements Growth

Rail Car Cost Growth

It was found that rail car cost has increased since 1980 at an average annual rate of 9.4% per year and that, if unchecked, the average rail car will cost over $2 million in 1995. Even with inflation removed, the average annual rate of growth has been more than 5% per year. Several analyses were performed to determine the correlation and impact of various parameters on cost. It was found that rail car size (length and weight) was most closely related to cost. A normalization of the data by weight did not, however, yield any substantial gain in understanding the cost trend.

A breakdown of the data between light rail and rapid rail showed that light rail vehicles have been on the average $29,000 more expensive and 5,000 pounds heavier each than rapid rail cars. That cost difference, however, is explained more by the small average lot size for light rail purchases than by any significant differences in the cars. The average number of light rail vehicles procured per order was 48 compared with 136 for rapid rail cars. Further analysis of the data showed that small lot sizes of less than 47 cars cost 21% more per car than lot sizes of 47 or more cars. There was not, however, a good general correlation between lot size and cost. This fact is explained by the significant variations in the conditions and requirements of the small orders and by the flattening impact on costs of huge orders by New York and Chicago. In spite of the lack of concrete statistical evidence, there is little question that larger order quantities do act to reduce per car costs.

Performance Growth and Technical Requirements

Performance and technical factors, which included all features and characteristics describing the physical rail car, were reviewed to determine what contribution the ever-changing requirements have on increasing rail car costs. The collective contribution of these changing requirements add up to about 47%. Because this study was primarily directed at acquisition costs, trade-offs between the up-front cost of purchase and the subsequent support, operation and maintenance cost are not directly considered. Nevertheless, it is important to emphasize the significance of life cycle cost considerations when determining subsystems to include in a new rail car purchase.

A number of hardware items which have been previously researched under other studies were not revisited. However, savings data from the previous studies are provided as reference. Specific performance factors discussed in this report are:

- Air Conditioning - If air conditioning is eliminated, it is believed a reduction of 1.8% to 4.5% on purchase price is possible. In spite of this potential reduction, it is the general consensus in the transit community that air conditioning is essential.
- Automatic Train Control and Operation (ATC/ATO) - There has been an erratic and increasing trend in the number of cars being purchased with some form of ATC/ATO. Reduction of 0.3% to 4.5% of the total car price is possible with its elimination, depending on the degree of automation.

- Propulsion System - The trade-off between direct current (dc) chopper control and dc cam control appears to be moot at this time. The initial cost of both systems is approximately the same and there is ample evidence that chopper systems, especially with regenerative braking, offer considerable operating cost savings. In addition, alternating current (ac) propulsion systems are now available at near or the equivalent of dc system prices, and promise significant life cycle cost savings. It is interesting to note that in the early 1970s, the propulsion system typically cost about 50% of the total cost of the car. Today, it more commonly represents 20% to 25% of total cost. Propulsion system costs have remained fairly stable, while other costs have gone up.

- Specification - Most recent specifications contain both performance and design requirements. It does not seem likely that the type of specification bears greatly on the car cost, but that other requirements are the real cost drivers.

- Standardization - The most likely benefits from standardization will result in large orders through combining of orders, or when previously built designs and systems are procured in lieu of new designs. It has been estimated that savings of 16.5% could be realized by standardizing subsystems.

Terms and Conditions Growth

The study indicates that UMTA's Guideline Contract Terms and Conditions (issued in 1978 and withdrawn in about 1981) are generally being used in transit car procurements. The study indicates that when the UMTA Guidelines are not used car costs are sometimes higher. In some cases where unduly restrictive clauses have been renegotiated, the contract price has been lowered as a result. Much of the risk to car builders for other requirements such as the Authority of the Engineer, Liquidated Damages, Termination and other clauses has been eliminated in most recent contracts. There is not sufficient data to quantify the impact of terms and conditions on rail car cost growth, but it appears that use of the UMTA Guidelines has actually tended to reduce overall costs.

Non-Performance Requirements Growth

The requirement for engineering analyses, documentation and technical and management plans has dramatically increased over the past 15 years. Although it is not possible to quantify the contributions of these requirements to increased car costs, it appears that a major portion of that increase has resulted from non-performance requirements. It should be noted, however, that there is a considerable benefit from these requirements in terms of better contract management, lowered risk of technical problems, and in many cases significant reductions in life cycle costs. In many cases, savings can be made by purchasing proven designs, systems and components which in turn can reduce documentation, analyses and testing requirements. The elimination of specific format requirements for some documentation can also save money by allowing the carbuilders and the vendors to use their existing documentation.

1.3 Cost Analysis

1.3(a) Typical Procurement

A "typical" 1988 rail car procurement is estimated to cost $1,277,678 per car. It is described as approximately 64 feet long, 75,000 pounds and capable of carrying 215 people at crush load capacity. The procurement quantity is 110 cars; it contains proven technology, i.e., air conditioning, chopper control with regenerative braking, cab signal automatic doors and destination signs, and has bi-directional controls. A typical procurement uses a standard set of terms and conditions and requires a comprehensive set of tests and analyses as well as complete documentation. Standard Federal and local regulations apply including Buy America, elderly and handicapped access, steel content and U.S. shipping.

1.3(b) Minimal Procurement

A "minimal" procurement is derived by selectively reducing or eliminating many of the cost driving features which are included in the above "typical" car procurement. The "minimal" car procurement maintains the basic functional characteristics of the "typical" car. Although it is unlikely that the "minimal" car procurement would satisfy most authorities exactly as described, it does represent a potential for savings of from 10% to 20% per car. It is noted that overall system life cycle cost impacts should be addressed in each procurement, not just initial cost.

1.4 Case Studies

Car purchases at four transit authorities were reviewed to gain insight, and to identify any meaningful lessons learned that might be useful in future rail car buys. In each case, different problems occurred and different lessons were learned.

In the case of the SEPTA Norristown High Speed Line, a small order for a very unique car was required to fit into the existing environment. In addition, the purchase order was very small, only 26 cars. The result was a very expensive car. This confirmed our belief that standardized cars and large lot size are important in holding costs down. It was recognized, however, by the study team that the procurement was an optimal solution to SEPTA's unusual requirements. The MARTA rapid transit car procurement illustrated the impact of cash flow, escalation and foreign exchange rates on rail car prices. After the initial bid prices were found unacceptable, negotiations on the progress payment schedule, escalation and monetary value adjustment conditions resulted in a $400,000 (27%) cost reduction per car. This is a dramatic result, but it is noted that it represents only the initial contract price and that over the course of the contract, inflation and changing foreign exchange rates added back $200,000 to the cost of each car. The provision of escalation and monetary value clauses to a contract, if written to satisfy the carbuilder, simply transfers the inflation and exchange rate risks from the carbuilder to the procuring authority.

The SCCTD light rail vehicle was basically a standard procurement of a car with many proven subsystems. A considerable benefit was derived from the "Safe Harbor Leasing" program which was used on the first 32 cars, before it expired. It was concluded that the SCCTD buy represented a reasonable application of available technology and manufacturing expertise and as such should represent a realistic light rail vehicle cost benchmark.

The CTA rapid transit car is generally recognized as representative of a basic car, frequently referred to as a PCC car with air conditioning. Although the procurement price was significantly lower than any others during the time when it was bought (1978), it is believed that the low bid price was due to a carbuilder not understanding the full scope of the work involved. It does, however, clearly show the benefits of purchasing standard designs with proven subsystems in large numbers, and with future options at good prices.

1.5 Conclusions

The study points to many areas that should be considered for potential cost savings when rail cars are to be purchased. There are many potential cost savings techniques available; for example keeping the car design simple. However, there may be significant adverse life cycle cost impacts associated with this choice.

Automated and sophisticated new subsystems have provided substantial operational improvements and life cycle cost savings. Nevertheless, they may create reliability, maintainability or performance problems.

The greatest cost savings identified in this study are from the use of negotiated procurements, existing designs, smaller cars, and large procurement orders. Significant initial cost savings have also been demonstrated from equitable escalation and monetary value clauses, but these add the risk of additional costs later in the contract.

The following techniques are likely to achieve bid price savings:

- Use of proven technology and reasonable performance requirements
- Use of UMTA Guideline Terms and Conditions
- Use of joint buys where possible
- Purchase of large quantities where possible
- Use of negotiated procurements where feasible

CHAPTER 2.0

INTRODUCTION

2.0 INTRODUCTION

In the past 15 years the cost of rail transit cars has increased at a rate that appears to far exceed the price increases of similar equipment. At the same time, the historical domestic suppliers of rail cars have abandoned the business, at least in part because of infrequent, irregular orders; costly terms and conditions; elaborate technical requirements; and substantially expanded engineering and documentation requirements.

A number of efforts have been made in the past to reduce the cost of rail transit cars. Guideline contract terms and conditions were developed in 1978, jointly by the suppliers, operators, and the Urban Mass Transportation Administration (UMTA) in an effort to eliminate punitive contractual provisions. Cars were procured jointly to take economical advantage of larger order sizes. A catalog of standard transit car equipment was developed to reduce equipment costs.

These and other UMTA initiated efforts demonstrated that cost savings could be made. However, these efforts were not enough to stem the tide of increasing rail car costs. In order to further address this persistent cost growth, UMTA has contracted with DYNATREND INCORPORATED to assist them in defining a Rail Car Cost Containment Program in order to:

- understand the reasons for the higher costs of recent rail car purchases
- develop a plan for the demonstration of a lower cost prototype rail car procurement

2.1 Purpose and Scope of this Report

This report documents the results of a study to determine whether deletion, reduction, or modification of some technical or contractual procurement requirements could be effective in the containment of future rail car procurement costs. The term "rail car procurement", for the purposes of this study, is considered to include the entire acquisition process including the type of procurement, the form of the specification, the performance and non-performance requirements, and the terms and conditions of the contract. At the direction of UMTA, this study is restricted to consideration of light rail and rapid transit cars only. The one exception is the market survey (see Chapter 7) which, to provide consistency with previous surveys, does include commuter rail cars.

2.2 Study Methodology

A considerable amount of literature (see Bibliography, Chapter 8) exists which addresses most of the areas generally considered to be the cost drivers contributing to the high rate of rail car cost increases. One of the goals of this study was to re-examine the results of previous studies, to update their findings if appropriate, and to consolidate these results into one document that could provide background data and information to assist the planning for future rail car procurements. As a first step, a detailed bibliography was developed to be as comprehensive as possible with regard to previous examinations of the issues felt to be contributing to rail car cost growth. A review and analysis of each document was undertaken. Summaries of key conclusions were prepared for reference and included as appropriate in this report.

The approach taken to quantify costs for the various elements affecting rail car procurements was to develop a cost breakdown structure (CBS) that would provide a common basis for collecting and analyzing costs for each of the rail car procurements that was identified as having taken place over the past 15 years. The rail car procurement costs used in the study analyses and included in this report, in all cases unless otherwise specified are initial contract cost. They do not include inflation, monetary value adjustments, change orders, spare parts, training or any other costs not related to the rail cars themselves, or any costs that occurred after the initial contract agreement. A data requirements document was prepared and a matrix of each of the germane technical and contractual provisions, opposite the identified procurements, was developed for use during data collection.

It was decided to approach the analytical effort in two phases. First was an analysis linking cost changes to changes in technical and contractual requirements.

This method provided insight into the cost impact of various performance and non-performance requirements, and of the contractual terms and conditions. It also provided insight into the more significant contributors to the rail car cost increases. An outgrowth of this task was a representative cost spread across the CBS with a cost proportion assigned to each element. To complete this analysis, a "typical" rail car was described and a cost estimate for its procurement was developed. An excursion from that model was then hypothesized as a "minimal" rail car procurement, and an attendant cost savings was estimated.

As an additional source of possible cost savings information, a second analysis was performed. Four specific rail car procurements were selected (see Chapter 6) for detailed review. The purpose of these case studies was to evaluate diverse and yet representative acquisitions for general applicability. Several interesting conclusions were drawn that should be useful to authorities planning future rail car purchases.

2.3 Outline of the Report

This report consists of eight chapters. Chapter 1.0 is an Executive Summary of the report containing conclusions and recommendations. Chapter 2.0 contains a general Introduction.

Chapter 3.0. Data Collection, describes the process of determining data requirements; the development and evolution of the cost breakdown structure, data collection formats and questionnaires; and the actual data collection process, including sources and data. It also includes a description of constraints posed by the lack of information, and the analyses based on the data collected.

Chapter 4.0, Data Analysis, discusses the performance and non-performance requirements, terms and conditions, and cost growth in rail car procurements from 1973 through the first quarter of 1988. It includes an evaluation of real cost growth (with inflation considered). It also includes the results of correlation analyses of cost to such factors as length, square footage, weight, passenger capacity, light rail versus rapid rail and order size.

Chapter 5.0, Cost Estimates, presents the rationale for and description of a "typical" procurement, defining it in technical and contractual terms and documenting its cost estimate. This chapter also discusses the deletions, reductions and modifications from the "typical" rail car that could potentially result in a "minimal" car and provides an estimate of the savings from these changes.

Chapter 6.0, Case Studies, contains a description of the following four rail car procurements:

- Southeastern Pennsylvania Transportation Authority (SEPTA) Norristown High Speed Line Light Rail Car - 1987 procurement from ASEA-AMTRAK
- Metropolitan Atlanta Rapid Transit Authority (MARTA) Rapid Rail Car - 1982 procurement from Hitachi
- Santa Clara County Transportation District (SCCTD) Light Rail Car - 1984 procurement from UTDC
- Chicago Transit Authority (CTA) Rapid Rail Car - 1978 and 1981 (option) procurements from Budd

This chapter describes the technical and contractual details of each procurement. An analysis of each case is presented, and a discussion of significant features presented.

Chapter 7.0, Market Survey, documents a market analysis of planned rail car procurements for the 1988-1995 time period. It presents an update to the N.D. Lea "U.S. Transit Rail Car Market Survey" (Reference 13) dated July 1987, and describes significant changes and identifies new systems.

Chapter 8.0 is a combined list of References and Bibliography.

CHAPTER 3.0

DATA COLLECTION

3.0 DATA COLLECTION

A major effort was undertaken to collect an extensive data base of rail car procurements. It was determined that a 15 year history would best serve the analytical needs of the study. A longer period of time would not likely contribute meaningfully to the study results, and would entail too large a data collection and analysis task for the time available. As is always the case when planning any analytical task, the type and availability of data could only be surmised when defining the data requirements and making plans for its collection. The data collection documents were prepared using the assumption that all desired data could be found. As might be expected, all of the data was not available or at least not available to the study team in time to be included in this project. However, considerable needed data was acquired and used in the subsequent analyses.

3.1 Cost Breakdown Structure (CBS)

A cost breakdown structure was developed to aid in capturing consistent data for all identified rail car procurements. Each element within the acquisition process has been included in the CBS so that when all costs are included, their sum will be the total cost per vehicle. During data collection the CBS was modified, as more appropriate organization was determined, so that the CBS depicted in Table 3-1 represents the latest evolved configuration.

3.2 Rail Car Procurement Data Base

Forty-nine (53) individual procurements of rail cars were identified for the 15 year period from 1973 through 1987. In addition, two acquisitions occurred during the first three months of 1988 which were also included in the study, for a total of fifty-one (55) as shown in Table 3-2. Some of the entries represent the exercise of options to earlier contracts, but are included because they are, in effect, independent transactions in the year dollars that their options were put on contract. Information was collected for each of these procurements through research of existing documents, and through extensive telephone contact. Of particular help was the "Roster of North American

Table 3-1

Cost Breakdown Structure (CBS)

1.0	Rail Car Procurement
1.1	Prime Rail Car Equipment
1.1.1	Air Conditioning System
1.1.2	Car Body
1.1.3	Communications Equipment
1.1.4	Electrical System
1.1.5	Fare Collection Equipment
1.1.6	Heating System
1.1.7	Propulsion System
1.1.8	Signal System
1.1.9	Truck
1.1.10	Design Engineering
1.1.11	Integration, Installation and Assembly
1.1.12	Test and Evaluation
1.2	Contractor Management
1.3	Engineering Analyses
1.3.1	Failure Modes and Effects Analysis
1.3.2	Reliability Analysis
1.3.3	Safety Analysis
1.3.4	System Engineering
1.3.5	Other
1.4	Data
1.5	Guarantee, Warranty and Reliability
1.6	Facilities

Rapid Transit Cars 1945 to 1980", The American Public Transit Association (Reference 9) and the "U. S. Transit Railcar Market Survey", N. D. Lea and Associates, Inc (Reference 13).

In addition to the descriptive details presented in Table 3-2, extensive information regarding rail car performance and non-performance requirements, and contractual terms and conditions, was also gathered and will be discussed in Chapter 4.0.

3.3 Case Studies

The four procurements listed below were selected for detailed review to supplement the basic study. In order to gain sufficient insight into each of the selected acquisitions, visits to each of the involved authorities were con-

Table 3-2. Rail Car Procurements

YEAR	AUTHORITY	CARBUILDER	TYPE VEHICLE	NUMBER OF VEHICLES	COST PER VEHICLE *
1973	TTC	HAWKER-SIDDELEY	RT	88	$ 226,250
1973	MBTA/MUNI	BOEING VERTOL	LR	230	$ 276,810
1973	CTA	BOEING VERTOL	RT	100	$ 293,210
1973	MUCTC	BOMBARDIER	RT	282	$ 334,000
1973	BART	ROHR	RT	100	$ 390,000
1974	CTA	BOEING VERTOL	RT	100	$ 301,600
1975	TTC	HAWKER-SIDDELEY	RT	138	$ 389,200
1976	MBTA	HAWKER-SIDDELEY	RT	70	$ 446,899
1976	MBTA	HAWKER-SIDDELEY	RT	120	$ 459,453
1976	MARTA	FRANCO-BELGE	RT	100	$ 562,540
1977	PATCO	VICKERS CANADA	RT	46	$ 730,435
1978	CTA	BUDD CO.	RT	300	$ 444,295
1978	GCRTA	BREDA	LR	48	$ 621,104
1979	SEPTA	KAWASAKI	LR	141	$ 476,596
1979	MDCTA	BUDD CO.	RT	136	$ 614,238
1979	BRRTS	BUDD CO.	RT	72	$ 616,138
1979	MTDB	SIEMENS-DUEWAG	LR	14	$ 630,000
1979	WMATA	BREDA	RT	76	$ 740,060
1979	WMATA	BREDA	RT	18	$ 791,920
1980	SEPTA	KAWASAKI	RT	125	$ 570,840
1980	BALMIA	BUDD CO.	RT	28	$ 630,950
1980	MTDB	SIEMENS-DUEWAG	LR	10	$ 878,800
1981	CTA	BUDD CO.	RT	300	$ 493,795
1981	NFTA	TOKYU CAR	LR	27	$ 645,000
1981	MUNI	BOEING VERTOL	LR	42	$ 768,584
1981	TRIMET	BOMBARDIER	LR	26	$ 775,521
1981	WMATA	BREDA	RT	200	$ 879,724
1982	NYCTA	BOMBARDIER	RT	825	$ 798,770
1982	NYCTA	KAWASAKI	RT	325	$ 844,500
1982	GCRTA	TOKYU CAR	RT	60	$ 872,770
1982	PAAC	SIEMENS	LR	55	$ 896,200
1982	NYCTA	WEST-AMRAIL	RT	225	$ 915,000
1982	BART	SOFERVAL	RT	150	$1,002,883
1982	MARTA	HITACHI	RT	30	$1,109,900
1983	SRTD	SIEMENS-DUEWAG	LR	26	$ 829,119
1983	TTC	UTDC	RT	126	$ 931,034
1983	MBTA	KINKI-SHARYO	LR	50	$ 993,000
1983	MARTA	HITACHI	RT	20	$1,062,000
1984	MTDB	SIEMENS-DUEWAG	LR	6	$ 852,000
1984	SCCTD	UTDC	LR	50	$ 891,660
1984	MBTA	UTDC	RT	58	$ 912,000
1984	TRIMET	BOMBARDIER	LR	7	$1,052,600
1984	MARTA	HITACHI	RT	30	$1,072,000
1985	PATH	KAWASAKI	RT	95	$ 970,000
1985	WMATA	BREDA	RT	72	$1,000,000
1985	MARTA	HITACHI	RT	20	$1,063,195
1986	MARTA	HITACHI	RT	20	$1,059,786
1986	MBTA	KINKI-SHARYO	LR	50	$1,060,000
1986	NYCTA	WEST-AMRAIL	RT	200	$1,109,748
1987	NYCTA	KAWASAKI	RT	200	$ 958,888
1987	MTDB	SIEMENS-DUEWAG	LR	20	$1,046,000
1987	LACTC	NIPPON-SHARYO	LR	54	$1,170,435
1987	SEPTA	ASEA-AMTRAK	LR	26	$1,617,910
1988	MTDB	SIEMENS-DUEWAG	LR	21	$1,135,000
1988	SCRTD	BREDA	RT	30	$1,570,000

* Initial contract cost, i.e., training, spares, escalation, change orders, etc, not included.

ducted by study team members. In addition, contact was made with carbuilders and other suppliers to gather additional cost information and to solicit their views on potential cost reduction areas.

- SEPTA Norristown High Speed Line Light Rail Car - 1987 procurement from ASEA-AMTRAK
- MARTA Rapid Rail Car - 1982 procurement from Hitachi
- SCCTD Light Rail Car - 1984 procurement from UTDC
- CTA Rapid Rail Car - 1978 and 1981 (option) procurements from Budd

3.4 Data Collection Assessment

A reasonable amount of the data that was identified as being required was found in some form, with the shortfalls mainly regarding level of detail. For example, the cost per car was always available, but the breakdown to a significantly lower subsystem and/or component level was usually not a part of the proposals made by the carbuilders, and therefore not a part of the record. This shortcoming naturally constrained the cost data to be studied to the same higher level of detail. However, by drawing on previous work done in this area and on the cases where detail was provided, assumptions could be logically made resulting in reasonable cost estimating relationships (CER) for extrapolation of costs to other circumstances.

It should be noted that the vast majority of suppliers and transit authorities responded very positively to the study team's request for information and support, and showed considerable interest in seeing the results of the study. The study team is satisfied that sufficient data was made available to assure a valid and meaningful conclusion to the study.

CHAPTER 4.0

DATA ANALYSIS

4.0 DATA ANALYSIS

This Chapter contains an analysis of the cost, performance requirements, non-performance requirements, and terms and conditions of the rail car procurements identified in Section 3.2.

4.1 Rail Car Cost Growth

There are many ways to look at the cost growth of rail cars. It is easy to be concerned when looking at raw cost data without considering the effects of inflation and the foreign exchange rate fluctuations over the period under study. Figure 4-1 shows a scatter plot of the raw data, where each point represents an individual rail car procurement. The costs are in current-year dollars (cost at the time of contract). No normalization of the data has been attempted in this case.

Figure 4-2 is the same data, but deflated to constant 1973 dollars. In other words, inflation has been removed from the data. The Implicit Price Deflator For Gross National Product (GNP) has been used to return the values to 1973 dollars. It was decided that this index best represented general price inflation because of its broad economic coverage and its lack of bias to any specific consumer or industrial sector. The index sources were The National Income and Products Accounts of the United States, 1929-1982 (Reference 32) and the Statistical Abstract of the United States 1988 (Reference 29). The implicit price deflator is described as a by-product of the deflation of GNP. It is derived as the ratio of current- to constant-dollar GNP and is a weighted average of the detailed price indexes used in the deflation of GNP. The index's components are as shown in Table 4-1.

It appears from Figure 4-2 that a considerable amount of the price increase depicted in Figure 4-1 is eliminated by removing the effects of inflation. This presumption is investigated further in the following sections. Again, in Figure 4-2, no attempt has been made to normalize the data.

Figure 4-1. HISTORICAL RAIL CAR COSTS

CURRENT-YEAR DOLLARS

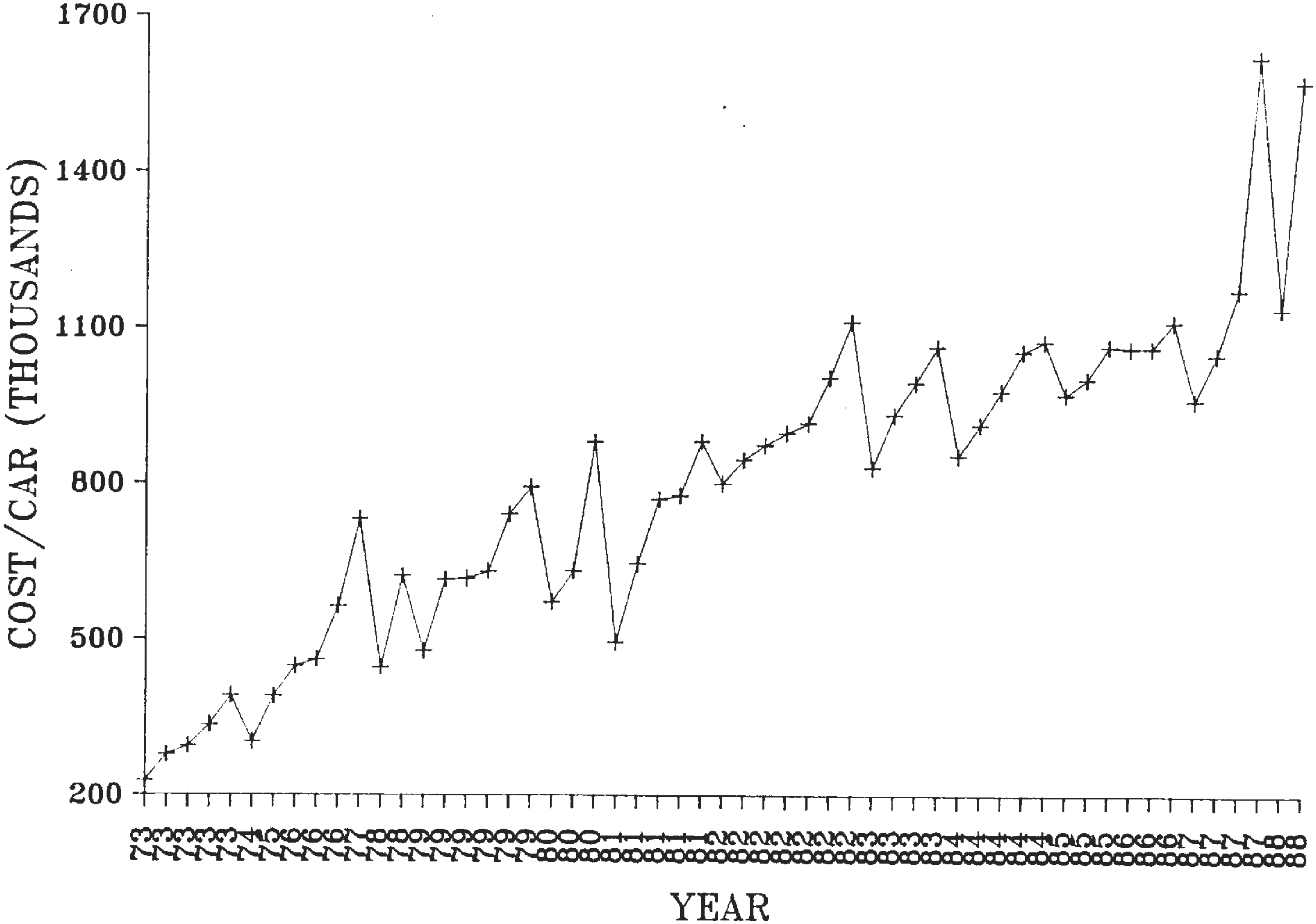


Figure 4-2. HISTORICAL RAIL CAR COSTS

CONSTANT 1973 DOLLARS

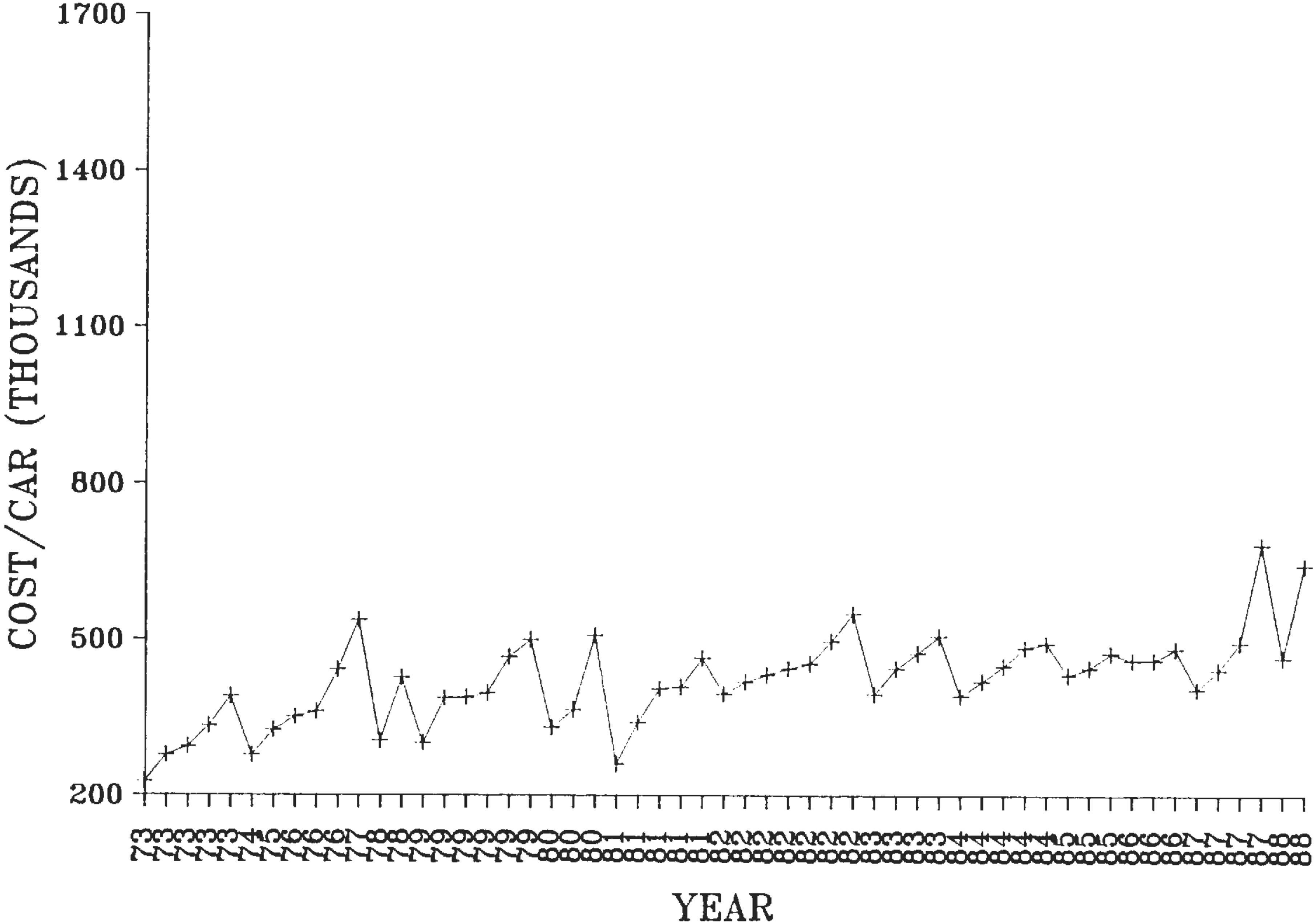


Table 4-1

Indices of the GNP

Personal consumption expenditures
- Durable goods
- Nondurable goods
- Services

Gross private domestic investment
- Nonresidential
  - Structures
  - Producer's durable goods
- Residential

Net export of goods and services
- Exports
- Imports

Government purchases of goods and services
- Federal
  - Defense
  - Nondefense
  - State and local

4.1.1 Data Correlation/Normalization

Historically, rail car data has been divided into light rail and rapid rail categories, and normalized by weight (pounds) or length (feet). During this study, a correlation analysis was conducted to determine which, if any, characteristic could effectively be used to normalize the data. It was also desired to investigate the relationship of the various parameters to car costs as part of the data analysis.

Several rail car characteristics were selected for consideration as normalization factors and correlation analyses were run on all combinations using the Northwest Analytical Inc. (NWA) "Statpak" (Reference 42). These computer runs resulted in the data presented in Table 4-2. Cost per car was stated in terms of constant 1973 dollars to remove inflation bias from the analyses.

Table 4-2

Rail Car Characteristics for Correlation/Normalization

CHARACTERISTIC	CHARACTERISTIC	COEFFICIENT
COST PER CAR	LOT SIZE	-.24867
"	LENGTH	.40640
"	CRUSH LOAD CAPACITY	.14944
"	WEIGHT	.54182
"	LENGTH TIMES WIDTH	.27644
LOT SIZE	LENGTH	-.51789
"	CRUSH LOAD CAPACITY	-.15320
"	WEIGHT	-.16080
"	LENGTH TIMEs WIDTH	-.38672
LENGTH	CRUSH LOAD CAPACITY	.55465
"	WEIGHT	.71762
"	LENGTH TIMES WIDTH	.84008
CRUSH LOAD CAPACITY	WEIGHT	.47649
"	LENGTH TIMES WIDTH	.65806
WEIGHT	LENGTH TIMES WIDTH	.51104

To help understand the meaning of the above data, the definition of correlation coefficient (r) is taken from Bernard Ostle's book "Statistics in Research" (Reference 43) where it is given as "... $-1 \leq r \leq 1$ where -1 represents perfect negative linear association in the sample and +1 represents perfect positive linear association in the sample. A value of 0 is interpreted to mean that no linear association between X and Y exists in the sample...." In this quote, X and Y represent the two variables being correlated.

Some interesting conclusions can be inferred from the correlation data. First, weight appears to be the best normalization factor because it has the highest correlation coefficient, but at .54182 it does not represent an especially high degree of consistency with car costs. Figures 4-3 and 4-4 represent cost per pound for the same data points as shown in Figures 4-1 and 4-2. The normalization of this data does not appear to make any significant contribution to understanding the information. When viewing all four of these curves, a definite anomaly appears as a spike at the last procurement for 1987.

FIGURE 4-3. HISTORICAL RAIL CAR COSTS

COST PER POUND (CURRENT-YEAR DOLLARS)

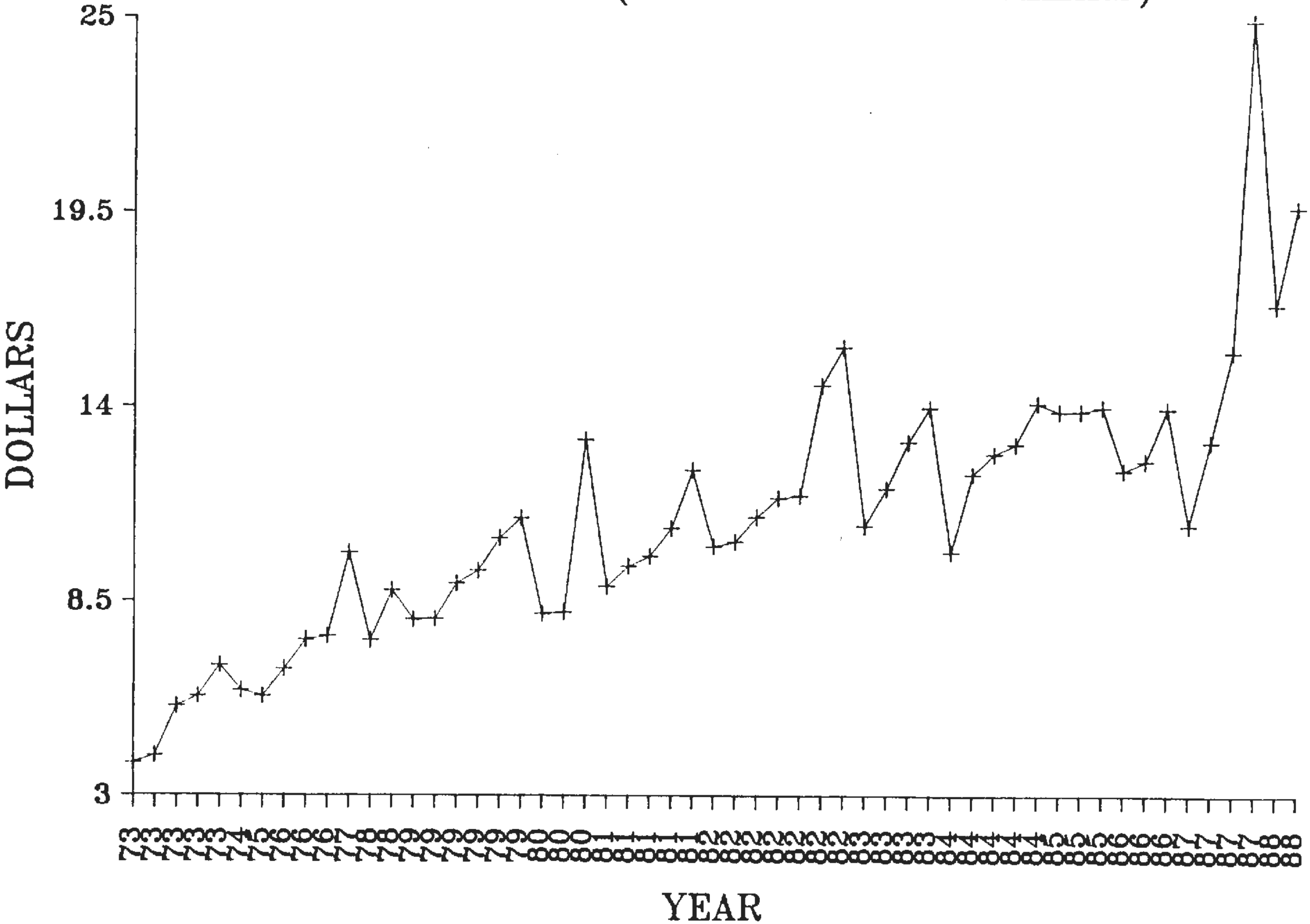
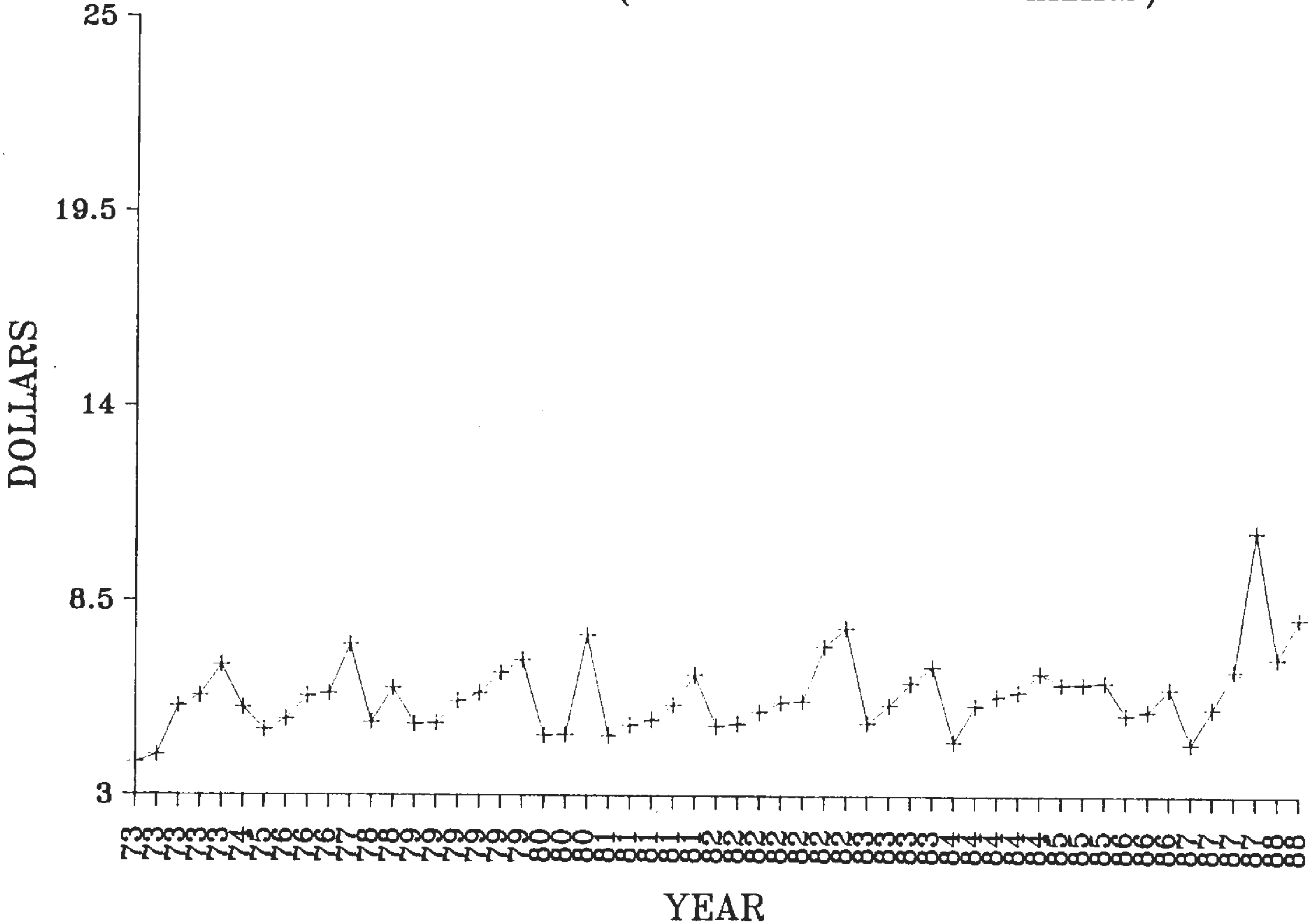


FIGURE 4-4. HISTORICAL RAIL CAR COSTS

COST PER POUND (CONSTANT 1973 DOLLARS)



This data point is the SEPTA procurement for the unique Norristown High Speed Line (NHSL) which is discussed in some detail later in Chapter 6. In performing the same correlation analysis as above on data with this one point removed, a somewhat improved coefficient of .62412 results for the correlation between car costs and weight.

Some other conclusions are: (1) lot size appears to vary inversely with cost per car as expected, but to only a mild degree (to be discussed again, below), (2) cost per car is nearly independent of crush load capacity, and (3) length and weight and square footage are closely correlated as they are also with cost per car.

4.1.2 Impact of Car Type and Lot Size

Next, the differences between light rail and rapid rail cars were investigated. The data shown in Table 4-3 (in constant 1973 dollars) is considered.

Table 4-3
Data Correlation by Car Type and Lot Size

	LIGHT RAIL		RAPID RAIL		ALL RAIL CARS	
	MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV
COST/CAR	431,393	86,354	401,982	88,158	414,711	91,705
LOT SIZE	48	53	136	147	112	136
LENGTH	75.9	8.6	67.8	10.7	70.3	11.0
CAPACITY	201	50	233	55	218	53
WEIGHT	75,956	11,905	70,793	10,414	71,666	11,265
SQUARE FEET	675	85	677	139	667	121

A comparison of the data shows that light rail vehicles are, on the average, about $29,000 more expensive and 5,000 pounds heavier than rapid rail cars. On the other hand, rapid rail cars are able to carry 32 more passengers (Crush Load). Both type cars have about the same square dimensions leading to the conclusion that rapid transit cars are wider (1.1 feet in fact). The significant difference, however, is the fact that when light rail vehicles were procured, the average number of cars was 48 as compared to an average of 136 for rapid rail cars. This lot size difference explains the higher average cost per car, as discussed below. A review of the characteristics and dimensional data indicates that both types of cars cover a full spectrum, overlapping each other, and leading to the conclusion that there are no compelling reasons to separate light rail vehicles from rapid transit cars when analyzing the data.

The above disparity in lot size, consistent with the difference in cost per car, leads to a conclusion that for lot sizes less than some number, prices per car are going to be greater than for procurements larger than that number. The question is whether there is a linear relationship (our data seems negative) or whether there is a breakpoint under which cars can be expected to be abnormally expensive.

A sensitivity analysis was conducted where data were divided into two groups by lot size, without regard to type car. The difference in average cost per car for various groups with different dividing points was then maximized. This analysis showed a significant difference in average rail car costs for lot sizes of 46 or less ($471,905) when compared with lot sizes of 47 cars or more ($391,363). In performing an analysis of the correlation of lot size to cost per car within these two groupings, it turns out that there is virtually no correlation.

There are several explanations for this lack of correlation within the selected groups (Group A $\geq$ 47 cars, Group B $\leq$ 46 cars). First, many of the large orders in Group A are the exercise of options to previous contracts which, although escalated, tended not to keep up with inflation. Secondly, many of these orders are from NYCTA and CTA, both of whom usually buy cars of the same, or similar, basic design many times and in large quantities, thereby flattening costs and obscuring the impact of lot size.

In the group of procurements of 46 cars or less (Group B), many unique circumstances prevail including a lack of commonality in design and other special requirements. It must be concluded that this group as a whole is more expensive because of the carbuilder's need to spread all of the non-recurring costs over only a few cars. More importantly, design and manufacturing costs, and the other special circumstances, apparently provide so much counteracting variability that they smother the expected correlation of cost to lot size.

4.1.3 Annual Trend Analysis

In order to analyze the data over time, annual weighted averages of the cost per rail car were calculated. The risk in doing this is that in some years there will have been a very limited number of cars procured, but will be represented on the curve with the same impact as those years where a large number of cars were acquired. In spite of this risk, however, it seems useful to look at the data in this way, keeping in mind that a small number of cars in a given year can produce an unreliable data point.

Figure 4-5 presents the weighted averages of the cost per rail car in current year dollars and Figure 4-6 shows the same information in constant 1973 dollars. The numbers in parenthesis, on the X axis, are the number of cars procured during that year. This data can be further broken down into two separate groups with light rail vehicles in one group and rapid rail cars in the other, as displayed in Figures 4-7 and 4-8, respectively. It is easy to detect that the 1977 single procurement of 46 cars has produced an anomaly in the data. It is not quite so clear whether the two procurements so far in 1988, for a total of 55 cars, have resulted in another anomaly in the data, or whether they represent a dramatically increasing trend. A study of the separate light rail and rapid rail data indicates a strikingly similar trend in costs, reinforcing the conclusion that they do not have any significant distinguishing characteristics impacting their costs. Therefore, this grouping by type will not be utilized in the remainder of the report.

A regression line was fitted to the current-year data for the points from 1980 through 1988. This period was used because it was current enough to be representative of today's cost patterns while also encompassing enough data points to make the regression meaningful. The average annual growth rate for the regression line was computed and rail costs projected from the 1988 regression point to 1995 to estimate where rail car costs are going and also to

FIGURE 4-5. ANNUAL RAIL CAR COSTS
CURRENT-YEAR DOLLARS (WEIGHTED AVERAGE)

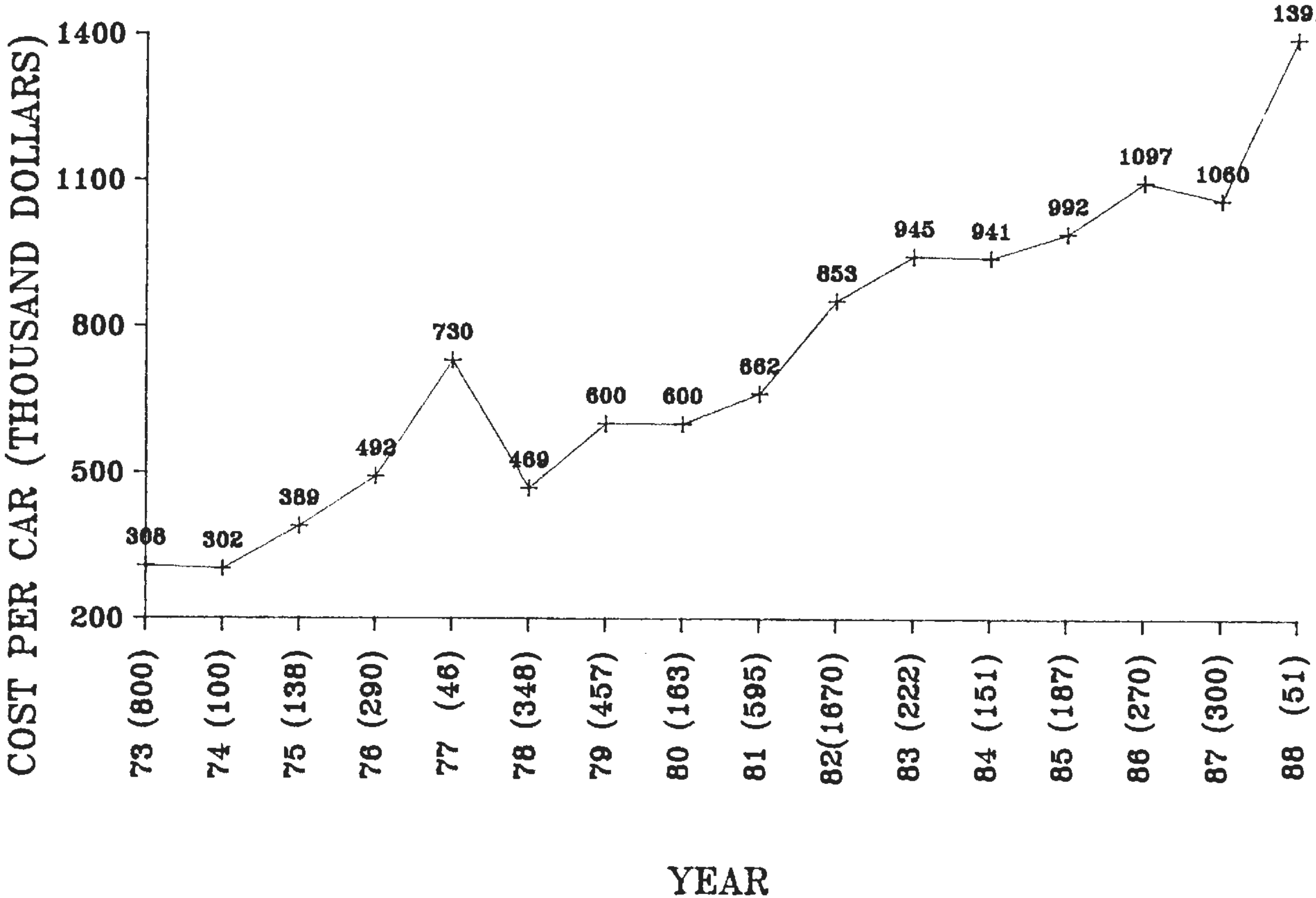


FIGURE 4–6. ANNUAL RAIL CAR COSTS

CONSTANT 1973 DOLLARS (WEIGHTED AVERAGE)

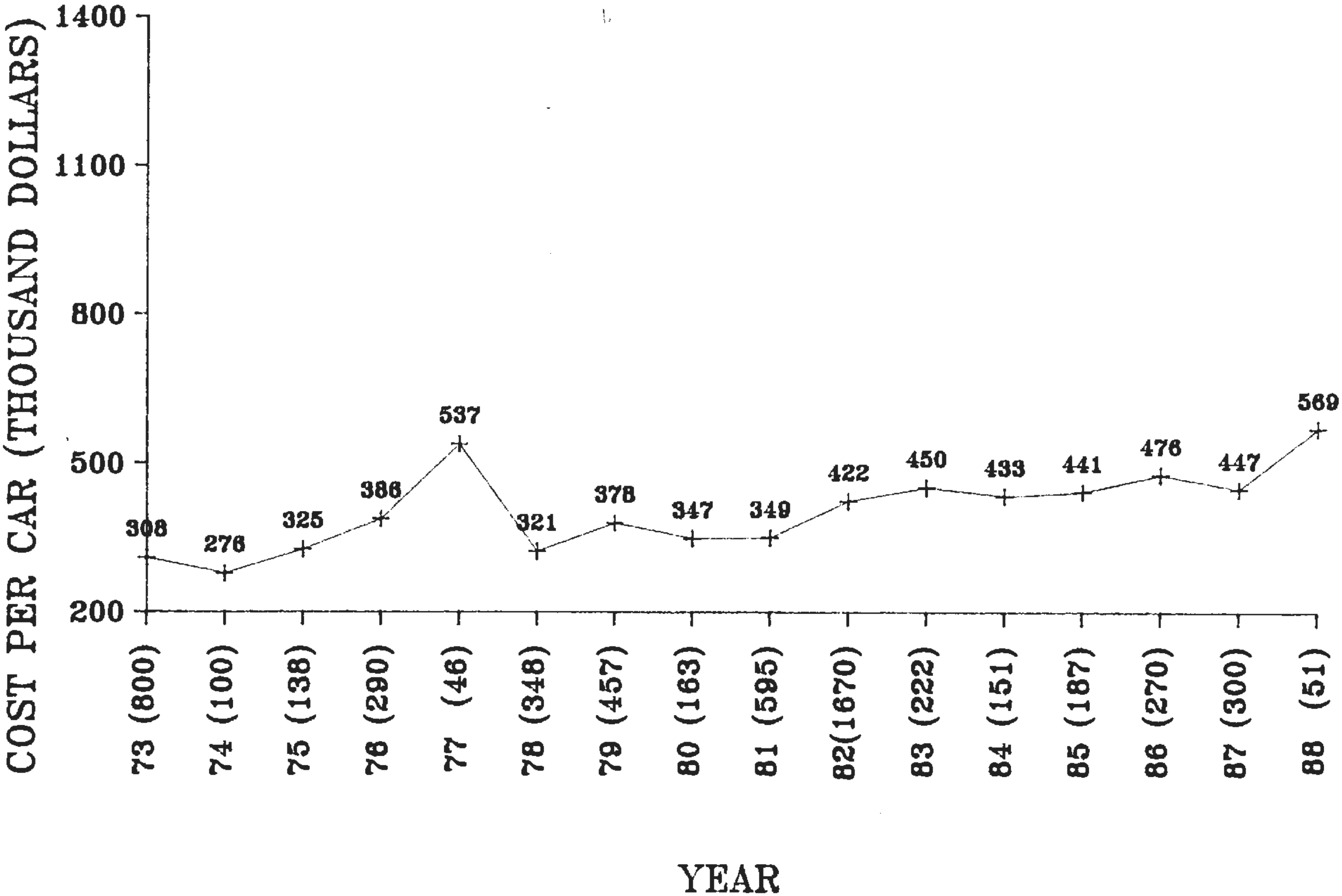


FIGURE 4-7. ANNUAL LIGHT RAIL CAR COSTS

CURRENT-YEAR DOLLARS (WEIGHTED AVERAGE)

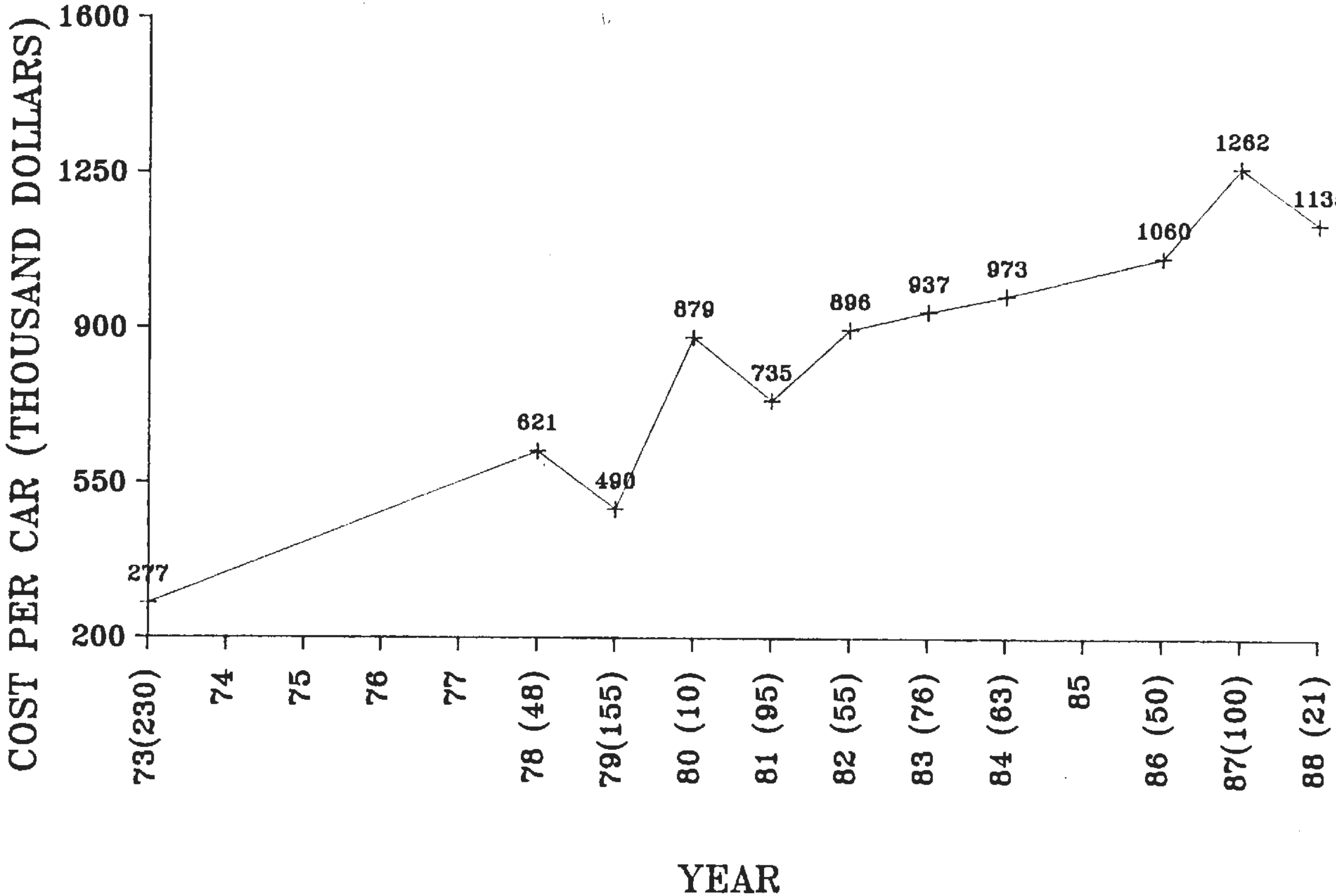
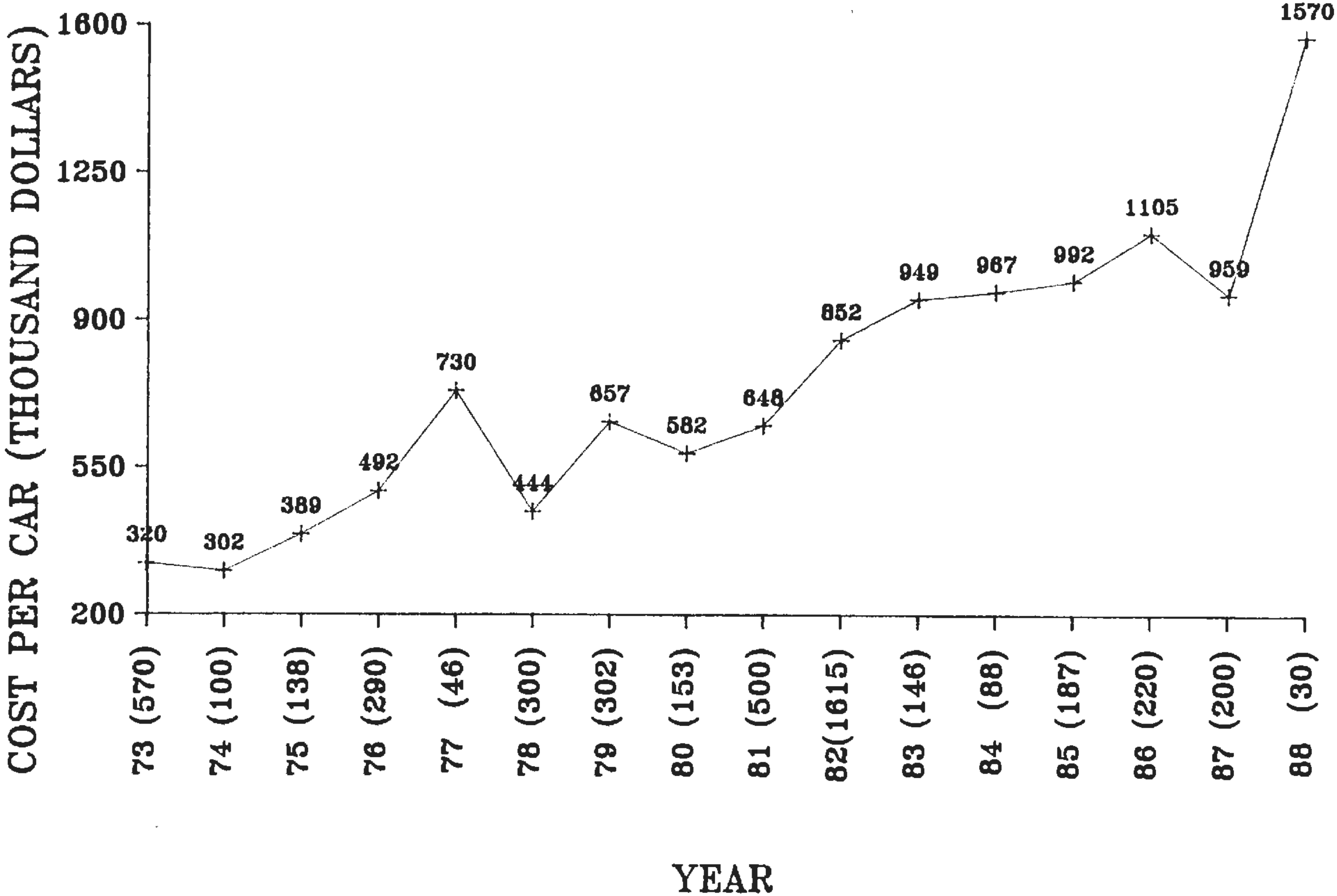


FIGURE 4-8. ANNUAL RAPID RAIL COSTS
CURRENT-YEAR DOLLARS (WEIGHTED AVERAGE)



evaluate whether the 1988 costs are an anomaly or a forewarning of the future. The outcome is disconcerting. Figure 4-9 shows the expected average cost of cars, in current-year dollars, increasing at an average annual rate of about 9.4% per year, to nearly $2.4M in 1995. The results tend to verify that the 1988 costs are consistent with the underlying direction of costs. This extrapolation is based on the assumption that inflation will average the same rate from now until 1995 that it has averaged since 1980.

Removing the effects of inflation from this analysis, the same process as above was followed using 1980 to 1988 data in constant 1973 dollars. Figure 4-10 shows the results with a projected cost in 1995, in constant 1973 dollars, of $739,000. In this case, with inflation removed, rail car costs still show an increasing trend, from 1980 to 1988, of an average of approximately 5.1% per year. This is a rate that clearly warrants serious efforts at reducing, or at the very least, containing rail car costs. From the above data, it can be concluded that over half of the rail car cost increase from 1980 to 1988 was non-inflation induced. The remainder of this report will investigate the factors impacting this cost growth.

4.2 Performance and Technical Requirements Growth

This section looks at changes in performance and technical requirements over the period covered by the data. It considers all features and characteristics that collectively describe the physical rail car itself. Specifically, the objective is to set a framework so that a share of cost growth can be attributed to changes in the rail cars themselves. The next two sections will take a similar approach to a history of changes in terms and conditions, and non-performance requirements. In considering performance and technical requirements, the areas of primary concern include the car body design and materials; the propulsion, braking and auxiliary systems; train control and operation; and performance levels. A discussion of other potential impacts is also included. The objective of this section is to find causal relationships, where possible, between performance and technical requirements and cost changes.

FIGURE 4-9. COST TREND (1980-1995)

CURRENT-YEAR DOLLARS (WEIGHTED AVERAGE)

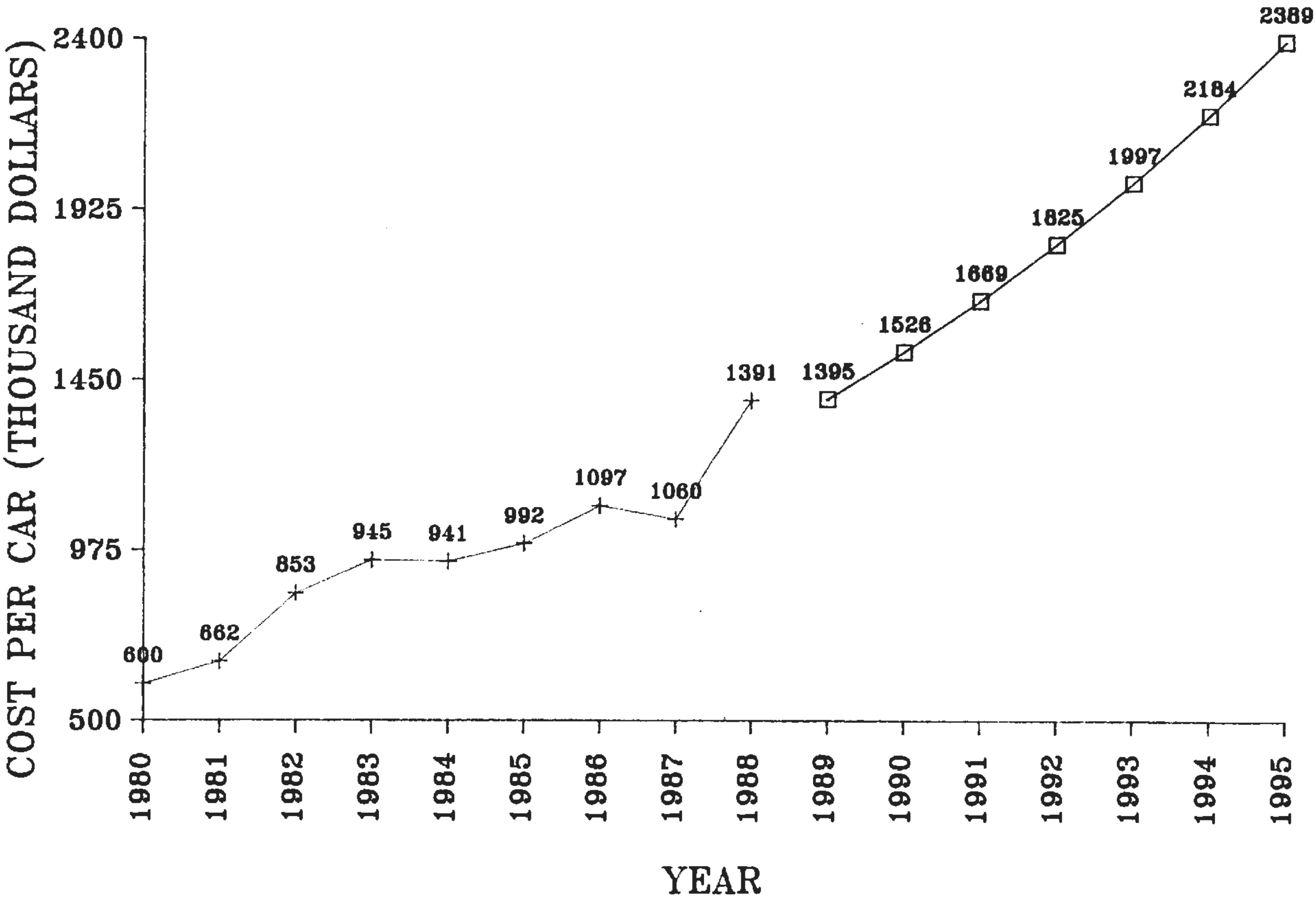
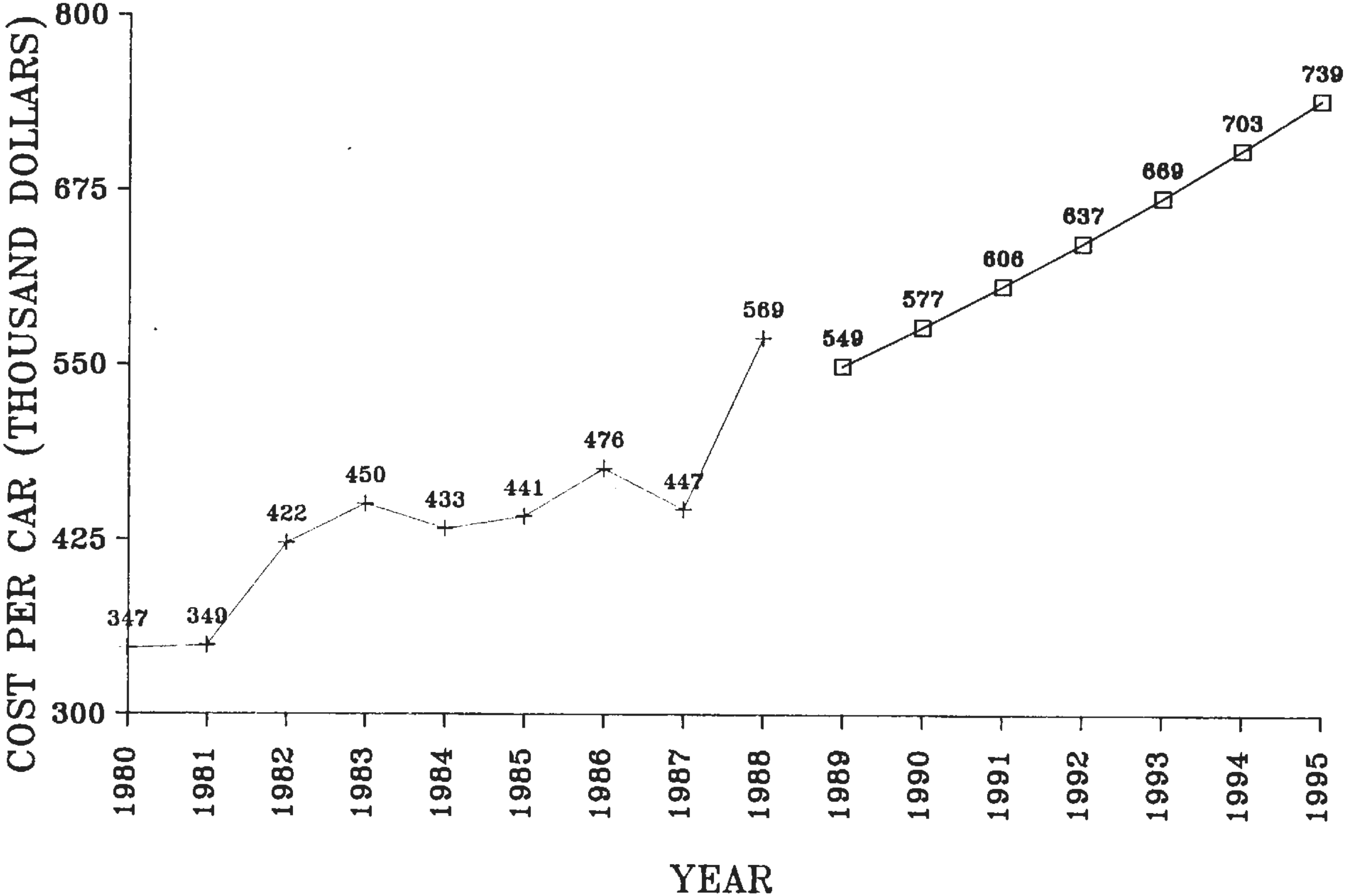


FIGURE 4-10. COST TREND (1980-1995)

CONSTANT 1973 DOLLARS (WEIGHTED AVERAGE)



This study is directed primarily at acquisition costs and, therefore, has not delved into the essential trade-offs between the cost of purchase and the subsequent cost of support, operation and maintenance. It is important to emphasize the significance of life cycle cost considerations when determining what type of subsystems to include in a new rail car procurement. Areas where life cycle costs should be considered when making specification decisions include the type of propulsion system, car body materials, door operation and control, trucks and suspension, brakes and environmental systems.

A part of any such trade-off analysis should also include evaluation of the state of readiness of the new system being considered. In the past, the advent of automated and sophisticated new systems has provided the promise of substantial operational improvements and life cycle cost savings, but sometimes reliability, maintainability and performance problems were delivered instead. Until a new system is proven, caution in assessing its benefits is advised. ARINC Research Corporation's final report "Development of a Plan, Guidelines, and Methodology for Developing and Implementing Life-Cycle Costing for the Procurement of Rail Transit Rolling Stock" (Reference 46), April 1981, provides a useful guideline to consideration of the total cost of ownership.

A list was developed of all performance and technical factors that were considered to have potential as cost drivers. From this list those factors were selected which would most likely be the major cost drivers and which also offered the most hope of getting sufficient information for a reasonable analysis. The performance and technical factors that were investigated for this analysis are discussed below. It should not be concluded that those items that were not selected have no cost savings potential, but rather that the magnitude of their individual savings would be less than the factors selected. Small savings do add up and it would be unwise to ignore any of them when developing rail car requirements.

A number of items have been previously researched in N. D. Lea's 1979 report "Cost Savings Potential of Modifications to The Standard Light Rail Vehicle Specification" (Reference 28). Although the data specifically applies to the SLRV, it seems reasonable to assume that savings for most rail cars would be of the same order of magnitude. Some of the estimates presented in the referenced report are listed below to provide a measure for consideration when making trade-off decisions. These savings are not all mutually exclusive and, therefore, the total savings possible would be something less than the sum of the items. In some cases, technological advances may have eliminated a portion of these identified cost savings. For example, current articulation units are now much less expensive and much more reliable than they were in 1979.

Table 4-4

Identified Cost Savings

TECHNICAL CHANGE	SAVINGS
Delete plug doors, and use straight body panels at tapered ends	4.17%
Simplify control requirements	2.41%
Simplify reliability requirements	1.77%
Allow wheels with damping rings	.64%
Relax car body smoothness requirement	.44%
Simplify articulation design	.36%
Delete operator cab enclosure	.27%
Delete remotely controlled destination sign	.13%
Delete stop request sign	.07%
Allow three piece windshield	.03%
Eliminate articulation section	5.52%
Doors on one side only	2.96%
Unidirectional car	2.67%
Delete compressed air	1.97%
Simplify friction braking	1.32%

The cost growth and specific impacts of selected performance factors are discussed below.

4.2.1 Air Conditioning

Although its deletion as a procurement requirement is frequently cited as a potential source of savings, the fact is that 92% of all new rail cars procured since 1973 have included air conditioning. The cost attributed to air conditioning for two different rail car procurements, one in 1982 and one in

1987, were $50,000 and $30,000, or 4.5% and 1.8% of the cost of the car, respectively. Although air conditioning requirements clearly vary according to the size of the car and the environment in which it is operated, it appears that an estimate of savings available by its deletion could be expected to fall somewhere between these two extremes.

The N. D. Lea report cited above (Reference 28) found that most of the supplier, engineering consultant, transit authority, and DOT personnel that they interviewed "...did not believe much money could be saved by relaxing ride quality, heating, air conditioning, or lighting requirements. It was generally accepted that for most cities today, air conditioning will be a requirement...." That is also one of the conclusions of this report. It is an underlying objective of urban mass transit to encourage maximum ridership. Certainly, in a world of nearly universally air conditioned automobiles, rail cars in most American cities must have air conditioning to compete.

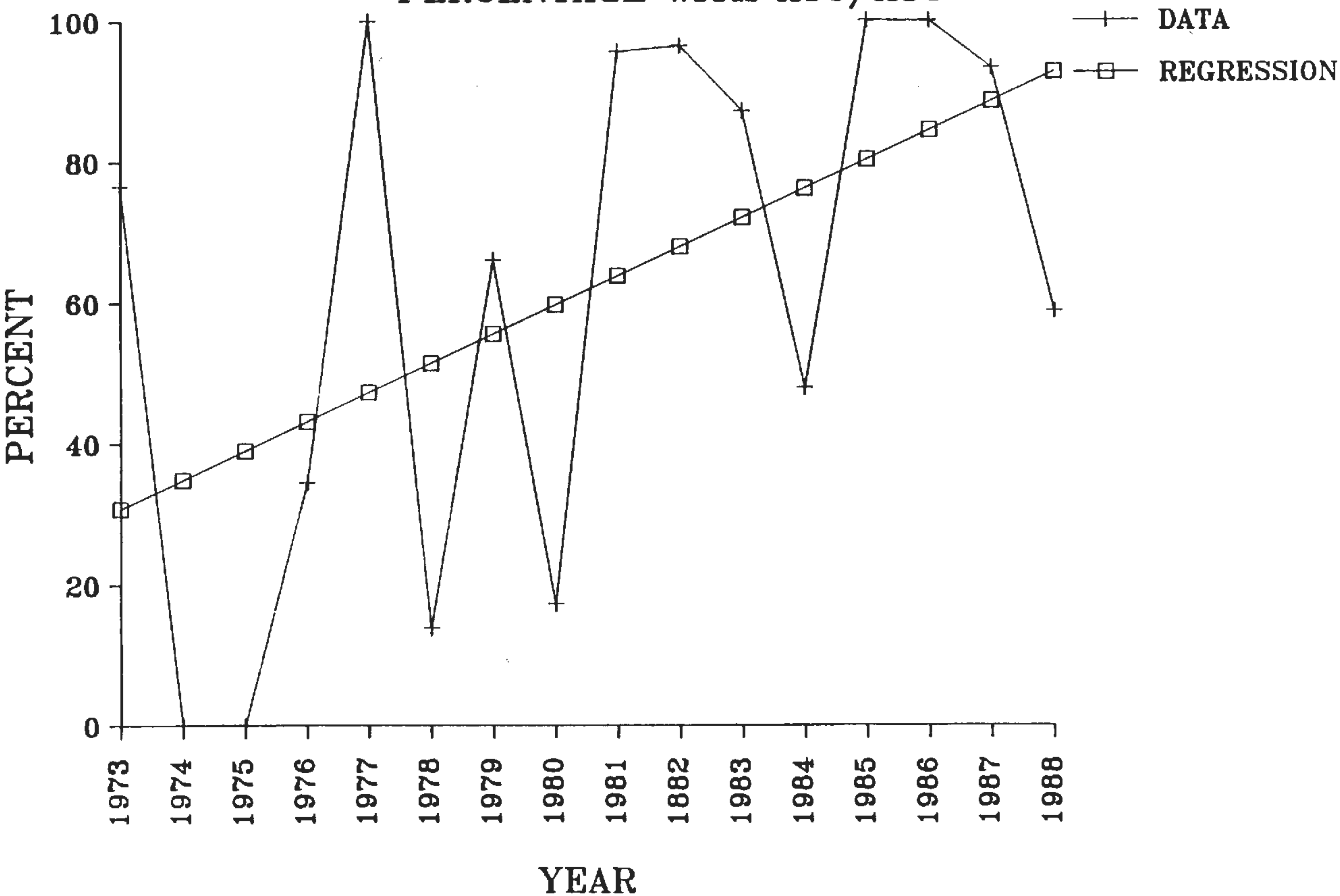
4.2.2 Automatic Train Control

There has been an erratic but steadily increasing trend in the number of cars being purchased with some form of automatic train control and/or automatic train operation. One of several variants of automatic train control is now found in about half of the car purchases, but fully automatic train operation is still quite uncommon. Figure 4-11 shows a plot of the weighted average percentage of rail cars bought annually with some form of ATC/ATO since 1973. A regression line is overlaid showing a rising trend with an average annual increase rate of 7.7%. It appears that some portion of the increase in rail car costs can be attributed to the increase in use of automatic train control.

To estimate the cost of ATC/ATO, the cost of spare parts for the SCRTD rapid rail car ATO system (Reference 47) was taken as representative of the cost of an installed system in a car. It is recognized that spares are sometimes priced at 1 1/2 to three times the installed cost (see Reference 10). However, by using the entire spares cost, engineering and integration costs are accounted for. In this case we would estimate ATO cost at 4.5% of the car

FIGURE 4-11. RAIL CAR PROCUREMENTS

PERCENTAGE WITH ATC/ATO



cost. The other end of the spectrum is the simple automatic speed control (governs top speed only) on the SLRV which is reported as only 0.3% of the car cost (Reference 28). It seems reasonable that the cost of ATC/ATO would fall within this range, depending on the system specification and complexity. There is also a significant transit system (non-carborne) equipment cost associated with ATC/ATO that must be considered when evaluating a tradeoff in this area.

4.2.3 Propulsion System

Over the years, one good example of a trade-off that has been decided in both directions, is the choice between chopper and cam propulsion control systems. Chopper control systems have been used consistently since 1973 in approximately 41% of the rail cars procured. The recent advent of ac propulsion systems has now extended and complicated this decision. The capital costs of these three types of propulsion systems appear to be quite close in terms of overall car costs. In 1982, the dc chopper control propulsion system for the MARTA rapid rail car cost $253,000 and the dc cam control propulsion system for the NYCTA R44 car cost $225,000. In 1987, the N. D. Lea and Associates report "Costs and Benefits of AC Propulsion" (Reference 21), estimated a cam controlled propulsion system at $230,000 and an ac propulsion system at $250,000. Although the exact cost of the ac propulsion system on the SEPTA NHSL light rail cars is not available, the carbuilder (ASEA) advised SEPTA that the cost of a dc chopper system and an ac system are now equivalent.

The chopper system is generally considered to provide up to 25% energy cost advantage over cam control primarily as a result of regenerative braking (Reference 44). An energy cost reduction study done for WMATA, by the Mellon Institute in April 1982 (Reference 45), estimated a savings of $8,500 per car per year (in 1982 dollars) based on the WMATA operating timetable. If the cars are used on the basis of two chopper cars per train, the savings were estimated at $16,000 per year per chopper car. Estimates of support cost savings for ac propulsion over a cam control system, made by SEPTA when considering the NHSL light rail car (Reference 23), were about 55% and included equipment maintenance, energy and spares costs but did not include capital costs. The N. D. Lea report (Reference 21) estimates the savings at approximately 30%, not considering the capital cost of cars (including less spare cars).

4.2.4 Other Factors

There are two other factors for which definitive cost impacts could not be identified within the scope and timing of this study which deserve comment.

Type of Specification - There has been considerable discussion regarding which type of specification, performance or design, is better. There have been very successful procurements with reasonable costs using both types of specifications. For example, procurements from big authorities such as CTA and NYCTA tend to use design type specifications because of their engineering capabilities and extensive experience, and requirement for standardization within their systems. NYCTA/CTA's rail car costs for this reason, as well as others such as lot size and evolutionary design, have consistently remained on the low side. Other authorities such as BART and the MBTA/MUNI Joint SLRV procurement have purchased cars through use of a performance specification (Reference 11).

In some cases such as Sacramento, San Diego, Buffalo and Los Angeles/LACTC, cars have been bought "off-the-shelf" from a manufacturer which had built a similar car before (Reference 7). Experience shows that most procurements use neither strictly performance nor strictly design specifications, but rather a hybrid fitting the particular needs of the authority. It does not seem likely that the type of specification bears greatly on the cost of the car, but rather that the underlying requirements are the cost drivers. New systems can afford to procure to broad requirements because they need not concern themselves with integration into an existing system with performance compatibility, and maintenance and spare parts standardization requirements. On the other hand, older systems should consider these requirements. They also have the experience to know which systems and components have operated well in the past. Thus, a more design oriented specification is used.

Standardization - This is another subject that is widely discussed as a source of rail car savings. Much has been written on this subject and will not be repeated here. The reader is referred to N. D. Lea and Associates report "Benefits of Rail Car Standardization" (Reference 10). This report concludes that "...standardization...has the potential for significant reductions in both capital costs and maintenance costs...". It is apparent that standardization, where it can be applied, yields a benefit in bid price.

A form of standardization results when an authority buys a car of the same design as one previously purchased. This practice derives its cost effectiveness in part from the same principle that drives costs down for larger lot sizes (see Chapter 3). These benefits can also be gained in the type of procurements where authorities have bought variants of previously manufactured cars. In cases such as these, fixed costs are minimized and very little design effort is necessary. Even when a different carbuilder is selected, but an existing car design is used, design costs can be small and technical risk minimized. It appears that it may be of benefit to encourage these type of procurements and larger lot sizes available through joint purchases.

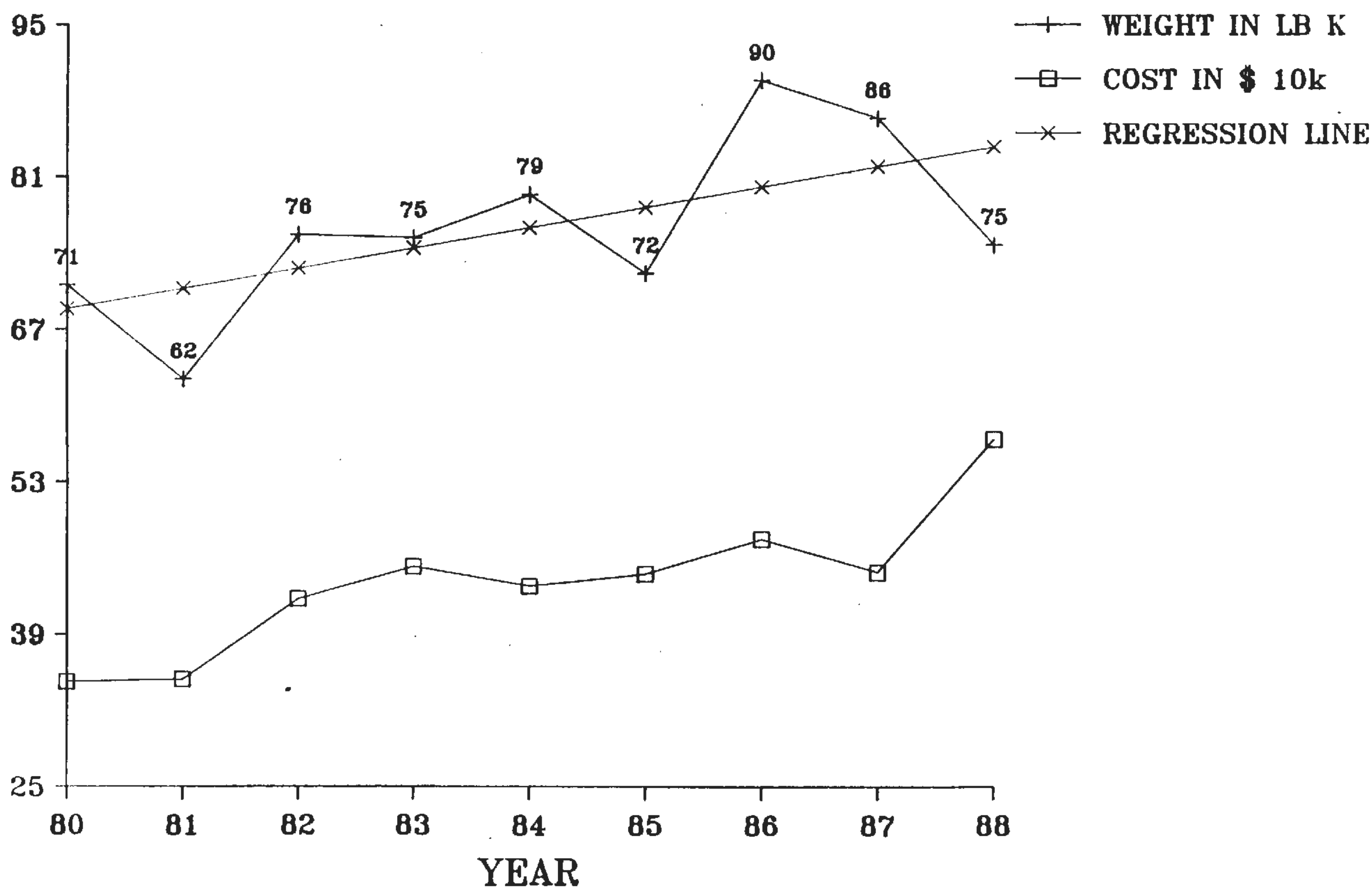
4.2.5 Conclusion

In assessing the overall impact of performance related requirements on rail car cost growth, a reasonable approach is to select a surrogate for the collective effect of performance related factors. That surrogate can arguably be designated as car weight. As was shown in Section 4.1, weight is fairly well correlated with rail car dimensions such as length and width, as well as with cost. In general, it is also true that the addition or enhancement of a subsystem in a car will add weight. Examples would be chopper control, air conditioning, automated door and destination signs, cab enclosures, additional braking systems, spin/slide systems, ATC/ATO systems, etc.

A preponderance of longer cars have been procured in the last few years. This additional length partially, but not totally, explains an increase in weight (and also car costs) which has shown an average annual growth rate of about 2.4%. Figure 4-12 shows the weighted average car weights by year,

FIGURE 4-12. CAR WEIGHT VS COST

CONSTANT 1973 DOLLARS (WEIGHTED AVERAGE)



juxtapositioned with the constant 1973 dollar curve of rail car costs. As was determined earlier in Section 4.1, the car costs increased at an average annual rate of 5.1%. Based on this line of reasoning and the above data, it is estimated that the impact of performance and technical factors on rail car cost growth is on the order of 47% (2.4%/5.1%).

Important performance and technical cost drivers are:

- Design maturity
- Order size
- Rail car size (length and weight)
- Automation
- Car body configuration
- Design features

4.3 Terms and Conditions Growth

4.3.1 Background

The impact of various terms and conditions on the cost of transit cars has been studied for many years. For example, references prepared during the 1973-1988 interval being addressed in this study include "An Evaluation of the Procurement Process Used to Purchase Rolling Stock and Technical Equipment for Mass Transit", U. S. Department of Transportation, March 1980 (Reference 11); "A Study of Transit Rail Car Guaranty, Warranty and Reliability Contractual Provisions", N. D. Lea and Associates, February 1982 (Reference 5); "Changes in the U. S. Transit Rail Car Manufacturing Industry", N. D. Lea, April 1983 (Reference 7); and "Special Guidelines For Rail Transit Equipment Procurements", U. S. Department of Transportation, March 1978 (Reference 19).

These and other references have developed several recommendations for containing costs associated with contract terms and conditions. These include use of negotiation in the procurement process, for example by using the so-called "two-step" acquisition strategy as opposed to the "one-step" sealed bid. This process requests technical proposals from all offerors as the first step, followed by cost proposals from those offerors judged technically qualified as a second step in the procurement. Negotiation enters this process prior to submission of the cost proposals. During this interval the buyer and each offeror can attempt to reach a mutual understanding of the procurement requirements. It should be noted that some state and local laws prohibit procurements other than sealed bid firm fixed price.

The use of escalation clauses to protect a contractor from excessive cost risk from unforeseen inflation rates is also cited as a recommended contract condition. This provides for equitable adjustment of the contract price to offset inflation of material and of labor costs during the contract life. Typically these clauses assume that sixty percent of a car's cost is materials and forty percent is labor. These clauses appear to have evolved from the period of high inflation of the early 1970's, and now seem commonplace in procurements.

A condition of Federal support for acquisition of rail transit cars is an additional group of terms and conditions which must be passed on to each participant on the contractor's team. Requirements imposed as a corollary to receipt of UMTA support include "Buy America" and minority participation. The "Buy America" provision, which became effective in 1978, mandates that the domestic content of a rail car exceed fifty percent of the component cost and that final assembly take place in the U.S. Minority participation clauses require that the carbuilder have an acceptable Equal Employment Opportunity (EEO) program and that goals be set for Disadvantaged Business Enterprise (DBE) participation as subcontractors and suppliers under the contract.

Other federally or locally mandated terms, such as steel content requirements and elderly and handicapped access requirements, also impact procurements in those areas. However, in some cases, the rail car cost may not be affected such as the San Jose light rail system which provides elderly and handicapped access by use of track-side lifts. The cars themselves have no special features for accessibility.

4.3.2 Data Analysis

This section addresses changes in required contract terms and conditions which occurred during the fifteen year analysis interval. The purpose of this analysis, as in the previous section, is to identify areas which show correlation with cost over the analysis interval. The candidate terms and conditions selected were:

- Authority of Engineer
- Bonding
- Buy America
- Cost of money
- Design reviews
- Escalation
- Financing
- Guaranty/Warranty
- Indemnification
- Insurance
- Liquidated damages
- Monetary value adjustment
- Procurement process
- Progress payments
- Renegotiation
- Spare parts availability
- Stop work orders
- Termination

Each term is discussed in detail in the following paragraphs.

Authority of Engineer - This term provides for a representative of the procuring agency to interpret contract conditions, including technical requirements of the contract specifications, and to order the carbuilder to make changes as deemed appropriate. Some procurements in the 1970's incorporated unilateral clauses, which exposed a contractor bound by a fixed-price contract to potentially significant risk. Recent procurements still include means for the procuring agency to modify/amend the contract provisions, but with bilateral, negotiated relief to the contractor.

Bonding - This term requires that the contractor obtain an irrevocable financial commitment from a capable source which will ensure that the buyer is reimbursed for costs necessary to correct any non-compliant actions of the contractor. Virtually all procurements required bonding of the contractor to secure the buyer against additional costs due to lack of performance.

Buy America - This provision was instituted by Congress in November 1978 and requires the domestic content of a rail car, purchased with UMTA assistance, exceed fifty percent of the cost of all components and that final assembly takes place in the U.S. It has been suggested that this may put upward pressure on the car prices, but quantification of the impact was not possible.

Cost of Money - This term provides for reimbursement to the contractor for the interest which the firm must pay to borrow money to pay for materials, labor, subcontractors, etc. No procurement was identified which provided consideration for cost of money. It should be noted that progress payment schedules which minimize negative cash flow would significantly reduce impacts of interest payments.

Design Reviews - Formal design reviews, where contractor technical staff describe their studies/analyses, mock-ups, subcontractor/vendor selections, and subsystem integration designs, are being used much more consistently now. Informal reviews are frequently referenced in specifications, but were not considered in this study since they are not legally imposed on the contractor.

Escalation - This term provides for adjustment to the contract price typically on a quarterly basis to offset the effects of inflation. Earlier procurements locked a contractor into a fixed price over the entire contract life. This became onerous during the 1970's and early 1980's, a period of high inflation. Virtually all of the more recent procurements have included escalation clauses based on Department of Labor indices for rail industry labor and materials. Generally, the escalations are weighted at 60% for materials and 40% for labor. This essentially transfers risk of inflation from the contractor to the procuring authority.

Financing - This term refers to inclusion of means to assist the agency in borrowing the money to purchase the rail cars. Consequently the proposed contractor team might include some financial entity such as a bank, and if it is located in a country with lower interest rates than those prevailing in the U.S., the team could offer the transit agency an attractive overall cost of acquiring the cars. No procurement was identified which included financing provisions in the specifications. However, CTA indicated that a planned major procurement was being considered to incorporate "innovative financing," and that alternative methods were being addressed at this time. During the lifetime of the "Safe Harbor" program this financing program, which allowed a transit agency to sell its right to depreciate the car over its lifetime, yielded major savings to those agencies successfully utilizing it (e.g., San Jose saved $150k on each of 32 cars). Also, as noted in Reference 7, NYCTA was able to save money due to favorable rates from foreign banks associated with two bidders.

Guaranty/Warranty - These terms, used somewhat synonymously, require specific actions on the part of the contractor if specified performance is not met. Virtually all procurements require, in writing, legally-binding warranties of (typically) two years for propulsion, braking, and other major subsystems, and (typically) five years for the car body, trucks, gearboxes, wheels, etc. These periods are in close agreement with data presented in Reference 5, "A Study of Transit Rail Car Guaranty, Warranty and Reliability Contractual Provisions". Within these warranties, the contractor will fix whatever fails to meet specified requirements. Additionally, excessive failures will result in the contractor replacing the failed component on a procurement-wide basis.

Indemnification - This term requires a legal provision to hold the buyer harmless for any and all actions of the performing contractor and its subcontractors/suppliers. Virtually all procurements include this provision.

Insurance - This term requires the contractor to provide liability and workman's compensation coverage. Virtually all procurements include this provision.

Liquidated Damages - This clause assesses cost penalties against the contractor (i. e., it reduces the amount paid) for failure to comply with certain contract specification provisions. The majority of the procurements included clauses providing for damages against the contractor for failure to meet specified transit car weight and/or delivery schedule.

Monetary Value Adjustment - This clause provides for changes in the contract price to offset changes in the fluctuations in currency exchange rates between the country of the contractor and the U.S. over the contract lifetime. Only one procurement (a 1982 MARTA purchase of Hitachi cars) was found to contain this clause, in spite of the preponderance of foreign suppliers active in the U. S. market. Again, any clause of this type tends to transfer risk from the car builder to the car buyer.

Procurement Process - This contract term refers to the type of acquisition used. Procurements were found to be approximately one-third of the "two-step" and two-thirds of the "one-step" type. These were uniformly distributed across the analysis interval. When higher than projected initial bids were received by MARTA using a sealed-bid strategy, an alternative procurement process was used to negotiate escalation, price, contract terms and conditions, and technical requirements. Subsequently the winning price was reduced to 84% of the original bid. This was possible when the Georgia legislature amended state statutes to allow this process.

Progress Payments - This contract term refers to payments made to the contractor during the period of performance of the contract, instead of in a lump sum at the end of the program. Although most procurements included provisions for progress payments, a wide range of schedules was found. This extended from a small up-front start-up payment (about ten percent) and a pro-rata share at acceptance of each car, to payments approaching half the contract value prior to acceptance of the first car. Negotiations of payment schedule have saved $1.4 M for the SEPTA Norristown procurement as discussed in Section 6.1. Also, NYCTA has identified progress payments as a favorable cost driver. It is noted that progress payments can improve cash flow to subcontractors as well, thereby improving their business posture and enabling them to lower prices which otherwise might include cost risk factors. Progress payments do not come free to an authority. There is an unspecified cost of money for providing funds earlier than would otherwise be required.

Renegotiation - This contract term provides the basis, if any, for readjustment of the contract price during the period of performance. The procurements which include any provision for renegotiation usually limit this area to price adjustment in the event of excessive failures of any component. Otherwise these events are covered through warranties in the majority of cases. No other basis for renegotiation clauses was found.

Spare Parts Availability - This contract term specifies a minimum time period during which the contractor assures the buyer that spare parts will be available. Most procurements required the contractor to provide lists of recommended spare parts, with or without pricing. Virtually no procurement specified that spares be available from the contractor for some time period after delivery of the last car. This may in part be due to the ability of buyers to purchase and/or fabricate parts to the as-built drawings which most all procurements require to be provided.

Stop Work Orders - This contract term provides the basis for the buyer to unilaterally direct the contractor to stop work on the project. All procurement specifications addressed stop work orders, but included procedures for equitable adjustments based on the cause for issuing the order. Stop work orders without adjustment provisions could be very onerous to a contractor who is forced to idle a production line. All of the stop work clauses of the procurements which were reviewed during this study contained adjustment provisions.

Termination - This contract term provides a definition of the buyer's allowable reasons to end the contract prematurely. All procurements routinely included adjustment clauses which would expose the contractor to cost risk in the event of termination for cause or default, so they would not be prone to exploitation by a contractor looking for the easy way out of a bad situation.

4.3.3 Conclusions

Conclusions are based on analysis of the effects of each term and condition on the cost of the rail transit car, if identifiable to that level of detail, or on the overall procurement. These analyses have been augmented by information extracted from the reference material listed in the Chapter 8.0 Bibliography, and by the expert opinions from transit authority professionals who contributed to this effort.

This study reinforces the need identified in Section 4.3.1 to include negotiations in car procurements. Further, the data indicates that even broader negotiation (to address bilateral agreements on progress payments, performance requirements, and limits on liquidated damages) would offer more opportunity for cost containment. This level of negotiation ideally would include means for the buyer to assess cost impacts of contract terms and conditions during the negotiation process, so that each element of cost could be analyzed.

A more open acquisition process may serve as another means to reduce transit car cost. One potential process commonly used by the Department of Defense uses four steps instead of the one or two steps used in the transit community. These steps provide for: (1) submission of both technical and cost proposals, (2) evaluation of both proposals by the buyer, (3) negotiations with each offeror which could be expected to accomplish the job, and (4) submission of final bids for the negotiated contract. The potential yield from this method lies in its ability to capitalize on the strengths of each offeror instead of being restricted to the buyer's interpretation of the market place. For example, different contractors may benefit by different progress payment schedules, and builders may have different levels of familiarity with alternative components. This approach can be particularly useful where predominantly performance related specifications are used, since it helps assure that innovative approaches to technology and management are fully incorporated into the proposals.

This study has concluded that contract terms and conditions recommended by UMTA are generally being utilized in transit car procurements. Examples where these guidelines have not been followed generally show increased cost, such as in the SEPTA Norristown procurement where lack of a provision for escalation was undoubtedly a cost driver.

Important terms and conditions cost drivers are:

- Type of procurement
- Regulatory provisions
- Escalation clauses
- Monetary value adjustment clauses
- Progress payments

4.4 Non-performance Requirements Growth

4.4.1 Background

As in the case of contract terms and conditions discussed in Section 4.3, contract non-performance conditions have been studied for many years in attempts to ascertain their effects on cost growth. For example, references prepared during the 1973-1988 interval addressed in this study include "An Evaluation of the Procurement Process Used to Purchase Rolling Stock and Technical Equipment for Mass Transit", U. S. Department of Transportation, March 1980 (Reference 11); "A Study of Transit Rail Car Guaranty, Warranty and Reliability Contractual Provisions", N. D. Lea and Associates, February 1982 (Reference 5); and "Changes in the U. S. Transit Rail Car Manufacturing Industry", N. D. Lea, April 1983 (Reference 7).

The analyses of light rail and rapid rail procurements over the last fifteen years indicates that requirements for technical and management plans and engineering analyses have become virtually universal during this period. Other types of documentation including drawings, manuals, and training courses have also been consistently required. In a 1987 procurement, SCRTD received bids which included prices of over $1M for manuals, over $250K for training, and approaching $1M for plan preparation (the plan bid prices varied widely; this was the highest price and reflects the offeror's estimate of cost). The total contract price was approximately $50M. These items represent about five percent of this price.

4.4.2 Data Analysis

This section addresses changes in non-performance requirements which occurred during the fifteen year study interval. The purpose of this analysis, as in the previous section, is to identify areas which show correlation with cost over the analysis interval. The candidate non-performance requirements selected were:

- Component interchangeability
- Documentation
- Engineering analyses
- Fit/finish
- Life-cycle-cost projections
- Maintenance
- Parts screening
- Technical/management plans
- Prototype
- Reliability demonstration
- Special test equipment
- Training

Each term is discussed in detail in the following paragraphs.

Component Interchangeability - This item defines the extent to which each item can be fitted on any car which uses the item, instead of having to be custom-fitted/adjusted to work with each specific car in which it is installed. Minimal requirement for interchangeability of components was found. This was generally limited to electronic components (e.g., microprocessor-based control system circuit boards) and often-replaced components (e.g., brake pads).

Documentation - This item defines the extent of design and production drawings, operator's and maintainer's manuals, and training materials required with the procurement. Universal requirements for as-built drawings, operator's manuals, and maintenance manuals were found. Design drawings were always required for mandated design reviews, and generally required even if formal design reviews were not part of the contract.

Engineering Analyses - This item defines the types of technical analyses required to be delivered as separate documents with the procurement, usually as part of a review prior to actual fabrication. Virtually universal requirements for stress and safety analyses to identify design flaws and failure modes were found. The majority of procurements required reliability analyses. At least half required maintainability analyses and to some degree human factors analyses and electromagnetic compatibility analyses (especially if chopper control was incorporated into the design). More recent procurements tended to require more extensive analyses, although as noted all procurements required at least some.

Fit/Finish - This item defines in detail any unique processes required for aesthetic or cosmetic appearance of the car. Normal conditions, such as freedom from sharp edges, are covered elsewhere in the specification. No unique requirements for special processes or specialized workmanship skills to fabricate cars were found.

Life-Cycle-Cost Projections - Approximately one-fourth of the procurements required detailed projections of overall life-cycle-costs associated with car operation under specified profiles (e.g., consists, specific authority civil engineering features, headway, etc.). For example, these procurements frequently required the car builder to compute the cost savings projected through the use of regenerative braking, assuming specified energy costs. NFTA used the computations to adjust bid prices and identify the lowest offer. MARTA, among others, included requirements for consideration of overall life-cycle-costs in the design process.

Maintenance - Virtually all procurements required extensive provision for maintainability by the authority using its available equipment (augmented by any special test equipment or tools procured with the cars), personnel (as trained in the procurement), and in-place procedures. New maintenance facilities, procedures, and equipments are specifically precluded in these procurements. CTA specifically identified familiarity with their in-place maintenance policies and procedures as critical to becoming a successful offeror.

Parts Screening - This item describes any non-standard processes needed to qualify a part for installation in a car. It is intended to enhance the reliability of the car by rapidly initiating certain types of failures in certain components (primarily electronic components) through tests prior to installation in the car. Minimal requirement for parts screening was identified and was limited to electronic components.

Technical/Management Plans - Virtually all procurements required plans for overall testing and quality assurance (sometimes combined into a single plan), and reliability. The majority of procurements required some degree of configuration management, primarily to address integration of subsystems and components selected during engineering analyses. Formal plans for maintainability were required less than half the time. Plans for systems engineering/engineering management were seldom required, as were plans for parts control. Growth in requirements for plans over the analysis interval was quite evident.

Prototypes - This term requires the delivery of a quantity of cars to the buyer or some other site such as the DOT Transportation Test Center for validation of specified elements of performance prior to approval by the Engineer for full-scale production. Few procurements required a prototype car. On the contrary, many specified designs that were already in revenue service or consisted of major components in revenue service. This would obviate the need for a prototype to validate a new design.

Reliability Demonstration - Most procurements required the contractor to demonstrate system reliability by collecting data under operational conditions, either during non-revenue service operation or as part of revenue service consists. In a few cases, data on component reliability was required as part of the final design process; this was waived for proven components. NYCTA requires a thirty day no-failure test of each car; others require either a lesser range of hours, or a specified number of miles.

Special Test Equipment - Virtually all procurements required the contractor to provide any unique tools or test equipment with the cars. In some cases, the items were known and hence called out explicitly. Otherwise, generic requirements were given. In either case, the contractor would not be exposed to excessive cost risk in satisfying this requirement.

Training - All procurements required the conduct of training courses for the authority's maintenance personnel. To a lesser degree, operator training was required; predictably this was included for initial car orders.

4.4.3 Conclusions

It is concluded that a trend of increasing requirements for engineering analyses, documentation and technical/management plans has occurred over the interval of this study. Although this is assumed to have had some effect in raising car costs, it would be expected to lower overall life-cycle-costs due to less risk of unforeseen problems with the car and an increased ability to maintain the car and thereby maximize its revenue service.

The need for expensive documentation, especially as-built drawings and maintenance manuals, may be reduced in some specific cases if an authority decides to contract out subsystem and component overhauls and heavy car repair. This may be more appealing to a small authority which can also save costs associated with facilities and heavy equipment required for this function. Another approach to documentation cost savings may be to allow vendor-prepared manuals and drawings instead of requiring the prime contractor to develop these materials to standard specifications.

Important non-performance cost drivers are:

- Documentation
- Engineering Analyses
- Technical/Management plans

CHAPTER 5.0

COST ANALYSIS

5.0 COST ANALYSIS

This chapter discusses the type of rail car procurements recently placed on contract, and defines a "typical" case. A cost estimate is developed for a "typical" 1988 buy. Deletions, reductions and modifications are considered and an estimate of their potential savings provided.

5.1 "Typical" Rail Car Procurement

In order to define a "typical" rail car procurement, a review of all of the rail cars procured since 1980 has been undertaken. There were 15 light rail procurements, for a total of 470 cars, and 17 rapid rail procurements, for a total of 3,049 cars during this period. The result of the review is a composite rail car procurement that will be used as a baseline for evaluating cost. This "typical" rail car procurement is defined in Table 5-1.

Table 5-1
"Typical" Rail Car Procurement

Description	LIGHT RAIL	RAPID RAIL	COMPOSITE
Lot Size	31.0	179.0	110.0
Length (feet)	78.2	62.3	64.4
Width (feet)	8.9	9.1	9.1
Height (feet)	11.8	11.8	11.8
Weight (pounds)	81,710.0	4,158.0	5,167.0
Capacity (passengers - crush load)	219.0	214.0	215.0

Although the light rail average car is longer and somewhat heavier, it does not carry many more people and does not affect the composite significantly because of their few numbers. For these reasons, the composite will be used for further analysis, but it should be noted that it is really more representative of a rapid rail car than a light rail vehicle.

The technology of the "typical" car is for the most part proven and not representative of the latest state-of-the-art. It has air conditioning, dc chopper propulsion and control, regenerative braking, cab signal, automatic doors and destination signs, and is double ended. Its car body is made with stainless steel, and configured and contoured to a specification which is a mix of performance and design requirements, and sets either limits or incentives for weight and sound levels. The light rail vehicles usually are articulated with an unpowered third truck.

The "typical" car has been procured using a reasonably standard set of terms and conditions, drawing heavily on the UMTA guidelines (Reference 19). It has required a comprehensive set of tests, analyses and plans, and has called for a complete set of design documents and drawings including as-built documentation. A standard set of Federal and state conditions are effective including Buy America, affirmative action, elderly and handicapped access, steel content, and U. S. shipping.

In order to estimate the cost of this car, it was necessary to draw on a similar analysis of cost from Section 4.1. In that section, a linear regression was calculated for all rail car purchases since 1980, the same period as the "typical" car described in this section. If the regression point for 1988 is taken, there is a reasonable degree of confidence that that is what the defined "typical" car would cost in 1988. That amount is $1,277,678. If some standard cost estimating relationships (CER) are applied for the various elements of a rail car procurement, the cost breakdown shown in Table 5-2 can be derived. The various CERs have been calculated based on information contained in References 5, 7 and 28, and from data provided by MARTA and a prominent carbuilder.

5.2 Potential Savings

During the course of this study, numerous representatives of the supplier industry and transit authorities were contacted for data and their opinions on issues related to the reduction or containment of car costs. Several areas of potential cost savings were identified and are described. Unfortunately, specific cost savings for individual areas were not provided, and remain elusive. Some general estimates are, however, provided in the discussion that follows.

Table 5-2

Cost Breakdown, "Typical" rail car

FACTOR	CER	COST
Car Body	27.0%	$ 344,973
Communications Equipment	0.5%	6,388
Electrical System	1.0%	12,777
Heating, Ventilating and Air Conditioning	4.5%	57,496
Propulsion System	22.0%	281,089
Train Control System	4.0%	51,107
Trucks	13.0%	166,098
Engineering	11.0%	140,545
Integration, Assembly, Test and Evaluation	4.0%	51,107
Guarantee, Warranty & Reliability	4.0%	51,107
Management, Data and Other Costs	9.0%	114,991
Total	100.0%	$1,277,678

Standardization - It was the opinion of both authority and supplier representatives that standardization could reduce rail car costs. This includes the development of standard configuration/performance specifications, and then constraining individual orders from unnecessary deviations. Specific examples were cited for brake systems and couplers. It was noted that some authorities require brake systems with microprocessor control while others insist on pneumatic control. Some transit authorities even operate more than one configuration within their own system. In the case of couplers, mechanical heads and electric portions vary widely from one authority to the next. The result is short manufacturing runs with everything made to order, requiring special setup, tooling and other fixed costs, which drive up equipment prices.

The issue of standardization has received considerable attention in the past. The N. D. Lea study "Benefits of Rail Car Standardization" (Reference 10) provides a good discussion of the standardization issue and concludes that capital cost savings of 16.5% could be realized if the many configurations are reduced to approximately six different models. This document was published in 1982 and reflected the situation at that time. It appears that today, there is a certain amount of standardization resulting from the tendency in some cases to buy cars similar to those manufactured previously (see Section 4.2.4 for further discussion). There is certainly a potential for savings in standardizing on subsystem specifications such as the brakes and couplers as discussed above.

Increased Order Size - It has been suggested that the consolidation of small orders and the use of options for future needs be encouraged. There is no question but that larger orders yield lower per car cost (see Section 4.1.2 for further discussion). There are also examples that the use of contract options can result in lowered future costs. For example, the CTA option exercised in 1981 provided for a car cost that was significantly below other cars bought that year. The number of cars purchased of the same type, whether by one authority, a joint order, or simply by buying a car similar to another authority is a real cost driver. It is this factor of economy of scale that provides the basis for the savings attributed to standardization. It is an equally valid principle for subsystems and components as well.

Regulatory Requirements - It has been suggested that a reduction or elimination of certain regulations would result in lower car costs. Some of these are:

- Reduce the extent and multiplicity of fire and safety standards. (Reference the National Fire Protection Association "Standard for Fixed Guideway Transit Systems", NFPA 130)
- Eliminate or reduce Buy America requirements.
- Eliminate or reduce affirmative action requirements.
- Reduce the Disadvantaged Business Enterprise (DBE) program. It was estimated by one carbuilder that participation can add as much as 4.5% to the cost of a car.

It is hard to determine the impact of regulation on rail car cost. Estimates range from 15 to 25% of the cost of some orders. It is argued that these programs yield a value to the public that is of greater magnitude than any savings available through their change or elimination.

Terms and Conditions - Several suggestions to reduce costs by improving certain contractual terms and conditions were received. These included the following:

- Reduce financial risk for the carbuilder by providing progress payments for near zero cash flow, including inflation and currency exchange protection, reducing liquidated damage rates and caps, and limiting liabilities.

- Restrict warranties to two years. Lengthy warranties end up requiring the supplier to perform normal maintenance which must be included in bid price.

- Eliminate warranty and retrofit clauses that require that transit authority personnel perform the actual work on the car.

Testing - A recommended area for cost savings was the elimination of requirements to repeat testing of materials that have already been qualified on previous rail car contracts.

Documentation - It was suggested that a reduction in the amount and detail of documentation required by a transit authority will result in lower cost. One carbuilder stated that the costs for their software activity have increased by 40% in the last 24 months alone. This carbuilder recommends minimizing the software requirements of contracts, particularly as they relate to mandatory project control reports, deliverables, and submittals of various types.

Technology - It was recommended that existing, proven designs be used in specifications and that improvements be evolutionary, not revolutionary. It is the contention of one carbuilder that, for authorities without in-house technical expertise, consultants are increasingly specifying changes to existing and proven rail cars just for the sake of change. This increases risks, creates the need for more testing, and inevitably leads to more problems.

Negotiation - A considerable amount of favorable comment was made on the negotiated contract process. One carbuilder said that they felt that the process of negotiation provides more flexibility and sharing of risk and, consequently, allows the carbuilder to provide a better price and better terms and conditions.

Design - The elimination of aesthetic features (such as fiber glass front ends) and unwarranted performance requirements (such as high top end acceleration) was recommended as a cost reduction area.

5.3 "Minimal" Rail Car Procurement

Based on the suggested savings areas above, and the analysis of the study team, certain changes to the "typical" rail car procurement can be considered. For convenience, this new case will be referred to as a "minimal" rail car procurement. To begin with, the car will be of the same general description as the "typical" car, but every effort will be made to procure the smallest car that will meet requirements, noting that the magnitude of cost is related to the size (particularly length and weight) of the car. The procurement will be for over 100 cars, will be the negotiated type, and will utilize a design and subsystems that have been previously manufactured, tested and used either by the buyer or at some other authority with a similar operating and maintenance environment.

The "minimal" car procurement will differ from the "typical" car in the following ways. It will have:

- Painted low alloy high tensile (LAHT) steel car body
- Carbody and panels with minimum contours
- Manual destination signs
- Conventional sliding doors
- Couplers with minimum electrical train lines
- Raceways built into carbody

- o Fasteners exposed
- o Interior materials and fixtures of basic design and quality
- o Communications equipment on a one per train basis, plug in units assigned to crew members
- o Lead acid batteries and inverters
- o Wayside signals, no train control system
- o Simple truck with mechanical springs and one piece wheels
- o Only quality assurance and test plans required
- o Qualification testing required only for new and unproven subsystems
- o Minimal engineering analyses required
- o Minimal data required with existing vendor documentation used wherever possible
- o One year warranty period
- o Monetary value and escalation clauses included
- o Progress payments providing zero cash flow deficits

It is not possible to do a detailed cost estimate of these savings because of a lack of specific data. The savings may be significant, possibly 10% and 20%. There are several considerations that must go into any decision on how to reduce bid price. As discussed elsewhere, life cycle costs are important. Many questions must be answered. For example: How much does using a steel other than stainless cost in maintenance over the life of the car? How does the minimal amount of data impact the repair of the cars and the ability to make or procure spares? What will be the impact of noisier cars, a less comfortable ride, plain appearance and a simple interior on ridership? What is the present value of the downstream costs of the escalation and monetary value clauses?

The greatest cost savers identified by this report are:

- Negotiated procurement
- Existing proven designs
- Smaller car sizes
- Large order sizes

Significant initial cost savings have also been demonstrated by using escalation and monetary value clauses. Some of the "minimal" car features could be upgraded, such as stainless steel instead of LAHT steel (less than 1% of the cost), without impacting the initial cost of the car significantly. It is clear that there are ways to save on procurement costs, and still satisfy the long term low operating cost objective of transit authorities.

CHAPTER 6.0

CASE STUDIES

6.0 CASE STUDIES

Four specific cases were studied to gain insight into real rail car procurements, and to identify methods that might be useful in future rail car buys. In each of these cases, the site specific environment dictated the form and conditions of the acquisition. This study is not intended to be an evaluation or critique of the process or the results of these selected examples.

6.1 Southeastern Pennsylvania Transportation Authority Norristown High Speed Line Light Rail Car

The information presented in this section is extracted from documents provided by SEPTA (References 22, 23, 24 and 25), and from in-person interviews.

The SEPTA staff began work on the Norristown High Speed Line (NHSL) car specifications in June 1985. The intent was to completely replace the existing outdated equipment. Bids were opened in August 1987. Although there was a high level of interest in the project from the rail car industry during the specification development and initial bid cycle (70 carbuilders and suppliers attended the pre-bid meeting), only two bids were received. This dearth of final bids is attributed to two factors: (1) because the bids were to be initiated prior to receipt of car purchase funding from UMTA, many prospective bidders were apparently reluctant to risk time, effort and costs associated with preparation of technical documentation required by the specification, and (2) the small size of the order (26 cars) was seemingly not as attractive to carbuilders as some larger orders under parallel procurements. The procurement of new NHSL rail cars was formally approved in December 1987. A basic description of these cars is provided in Table 6-1.

6.1.1 Performance Requirements

The NHSL car is unique in many ways, and serves as proof that non-standard cars are usually high cost. This impact is magnified by the small lot size and the fact that this procurement is a complete line changeover. There will not be any follow-on orders for additional replacement cars. Features that make the

Table 6-1

SEPTA NHSL Rail Cars

Procurement Year	1977
Car type	light rail
Number of cars	26
Carbuilder	ASEA-AMTRAK
Cost per car	$1,617,910
Length	65 feet
Width	9.7 feet
Height	13.6 feet
Weight	65,000 pounds
Car body material	stainless steel
Articulated	no
Air conditioned	Yes
Propulsion	alternating current
Train operation	manual
Train control	full cab signal and speed control
Operation	two-way train up to four cars

NHSL car unique are: (1) high level doors similar to rapid rail systems, (2) onboard fare collection is used to preclude the need for entry control at stations, and (3) third rail current collection is used for power while operating on the line. A pantograph system is used for operation in the maintenance yard and car barn.

The specification is primarily of the performance type, intended to result in "state-of-the-art" and evolutionary solutions to the specified requirements. There are some detailed requirements where parts and components, used in other SEPTA cars, were prescribed in order to standardize on proven systems, minimize the number of new spare part items needed in stock, and avoid the need to duplicate existing maintenance capability. The specification calls for extensive engineering testing supported by a pilot car provision. A pilot car is to be delivered approximately 10 months before the second car (which also can be used as a pilot car) is delivered. One a month deliveries start five months later and continue until all of the 26 cars have been provided.

6.1.2 Contract Terms and Conditions

The following is a description of some of the main terms and conditions of the contract. The detail provided here is to show a representative set of terms and conditions for reference. This detailed approach will not be duplicated for the other three cases.

Performance Bond - 50% of contract amount until delivery of the pilot car, then 25% of contract value until all cars are delivered.

Maintenance (or Warranty) Bond) - 10% of contract amount to secure the contractor's faithful performance of its warranty obligations.

Indemnification - Assume responsibility and liability for damages, loss and injuries to the extent caused from negligent or wrongful act, action, omission or failure to act when under duty to act on the part of any parties for whom the contractor is responsible.

Risk of Loss - Provide and pay for insurance to cover all loss and damage up to acknowledgment of delivery by SEPTA.

Insurance - Workmen's compensation, $10,000 public liability insurance, and all risk property insurance equal to 100% of contract value.

Delays Beyond the Control of The Contractor - Failure to perform in accordance with the schedule, when beyond the control and without the fault or negligence of the contractor, shall not be considered default except with respect to defaults of subcontractors.

Authority of The Engineer - The Engineer, designated by SEPTA, will be the technical representative of SEPTA to the contractor with authority to review and interpret drawings and contract technical submissions, review and approve schedules and design reviews, review invoices and progress payments, accept the cars and their equipment, issue minor changes to the technical specification, and perform all other interface functions of a technical nature. All orders and directives issued will be in writing.

Warranty - Make any necessary repairs to and any replacements of all parts that are not free from defects in design, material, or workmanship for a period of three years from the date of acceptance. Specific warranty coverage is prescribed for an excessive number of operational failures defined as failures of the same type on 20% or more of the delivered cars, or at any time after 10 cars have been accepted, when 20% of the cars are simultaneously inoperable regardless of cause.

Progress Payments - Provided based on milestones which result in the majority of payment for car deliveries. This subject is discussed in detail later.

Liquidated Damages - $1,700 per day for each day in excess of the contract time requirements that 15 cars have not been delivered. $100 per car for each day a car is not available for service due to the lack of warranty spare parts or timely filling of SEPTA's orders for spare parts. $25 per pound in excess of the specification weight requirement for each excess pound of each car overweight.

Termination - The contract can be terminated for cause anytime the contractor fails to satisfactorily remedy an identified breach or default. The contract can also be terminated in whole or from time to time as deemed in the best interests of SEPTA.

Cargo Preference - Must use U. S. flag vessels to ship at least 50% of the gross tonnage involved.

Buy America - Must comply with Buy America Act (see Section 4.3).

Steel Products - All products shall be produced from steel made in the United States.

6.1.3 Other Requirements

The following additional requirements are presented to provide a comprehensive view of the SEPTA NHSL light rail car procurement:

Analyses - Car functional, weight, stress and natural frequency analyses are required.

Mock-Ups and Models - A full size interior mock-up of the end of the car, and a full size underfloor mock-up complete with trucks, is required. A one meter scale model of the car exterior is also required.

Drawing Approval - Finished production drawings must be approved by The Engineer prior to the start of fabrication of parts for the pilot car.

Plans and Reports - A program management plan is due 45 days after notice to proceed and progress reports are required monthly. Both configuration management and quality assurance plans are required, and each must be accompanied by a status report every 45 days.

Publications - Operational manuals are required in accordance with MIL-M-63036A, and the Air Transport Association of America Specification 101 for other documents. Operator, running maintenance, heavy repair and wreck repair manuals are required. A parts catalog and an as-built technical specification are also required. One year following delivery of the last car, a complete set of as-built drawings must be supplied.

6.1.4 Discussion

The SEPTA NHSL rail car is an interesting hybrid. It operates on a right of way with a third rail. It uses platform loading at established stations, and on-board fare collection. It is equipped with a pantograph so that it can operate within the maintenance yard and car barn. Significantly, it will be equipped with an alternating current propulsion system, the first revenue fleet in the U.S.

There were several trade-offs that had to go into the planning for this car. These included the decision to have fares collected on the cars, as opposed to fare collection at the stations. This decision led to the requirement for a unique placement of doors, and consequently a non-standard body. It was estimated by SEPTA that the need for a specially designed body could be responsible for between $100,000 and $150,000 additional cost per car. This cost had to be weighed against the initial cost of establishing fare collection capability at each station, and its continuing maintenance cost.

The yard and carbarn that will be used for NHSL rail car maintenance is equipped with overhead trolley wires. The cost of equipping the cars with pantographs in addition to their third rail current collectors was compared with adding third rail in the yard. This pantograph system is estimated to have cost about $16,000 per car.

Another trade-off was between a totally performance related specification, and the partially design specified requirements used. SEPTA believes that the long term savings are significant and outweigh the estimated $100,000 to $150,000 added to the cost of the cars. This is especially true in the areas where systems and components are called out that are identical to ones already in the SEPTA inventory. A key example is the air conditioning system specified which is the same as one used on another car fleet, for which SEPTA already has an established repair capability.

As cited earlier in the report, the ac propulsion system did not add substantially to the cost of the car and, if the system proves as reliable and low cost as anticipated, the improved operation and savings will provide a very significant benefit. A specific cost for the stainless steel body was not estimated, but the trade-off against long term savings from maintenance was necessary. The selection of stainless steel is consistent with the majority of recent rail car purchases.

A review of the terms and conditions and other requirements does not reveal many areas that could be identified as unduly driving up costs. However, two areas require consideration. First, the lack of escalation and money value adjustment clauses in the contract has made it necessary for the carbuilder to make estimates of inflation and exchange rate fluctuations over the time period of the contract. It cannot be determined what additional cost was added to the car to mitigate this risk, but it is undoubtedly significant.

The other area is progress payments. $1,482,000 was deducted from the contract, by change order, as a result of a revised progress payment provision. A comparison of progress payment schedules is shown in Table 6-2.

Table 6-2

Comparison of Progress Payment Schedules

	ORIGINAL	REVISED
YEAR 1	15.0%	40.0%
YEAR 2	25.0%	7.5%
YEAR 3		34.7%
YEAR 4	55.0%	15.8%
YEAR 5		
YEAR 6	5.0%	2.0%

In any progress payment scheme, the key is whether the contractor has a positive cash flow, or whether a negative cash flow must be financed because progress payments do not keep up with disbursements. This factor has been cited as a major driver in keeping NYCTA rail car costs down.

It can be concluded that the relatively high cost of the SEPTA NHSL rail car was primarily the result of the unusual system requirements driving its unique specification. Paramount in the bid price level was the small order size of 26 cars. If it had not been necessary to have such a non-standard configuration, the impact of the few number of cars could have been ameliorated by teaming up with another authority, or combining with another SEPTA buy, so that an economical order size would result.

6.2 Metropolitan Atlanta Regional Transportation Authority Rapid Rail Car

The information presented in this section is extracted from contract specifications, from telephone calls to MARTA personnel, and from an in-person interview.

The purpose of this procurement was to obtain additional cars necessary for planned expansion of the MARTA system. In order to maintain bid flexibility while ensuring a high degree of compatibility with the existing MARTA infrastructure, a performance specification with tailored specificity was developed by consulting engineers for release in November 1981. Bids were received from four offerors in March 1982. At that time Georgia State law required public agencies to accept the lowest technically acceptable bid. The state legislature passed a law in April 1982 allowing negotiated procurements in certain cases. Immediately after, all bids were rejected as being some 50% higher than the Engineer's estimate.

Subsequently MARTA made some modifications to the specification to attempt to obtain a lower bid. These modifications included two areas of major significance: (1) a payment schedule more favorable to the vendor, and (2) an agreement by the authority to assume currency fluctuation risk by including provision for Monetary Value Adjustment (MVA). The revised specification was released in May 1982, and proposals were received in July 1982. After negotiations in August, requests for bid were made and bids received. An award recommendation for Hitachi in the amount of $35,470,000 was made for 30 cars in September. The Engineer's estimate, which resulted in the rejection of the original high bids, was approximately $37.5M.

Several modifications of major significance were processed after award. In September 1983, 20 additional cars were contracted for $21,240,000. In June 1984, 30 more cars were contracted for at $32,160,000. In June 1985, 20 more cars were added at $21,263,900. In January 1986, 20 more cars were added at $21,195,720. This aggregates to 120 cars at approximately $140.6M.

During this time interval (September 1982 to January 1986) the Japanese Yen increased in value by almost 100%. In June 1986 a modification was issued which changed the way in which the MVA was computed and paid in order to clarify contract terms. By the time the contract was over at the end of 1987, the MVA cost to MARTA was almost $19M, based on that proportion of the procurement incurred in Japan. On the domestic costs (which were well over half the total) escalations were only about $8M over the same period. In other words, the escalation and MVA raised the total price by almost 20% over the five year contract. On an individual car basis (as computed by dividing total cost by total car quantity in each procurement phase), the first contract option cost per car is $1,062,000, and the last option per-car cost is $1,059,786. These computations show the true car cost in 1982 dollars exclusive of escalation, MVA, other costs such as spares, and fixed contract costs such as plans, analyses, etc.

A basic description of these cars is provided below:

Table 6-3
MARTA Rail Cars

Procurement Year	1982
Car type	Rapid rail
Number of cars	30 (basic contract) 120 (all options)
Carbuilder	Hitachi
Cost per car	$ 1.06 M (average)
Length	75 feet
Width	10.5 feet
Height	11.8 feet
Weight	81000 pounds
Car body material	Stainless steel
Articulated	No
Air conditioned	Yes
Propulsion	Chopper
Train operation	Automatic
Train control	Yes
Operation	Single-ended

6.2.1 Performance Requirements

This procurement contained what is considered to be a performance cost driver. Acceleration and deceleration requirements of 3.0 miles per hour per second were, in 1982, still unusual for the weight (81,000 pounds) of the car. This requirement necessitated a propulsion/regenerative braking subsystem cost of $358.7K per car ($253K for propulsion equipment, $3.2K for current collectors, and $102.5K for propulsion engineering), which is approximately 35% of the car cost.

6.2.2 Contract Terms and Conditions

Several terms and conditions requirements were cost drivers:

- o Requirements for compatibility with existing MARTA stock provided by Franco-Belge (now SOFERVAL, an unsuccessful bidder with a fully-compliant car but a much higher price) meant that the Hitachi price was higher than it may have otherwise been. This requirement precluded Hitachi from getting potentially lower prices from competing vendors.

- o The "Buy America" clause necessitated use of a domestic vendor for the propulsion subsystem since the required high performance level raised the cost to the level where a foreign vendor selection would have resulted in non-compliance.

- o The warranty period requirement was for three years, which is greater and more costly than the more common two year warranty (as discussed in Section 4.3).

6.2.3 Non-performance Requirements

Two non-performance requirements might have been changed for some net savings, although they are not considered significant. These are:

- o Since the preponderance of car subsystems are identical to those already in revenue service, training could have been reduced.

- o Testing and test reporting requirements imposed on each car might have been reduced after the initial 30 cars had been accepted.

6.2.4 Discussion

The MARTA procurement serves to highlight several causes of cost growth. The progress payment, escalation and MVA terms in the contract raised the initial bid price to almost $1.5M per car, which was about $400K higher than the

Engineer's estimates. When the procurement specification was restructured to allow significantly more favorable (in terms of cash flow) progress payments and by shifting escalation and MVA cost risk to the authority, the cost was nearly the same as the Engineer's original estimate. The $400K apparent cost savings was realized as follows:

- The impacts of the escalation and MVA clauses meant that initial cost was significantly reduced. However, MARTA had to pay over $200K more per car than the final contract bid to compensate for inflation and the change in yen exchange rates

- MARTA was able to save on the original 30 car bid by changing the progress payment schedule to suit the contractor's cash flow situation

- Minor other savings were realized on other contract modifications and options

An additional cost driver was the propulsion/braking subsystem performance requirement. As noted earlier, the only engineering change from previous MARTA cars was related to this requirement. The total impact of propulsion equipment and engineering was approximately $360K per car. As noted in Section 5, propulsion costs are typically 22% of car costs, and total engineering costs are about 11%. Assuming that propulsion engineering is about 1/4 of all engineering, it is inferred that a typical car propulsion cost (equipment and engineering) is about 25%. In this case, that would be about $270K, or $90K less than the higher-performance MARTA car being procured.

Other cost drivers included the non-typical three year warranty, and restraint of open competition for subsystems necessitated by compatibility requirements and "Buy America" contract clauses. The MARTA procurement clearly and quantitatively illustrates the effects of the above three cost drivers on the price of rail transit cars.

6.3 Santa Clara County Transportation District Light Rail Car

The information presented in this section is extracted from contract specifications, telephone calls to SCCTD personnel, and from an in-person interview.

The specification preparation was begun in 1982 as part of the overall program to provide a rail transit system connecting several rapidly-developing industrial parks and nearby residential areas with the downtown San Jose area. The line connecting the industrial areas and city is completed. Extensions into the residential areas are scheduled for completion in 1991. Bids were received in March 1983 and an award was made to the Urban Transportation Development Corporation (UTDC) in October 1983. Out of six technical proposals received, five bids were solicited.

A basic description of these cars is provided in Table 6-4.

6.3.1 Performance Requirements

The SCCTD car is not considered unique, although its weight is somewhat higher than most other transit cars. Its braking performance requirement of 3.5 mph per second is higher than other cars of this type, but is mandated by the California Public Utilities Commission.

6.3.2 Contract Terms and Conditions

A two-step procurement process was used. Terms and conditions were considered typical (see Section 4.3 for discussion) with the following additional details.

- Requirements imposed by Federal, state, and local codes for minority enterprise participation were included. However requirements for performance bonding were difficult to meet by small minority businesses which were participating.

Table 6-4

SCCTD Light Rail Car

Procurement Year	1983
Car type	Light rail
Number of cars	50
Carbuilder	UTDC
Cost per car	$892,000 (average)
Length	88.5 feet
Width	8.7 feet
Height	12.5 feet
Weight	98700 pounds
Car body material	Low alloy, high tensile strength steel (LAHT)
Articulated	Yes
Air conditioned	Yes
Propulsion	Resistors switched by cam
Train operation	Manual
Train control	No speed control
Operation	Two-way

- o Requirements of the "Buy America" contract clause and other regulations impacted the procurement in several ways: steel had to be procured in the United States and shipped to Canada for assembly, two different local assembly plants were needed to assemble the truck subsystems and the overall vehicle, and UTDC had to necessarily limit component sources from competition in order to meet percentages.

- o Although there was a requirement that the successful contractor provide a "standard warranty", this term was not defined in the SCCTD contract.

6.3.3 Non-performance Requirements

Non-performance requirements were considered typical (see Section 4.4 for discussion) with the following additional details:

- o The test program required extensive dynamic testing. Two vehicles were sent to the DOT Transportation Test Center as part of the test program.

- The air conditioning unit which was selected by UTDC was a new design which resulted in a requirement that UTDC demonstrate air flows through the car.

- Acceptance testing was performed by SCCTD in San Jose.

6.3.4 Discussion

As noted above, this was basically a standard procurement of a rail car which incorporated components proven elsewhere in revenue service. SCCTD was able to benefit from the contractor's expertise in designing a technically-advanced articulation joint, with no cost impact. Also, SCCTD implemented requirements for elderly and handicapped access by using trackside lifts which were designed to interface with a standard door design (height and width). This cost (estimated at about $18,000 per station) was less than the typical costs of lift equipped cars.

SCCTD believes that the price paid for these cars was reasonable, based on its understanding of the rail car marketplace for cars of this performance level and procurement quantity. SCCTD was able to qualify 32 of the cars for the "Safe Harbor Leasing" program, thereby permitting sale of the cars to a local bank, which then was able to depreciate the cars for Federal tax purposes. SCCTD estimates that this mechanism was able to reduce the effective purchase price of these 32 cars by approximately $150,000 each. Obviously this savings came at the expense of the Treasury Department through loss of tax revenues.

It should be noted that the California state sales tax (formerly 6.5% and raised to 7% at the beginning of the contract) was levied on these cars as an additional procurement cost.

SCCTD suggested several changes which it would consider in any future car procurements, as follows:

- Use alternating current and regenerative braking, since the technology is validated and costs are much lower over the car life cycle.

- Include a reserve of perhaps 5% of the contract value for renegotiations through the design phase to accommodate any changes that occur.

- Pay much more attention to the offeror's proposed uses of disadvantaged business enterprises and local assembly points in order to assess impacts that these proposed terms might have on the authority's management costs relating to the procurement.

It can be concluded that the SCCTD rail car represents a reasonable application of available technology and manufacturing expertise, and as such should represent a realistic light rail vehicle cost benchmark.

6.4 Chicago Transit Authority Rapid Rail Car

The information presented in this section is extracted from contract specifications, telephone calls to CTA personnel, and from an in-person interview.

This contract was originally awarded to Budd in 1978 for 300 cars with an option for 300 additional cars to be exercised in 1981. Prices shown below are an average of the initial car price of $444,295, and the final car price of $559,332. These cars are similar to those bought by CTA for many years, and are procured in volume using contract specifications prepared in-house by the authority's engineers. The subject procurement was won by Budd at a price some $100,000 per car lower than the other sealed bids received by CTA. Since the procurement represented essentially more of the same cars as had been supplied previously and was a standardized, established design, virtually no change orders were issued during its production.

A basic description of these cars is provided in Table 6-5.

Table 6-5
CTA Rapid Rail Cars

Procurement Year	1978 and 1981 (option)
Car type	Rapid Rail
Number of cars	300 plus 300 (option)
Carbuilder	Budd
Cost per car	$500,000 (average)
Length	48 feet
Width	8.7 feet
Height	12 feet
Weight	54400 pounds
Car body material	Stainless steel
Articulated	No
Air conditioned	Yes
Propulsion	Cam
Train operation	Manual
Train control	Yes
Operation	Single-ended

6.4.1 Performance Requirements

No unique performance requirements were included in the specifications. In fact, this car is often cited in the industry as representative of a basic rail transit vehicle, similar to the PCC Car with the addition of air conditioning.

The only specification change contemplated by CTA in subsequent procurements, including a planned 1989 buy, is the inclusion of additional air conditioning capacity to accommodate current experience with local weather conditions, which previous specifications addressed too conservatively.

6.4.2 Contract Terms and Conditions

A one-step procurement was used. Typical contract terms and conditions were used as defined in Section 4.3 of this report. The following additional details were noted:

- Progress payments of up to 45% at prototype delivery are included.
- The escalation clause specifies a 55%-45%, instead of 60%-40% split, between materials and labor.
- Liquidated damages for overweight and late delivery are capped at 10% of the contract value.

6.4.3 Non-Performance Requirements

Non-performance requirements (as defined in Section 4.4 of this report) are minimal. The following details were noted:

- Only a stress analysis was required.
- Only test and quality control plans were required.

Any costs which might have been saved on this procurement through lack of requirement for more detailed analyses and plans is considered to be small when allocated over the 600 cars of the overall Budd procurement.

6.4.4 Discussion

The CTA car represents a very "basic" procurement in many ways:

- First, performance is strictly at the low end of the available technology, basic propulsion/braking, standard body and door designs, and extensive use of service-proven components and subsystems. This approach by CTA is actually mandated by constraints imposed by its infrastructure on which service began in 1896. This is characterized by old steel elevated structures, a track bed featuring weight limits, and low radius curves. Further, CTA has in-place an extensive maintenance support capability which is designed to accommodate its family of car components. Consequently, this procurement has acted to hold rail car performance requirements related cost growth down, especially when considering the large procurement quantity.

- Second, well known and reasonable terms and conditions were used in the contract. Consequently, this procurement had no effect on rail car terms and conditions requirements cost growth.

- Third, non-performance requirements were held at the absolute minimum level. Since all components were proven and available with established reliability, no component screening or burn-in was required, and no overall car mean-time-between-failures or mean-distance-between-failures test was mandated. This procurement resulted in keeping non-performance requirements related cost growth down.

This procurement has acted to hold industry wide rail car cost growth average numbers down. When the bids were received, CTA found that, not only were prices actually lower than other procurements in the same period, but that the winning offeror was approximately $100,000 (i.e., 20%) per car lower than all the other offerors. Two critical observations made by CTA are discussed below.

- All prices bid were lower than comparable procurements for two key reasons: (1) cost growth factors as discussed above were negative, and (2) multi-year buy of 600 cars ensured long-term, steady work for the winner.

- The price Budd quoted was believed to be unrealistically low. In addition, the escalation clause was insufficient to keep up with the inflation at that time.

It can be concluded that the CTA rail car represents a favorable production quantity and delivery schedule, and a conservative application of available technology and contract conditions, but an unrealistically low bid price and as such should not be considered to represent a realistic rail transit vehicle cost benchmark.

CHAPTER 7.0

RAIL CAR MARKET ANALYSIS

7.0 RAIL CAR MARKET ANALYSIS

While ridership on the country's urban rail transit systems continues to grow, the number of new rail cars on order continues to fall, down 63% in the past four years. In the same four years the Federal funds for rail capital and operating assistance have dropped nearly 50%, from approximately $2.3 billion in FY 1985, to $1.3 billion in FY 1987, and $1.2 billion in FY 1988.

Part of the reduction of new rail car orders is a result of the December 31, 1987 expiration of the Safe Harbor Leasing Act under which public transit authorities sold their rail cars to private corporations and leased them back, giving the leasor significant tax benefits through depreciation. To qualify for these tax benefits the rail cars must have been delivered and in service before the expiration of the Act on December 31, 1987. Many transit authorities placed new rail cars in service during 1986 and 1987 to take advantage of the Act before its expiration. Thus, these cars with 30 to 35 years of expected life will not need to be replaced until the year 2016 or later. Furthermore, during the last two years many transit agencies have chosen to remanufacture their aging rail cars, at less than half the cost of a new car, and believe that they have added another 20 - 25 years of useful life. For example, the Port Authority Transit Corporation (PATCO) is remanufacturing its 1968 Budd cars (28 of 75 were complete as of July 18, 1988) for approximately $175,000 per car and fully expect these overhauled/upgraded cars to be useful for another 20 years (See Reference 15).

For the purposes of this report, it was decided to update the 1987 N.D. Lea & Associates rail car fleet survey concentrating on the rail car purchases planned between now and 1995. The results of these contacts are shown on Tables 7-1 through 7-4. Quantities are shown in the year that the authorities expect to place orders. It must be noted that most of the procurements shown on these tables are "planning only" and subject to many caveats, conditions, approvals, etc.

The following car procurements are possible in the 1989-1990 period (See also Tables 7-1 through 7-4):

<u>Rapid Rail</u>	Boston	MBTA	Blue Line
	Boston	MBTA	Orange Line
	Boston	MBTA	Red Line
	Chicago	CTA	
	New York	NYCTA	
	Philadelphia	SEPTA	
	Washington	WMATA	
<u>Light Rail</u>	Boston	MBTA	Green Line
	Buffalo	NFTA	
	Los Angeles	LACTC	
	Portland	Tri-Met	
	San Francisco	MUNI	
	St. Louis	Bi-State	
<u>Commuter Rail</u> (Unpowered coaches <u>not</u> considered)	Connecticut	DOT	
	New York	Metro North	

Table 7-1
Potential Market
Rapid Rail Cars - Short

	1988	1989	1990	1991	1992	1993	1994	1995	Post 1995
Boston MBTA									
Blue			25						
Orange			40						
New York - NYCTA									
Replacements			200	200	200	200	200	200	
Prototype Prog.	36								
Chicago CTA	50	238		200					300
Philadelphia SEPTA			30			240			
NY/NJ PATH				29					247
Total	86	238	295	429	200	440	200	200	547

Table 7-2
Potential Market
Rapid Rail Cars - Long

	1988	1989	1990	1991	1992	1993	1994	1995	Post 1995
Boston MBTA Red			100-150						76
Los Angeles SCRTD	30				42				110
Pittsburgh PAAC						28			
Atlanta MARTA							25		
Philadelphia SEPTA							25		
Baltimore MAMTA									100
Washington WMATA		98			100				
Cleveland GCRTA									60
San Francisco BART					136				390
Total	30	98	100-150		278	28	50	114	736

Table 7-3
Potential Market
Light Rail Cars

	1988	1989	1990	1991	1992	1993	1994	1995	Post 1995
Boston MBTA									
Green			50-75						
Los Angeles									
LACTC	54			40				33	63
LACTC-Automated			37			11			
Buffalo NFTA		6-10							
San Francisco MUNI			30		130				
Sacramento SRTD					22				
Houston MTA					80				
San Diego MTDB						20			
St. Louis Bi-State		31							
Philadelphia SEPTA									
Media/Sharon Hill							6		
City Transit Div.					88				
Baltimore MTA	40								
Portland TRI-MET		10							
San Jose SCCTD									50
Cleveland GCRTA									48
Total	94	47-51	117-142	40	320	31	6	33	161

Table 7-4
Potential Market
Commuter Rail Cars

	1988	1989	1990	1991	1992	1993	1994	1995	Post 1995
Boston MBTA Unpowered Coaches Hi-Cap. Coaches	 67 75 (+ opt. 70)								32
New York LIRR EMU EMU Bi-Level Bi-Level Coaches (Unpowered/Hi Capacity)	 12							242 or 182 86	522 or 392 20
Metro North CR Unpowered Coaches EMU			 10 18		 60		 10		
Connecticut DOT M-4 Type Cars Unpowered Coaches		 30 10							
San Francisco CALTRANS Unpowered Coaches			13						
Pittsburgh PAAC Unpowered Coaches									10
No. Indiana CTD	14								
No. Virginia Tran. Com. Unpowered Coaches	38								
Philadelphia SEPTA				70					54
Chicago METRA Unpowered coaches	16	50	50-100						
New Jersey Transit Unpowered Coaches		75		58					
Total	222 (+ opt. 70)	165	91-141	128	60		10	268-328	508-638

CHAPTER 8.0

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8.0 REFERENCES AND BIBLIOGRAPHY

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