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Rising light rail capital costs are a significant concern for the Federal Transit Administration and for its partner agencies at the local level. The report discusses three distinct types of cost growth: cost overruns, unit cost escalation, and project escalation. Specific factors that push costs higher include lack of in-house expertise, regulatory mandates, poor or non-existent competition among vendors, and the use of custom designs. Evaluations of capital cost increases should also include an analysis of total lifecycle costs, since some project elements may more than pay for themselves in operational savings. The study suggests that training, peer reviews, less restrictive procurement requirements, and improved understanding of lifecycle costs and standards could help mitigate future cost growth.

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Executive Summary

The apparent increase in light rail transit capital costs is a significant concern for Federal Transit Administration, as well as for its partner agencies at the state and local levels. While unit costs have shown no clear trend over the past decade, many individual agencies are experiencing unexpectedly high project costs, and could use assistance in both bringing these costs under control and in gaining tools to better anticipate ultimate project costs.

There are three distinct but interrelated ways in which costs may appear to rise over time, some of which are illustrated by the data from this study:

- Cost overruns occur within individual projects, in which final costs exceed initial forecasts. These are an ongoing problem that plague major public capital investments of all kinds.

- Unit cost escalation occurs when unit costs for comparable projects rise over time, due to changes in the costs of factor inputs (such as labor and materials) or the costs of construction or specialized services. According to data analyzed for this study, the past decade has seen relatively stable unit costs. However, price spikes can cause significant short-term problems, and a future inflationary cycle is always a possibility.

- Project escalation occurs when changes in the scope or complexity of projects cause costs to rise over time. This is exemplified by recent trends towards smaller and more technically complex projects.

Our analysis shows that since the mid-1990s there has not been a statistically significant increase in prices in any individual light rail transit asset category. However, there remain significant differences in unit costs among projects, and all three of the above factors come into play in explaining these disparities. Ongoing problems with cost containment have implications for the ability of the FTA and its partner agencies to keep up with demand for funding of light rail transit capital projects.

Guidance or policy development in the following areas would help agencies to better contain costs over the long term:

- Technical and Institutional Capacity. Agencies with in-house expertise are generally better able to contain project costs than those without. Training and technical assistance on state-of-practice cost estimation, procurement, project management, and lifecycle economic analysis techniques would help agencies develop the expertise they need to control costs.

- Regulations. Existing administrative mandates limit the ability of transit agencies to adopt more innovative procurement and project management practices.

- Competition. Preserving a competitive marketplace is essential to controlling the costs of LRT-related procurements. Federal policies should encourage a free and open marketplace by revisiting its requirements for contractors, and by discouraging the use of proprietary technologies that limit market competition.

- Lifecycle costs. Capital cost components should be judged by the net present value of the full range of operating and capital impacts that they create over time. Some project elements may more than pay for themselves in operational savings; others may impose an ongoing maintenance burden without any redeeming societal benefits.

- Standards, either relating to the process of procurement and project management, or to the design of specific project components themselves, may play a significant role in helping contain project costs. They should also be evaluated using a lifecycle approach. Standards are but one of several related strategies for reducing the project lifecycle costs; others include harmonization, optimization of design, and reduced use of specification.

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1. Introduction

With the development of new light rail systems throughout the U.S. over the last quarter century, concerns have arisen over cost growth on these capital projects. Rising costs pose a significant challenge for agencies seeking to finance new projects. Because of limited federal funds for discretionary capital transit projects, rising costs can mean that individual projects will eventually be funded at lower levels and that some projects will remain unfunded. Locally, this can delay or eliminate the benefits that new investments might provide, adversely affecting system users, agency revenues, and potentially the economy.

This report explores potential factors driving changes in the costs of light rail transit systems in the United States. Section 2 categorizes and explains the factors driving capital costs. Section 3 follows with a discussion of cost drivers affecting particular capital components. Section 4 relates capital costs to a wider framework of lifecycle costs. Section 5 explores the applicability of standards as a means of controlling cost growth. Section 6 concludes the report with recommendations for further research and policy guidance.

2. Why do costs escalate?

There are three distinct but interrelated ways in which costs may appear to rise over time:

- Cost overruns within individual projects, in which final costs exceed initial forecasts;
- Unit cost escalation, in which unit costs of comparable projects rise over time; and
- Project escalation, in which the scope and complexity of projects increases over time.

All three have implications for FTA’s ability to keep up with demand for funding of light rail transit capital projects. This section will consider each in turn, with reference both to the literature and the research findings of this study. A more extensive review of the literature on this topic can be found in Appendix A.

2.1. Cost overruns

Cost overruns are a common phenomenon of large publicly-funded capital projects. Studies of its incidence in the transit sector in the United States have found that final costs typically exceed preliminary forecasts by 50% or more.[1] As projects are developed, costs rise as projects become more complex, unforeseen conditions are encountered, and delays erode the real value of the original budget. Factors that contribute to overruns include:

- <u>Systematic underestimation</u>, including the failure to adequately assess risks, foreseeable adverse conditions, and the full range of project cost components.

- <u>Lack of concern for ultimate costs</u>, since the majority of funding is provided by an external source.[2]

- <u>Procurement methodologies</u>: the standard low-bid procurement method frequently results in large cost overruns and delays.

The Federal government and local agencies have developed a number of tools to combat cost overruns, including:

- <u>Full Funding Grant Agreements (FFGAs)</u>: Since the late 1980s, FFGAs have capped the FTA's dollar obligation on individual projects, transferring risk to the local level.

- <u>Project Management Oversight Contractors</u>: FTA requires that independent consultants monitor the management of risk on individual projects.

- <u>Risk assessment</u>: FTA has begun to require that New Start applicants prepare detailed risk assessments and plans to reduce risk before funding is approved.

- <u>Contracting methods</u>. Individual agencies have begun to experiment with new contracting strategies, including design-build, request-for-proposal, and construction manager at risk.

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[1] Flyvbjerg *et al*. (2003); Menendez (1993); Pickrell (1990).

[2] Flyvbjerg *et al* (2003, 2005); Mackie and Preston (1998); Pickrell (1990); Wachs (1989).

> Other facility owners have experimented with performance-based selection and other methods for significantly reducing client risk.[3]

A forthcoming report will evaluate the effectiveness of these and other efforts.[4]

2.2. Unit cost escalation

Previous studies showed that light rail project costs increased significantly during the 1980s and early 1990s.[5] Since then (and contrary to perception), unit costs for light rail systems appear to have stabilized; prices of some components, notably direct fixation trackwork, may have fallen (see the authors' statistical analysis in Appendix B). Among the factors that likely contributed to the earlier increase and that may continue to affect project costs are the following:

- Commodity prices. Transit projects are highly dependent on a number of commodities. In the 1980s and early 1990s, input costs grew slower than inflation, as measured by the Consumer Price Index.[6] Despite this moderate long-term trend, commodity prices can show great volatility in the short term. In 2004, the price of iron and steel products increased 33%; in 2005, energy and concrete prices have risen significantly.

- Domestic content requirements. Congress strengthened Buy America requirements for railcars in the late 1980s and early 1990s, potentially increasing the prices of many foreign- and domestically-produced components, by limiting competition and requiring investment in domestic assembly plants.

- Technical capacity. Agencies with less experience on rail capital projects may be less effective at managing costs than agencies with more in-house expertise. Many agencies must rely on external consultants to develop specifications for procurements. This can drive up the costs of procurements by overlooking innovative opportunities to simplify projects or avoid change orders later on, and preventing the emergence of an

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[3] Kashiwagi (2001).

[4] Booz Allen & Hamilton (2005).

[5] Booz Allen & Hamilton (2003).

[6] Booz Allen & Hamilton (1995a).

"institutional memory" that can prevent the repetition of past mistakes and improve on the quality of successive project management and oversight.

- Lack of competition. Large fixed costs, the need to interface with existing systems designed and maintained by competitors, and contracting requirements that only large firms can meet collectively create a large barrier to entry for new competitors in the vehicle market. The relatively small size of the U.S. market and the necessity of building custom units for each property further limit the potential for competition. In addition, custom vehicles (i.e., system specific rail cars) often require difficult to procure replacement parts as the age of the vehicle increases. Single bidders or custom designed parts lead to expensive procurements.

2.3. Project escalation

Some trends in project costs can be due less to rising costs for individual units than to qualitative changes in the nature of the projects themselves (see Section B.5). Such changes include the following:

- Right-of-way complexity. Systems that require acquisition of new right-of-way, or construction of new tunnels or elevated structures, will be more expensive than projects that take advantage of existing publicly-owned rights-of-way. Over the past 10 years, the percentage of newly constructed right of way significantly increased.

- Start-up costs. Starter systems may entail greater fixed costs for maintenance facilities, storage yards, and other system elements. The share of projects that were starter systems declined before 1995, but has remained level since then.

- Project scale. Projects are smaller than they were twenty years ago. Before 1995, the size of projects significantly decreased in terms of total route miles, number of stations, and number of vehicles, but this trend has since leveled off. Many soft costs associated with projects are independent of project size, so they become disproportionately expensive for small projects. On the other hand, once capital projects grow large and complex enough that they require coordination among multiple contractors, soft costs can again begin to grow rapidly.

- New technologies. Demand for new technologies such as low-floor vehicles, customer information systems, automatic train control and electronic fare payment systems can all add significantly to project costs. Further, new technologies have to go through years of use before lifecycle costs are known and can be optimized. Throughout the study period, light rail vehicles have become increasingly likely to incorporate more high tech features. This trend has continued through the past decade.

3. Key Findings

The research team conducted a series of in-depth interviews with staff at the American Public Transit Association, two industry experts, and four large transit properties with experience in multiple rail modes. Respondents were asked to identify the key factors driving the costs of their rail capital projects generally, as well as with specific reference to key project components (soft costs, vehicles, guideways, power systems, etc.). A summary report on the interviews can be found in Appendix C.

3.1. Soft Costs

Soft costs – including planning/feasibility studies, preliminary engineering and design, final design, construction management, project management, and project initiation costs – represent the single largest cost category: an average of 22.9% of total project costs since 1995. There is no significant growth trend for these costs. There has also been no systematic research on them. For example, it is not clear whether the differences among agencies are due to real cost containment, or differences in accounting methods.

Technical and Institutional Capacity. In contrast to agencies that operate more mature modes, agencies building light rail projects are relatively inexperienced, and rely heavily on external consultants. Agencies with in-house expertise are generally better able to contain project costs than those without. There are a variety of ways in which different forms of expertise can help contain costs:

- Collaborative planning expertise. Early outreach to gain the cooperation of utility companies and other public agencies that share a project's right of way can reduce the chances of expensive surprises later on. Similarly, skillful building of consensus with community groups can reduce the risk of litigation.

- Technical expertise. Many agencies proposing light rail projects have limited in-house experience designing and operating these systems. The ability to evaluate the impacts of technologies and design specifications on capital and operating costs internally can be very helpful in optimizing system design.

- Project management expertise. Ineffective design of procurement solicitations and contracts can have very expensive consequences. An agency that understands the appropriate times to bring in contractors, and how to design agreements with them that maximize the value gained from their work, will save money and reduce risk.

- FTA role in capacity-building. Its construction roundtable, peer reviews, and other initiatives were all spoken of positively in this regard. FTA could also fund independently-prepared, detailed case histories that evaluate how agencies have conducted their LRT procurement processes. It could also build upon the peer review process to help agencies get a better focus on scope, schedule, and budget. FTA can require smaller properties, or properties new to the rail car procurement process to take courses from the National Transit Institute designed to build institutional capability.

Impacts of Regulation.

- National Pollutant Discharge Elimination System regulations stand out because they are inherently expensive to comply with, no matter how accomplished an agency might be in dealing with them in the past.

- Federal procurement and project management rules can increase costs and squelch innovation and flexibility. These rules force agencies to organize their workflow and teams in very specific ways, adding administrative time and expense.

- Federal regulations on the advance payment of contractors were also cited as a concern. Producers incur significant costs long before project delivery; yet under current rules, FTA requires payments to be made to contractors only upon delivery. Agencies with significant capital resources are saving money by paying as much as 45% of the project costs as pre-defined milestones are met; but smaller agencies cannot afford to do this.

- Federal performance bond regulations also have unintended consequences. Current federal rules require a 100% performance bond as insurance for every construction contract. But transit projects often need to be broken down into smaller contracts simply to enable contractors to be bonded. This increases soft costs, as the complexity of contract management and inter-project coordination grows. Selectively relaxing the 100% performance bond requirement could help mitigate this problem.

- Federal safety regulations, especially the safety certification process, were identified as particularly burdensome. See Section 3.5 below.

- Most other regulations were not cited as problematic. "Buy America" regulations were claimed not to be too costly, and the ADA has to be budgeted for, but these two regulations have been around for long enough that agencies are accomplished in dealing with them in a cost-effective manner. The same is true for diversity requirements.

- FTA's formalization of risk assessment procedures has had a helpful and positive impact.

3.2. Light Rail Transit Vehicles

After sharp growth in the early 1990s, there has been *no significant trend* in LRT vehicle prices over the past 10 years. Yet despite this lack of a larger statistical trend, rail car costs remain an important concern of transit agencies, some of which have seen sharp cost increases from procurement to procurement. Numerous factors were cited as influencing light rail transit vehicle costs:

- Commodity price volatility has caused short-term escalation in vehicle costs. In 2004, steel prices rose sharply. This year has seen a dramatic rise in energy costs.

- The complexity of vehicles continues to grow, as they continue to add new technologies and features (see Appendix B).

- High cost of small procurements. Engineering design and testing costs tend to be fixed, so smaller procurements tend to be more expensive. They also lose the benefit of economies of scale that larger procurements can provide. Joint procurement of vehicles by peer agencies can help reduce fixed costs, but tends to be limited by the tendency of individual agencies to want to overspecify vehicle designs.

- Market conditions, especially the small field of competitors. The market is dominated by a handful of foreign companies. Domestic content requirements, customization, and the small size of the U.S. market are significant barriers to entry for potential competitors.

- Unavailability of insurance bonds. Many agencies require contractors to purchase insurance bonds, but obtaining bonds for large contracts can be difficult. The bonding industry has shrunk, and is hesitant to post bonds for rail cars because the industry has a reputation for problems and delays. This affects the size of contracts which can be offered and the pool of contractors eligible for each contract.

- Overdesign. Rather than emulating LRT systems abroad, many U.S. LRT systems adopt design standards for signals, power systems, and crashworthiness more appropriate for heavy rail or commuter rail systems. Heavier vehicles require longer braking distances, longer headways, and more cars per train, creating conditions where the system provides less frequent service at higher cost.

- Soft costs are a significant component of light rail vehicle costs. An analysis of cost components for nine vehicle procurements shows that bonds, insurance, engineering, testing, taxes, training, contingencies, and other costs (excluding spare parts) add an average of 19% (and as much as 67%) to vehicle costs.[7]

3.3. Guideways

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[7] Authors' analysis, based on Federal Transit Administration (2005).

Overall, there has been no significant trend in the cost of guideways over the past decade. One subtype of guideway costs – the direct fixation of track onto structures – has gotten significantly cheaper over the past ten years. Several factors were cited as contributing to guideway costs:

- Unique local conditions, such as the need for utility relocation, and project alignment requirements dictated by varying topography and existing rail lines, are a major factor determining guideway construction costs.

- Noise and vibration dampening systems add to costs, but can provide benefits in terms of reduced vehicle maintenance needs, and higher operating speeds at sensitive locations.

- Very large projects can be more expensive. Construction projects generally lack economies of scale. Very large projects may actually see *diseconomies* from the limited ability of most contractors to get bonded above $200 million. Splitting contracts into multiple parts to facilitate competition has the disadvantage of increasing soft costs and the complexity of coordination among multiple parties.

A number of local conditions can sharply drive up project costs:

- Right-of-way acquisition is a key cost for LRT projects, particularly when agencies must negotiate with private railroads to purchase their land, or obtain permission to use it. Private railroads often require very long timeframes for negotiating these agreements, which can result in expensive delays. The Federal Highway Administration has developed strategies for avoiding these delays, through an early acquisition process.

- Environmental cleanups can also be extremely expensive. When light rail projects are being developed to revitalize declining industrial areas, the chances of encountering environmental contamination are high.

3.4. Power Systems

Electrification and power systems have shown no significant growth trend since 1995. Two factors cited as cost drivers for this asset category:

- Overdesign. Light rail systems are often built with heavy catenaries more appropriate to the higher speeds of commuter or intercity rail. In Europe, many systems use lower-cost designs in which lighter catenaries are attached to adjacent buildings or other existing infrastructure.

- New technologies, such as stray current mitigation technologies or dual mode power systems, improve the flexibility or reliability of the system but increase initial costs.

3.5. Safety and Security Technologies

Several respondents cited safety and security as areas requiring more attention.

- Safety standards have a significant impact on project costs. Interview respondents praised FTA’s system-oriented approach (in contrast to the Federal Railroad Administration’s equipment-based focus), but worried that it is growing too complex. A tremendous amount of time and expense in the last quarter of a project is spent on the safety system certification process, and streamlining of this process could be beneficial.

- Fire safety and tunnel ventilation standards. Some agencies are concerned that existing guidelines encourage overbuilt systems, because the codes for rail tunnels are ambiguous. Ventilation security technologies are growing smarter (e.g. allowing continuous tracking), and future standards could reduce costs by taking advantage of this.

- Security is receiving greater attention, both in the design of projects, and in construction and operational procedures. Smart sensing and surveillance technologies could lower the capital and operating costs of security systems, while improving their effectiveness. Yet other technologies – such as the use of silent cab alarms on LRT systems – can increase operational costs without generating real benefits. Agencies need more guidance on how to evaluate these investments in a lifecycle cost and risk assessment framework.

3.6. Market Structure

Market conditions were raised repeatedly by the interviewees:

- Limited competition among light rail vendors, tunneling contractors, and ticket vending machine manufacturers is impacting costs.

- The performance bond industry, itself seeing declining competition, is reluctant to insure transit projects, thereby helping limit the entry of new competitors into the marketplace.

- The decline in domestic-based sourcing can increase the potential for risk due to currency fluctuation. This risk is usually borne by the contractor, built into the cost of its services.

- Closed standards. In the procurement of new technologies, agencies should be especially cautious about the implications of projects that use proprietary standards. Companies winning technology-related contracts often use their control over their own technologies to limit entry of new firms into the market for future contracts. Agencies can find themselves "locked in" to a single vendor, not just for the specific technology being procured, but also for spare parts and for other systems that must interface with that technology. They are often powerless to sanction the vendor for poor performance.

3.7. Procurement Techniques

There are a wide variety of approaches to contracting and procurement. The traditional approach to capital project procurement ("Design-Bid-Build") involves separate contractors for the design and construction of projects, thereby reducing opportunities for innovative cost-saving designs. After a low-bid contract is awarded, project costs can easily grow by 20% or more. Alternative techniques seek to increase the flexibility of this process to allow for greater innovation and incentives for cost savings:

- In general, negotiated procurements take longer and add costs up front, but result in better cost control and project value. These methods are familiar to many international contractors, because they are common overseas.

- Design-Build procurements use a single contractor for both of phases of the project to create more opportunities for cost savings, but require a greater degree of involvement and technical proficiency from the transit agency.

- General Contractor/Construction Manager (GCCM) approaches also bring the construction contractor into the process before the bidding stage, and provide the public agency with an opportunity to reduce costs by assuming greater risk.

- In Design-Build-Operate-Maintain, a private consortium carries a project from design through operations (typically 10 years or more), before returning it to public control. The consortium is responsible for achieving certain performance standards, but otherwise has discretion as to the design and operation of the system. In theory this provides an incentive to minimize lifecycle costs; but in practice, if performance incentives are too strong, contractors tend to overdesign the capital components of the project.

- Warranties reduce the risk of procurements, but at a higher initial cost. The cost of warranties may grow when contracts allow occupancy well before the final close out of a contract. That represents a substantial risk to the contractor and many contractors will price that risk into the cost of the warranties they offer. The structuring and management of risk is one of the most difficult challenges in containing project costs while ensuring that they can be successfully completed.

4. Operating impacts and customer benefits

Many of the observed changes in the nature or costs of capital assets occur because agencies want to maximize the value of their investments. A least-cost capital investment may save money in the near term, but ultimately may not represent the best taxpayer value. In many cases, systems with incrementally higher capital costs may yield better operational reliability and efficiency, lower maintenance costs and greater customer benefits.

This research, and earlier work done by the authors for the New York Metropolitan Transportation Authority,[8] produced numerous examples of capital projects that appeared to be inessential, but which provided net real benefits to the transit agency and the taxpaying public (see Figure 1).

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[8] Paaswell, Goldman, and Peters (2004).

Capital Cost Component	Capital Cost Driver	Internal Impacts	Direct Customer Impacts
Revenue Vehicles	Low-floor vehicles	Allows for simpler and less expensive platform design; eliminates need for wheelchair lifts; reduces dwell times, providing more efficient operations.	Improved accessibility; faster boarding and travel times.
Revenue Vehicles	AC traction motors	Energy cost savings, lower maintenance costs	
Railcar Maintenance Facilities	Larger facility and more maintenance stations per vehicle	Enables implementation of a "lifecycle maintenance" program with pre-scheduled overhauls to improve reliability and extend vehicle life	Improved reliability and quality of service.
At-Grade Guideway	Concrete ties instead of wood ties at high-traffic locations	Minimizes repetitive disruptions that presently occur due to cyclical replacement of wood ties.	Fewer service disruptions.
Electrification	Higher-gauge power distribution system	Reduced energy loss, better acceleration, potential for longer trains, fewer substations	Improved reliability of air conditioning,faster travel times
Bridges and Structures	Smart sensing technologies	Ability to identify structural problems early, reducing monitoring costs and the need for larger-scale structural repairs later on.	
Soft Costs	Warranties	Improved incentives for contractors to perform quality work; reduced agency risk	

Figure 1. Examples of capital project elements that reduce long-term costs

Transit capital improvements – whether in the creation of new systems or in the rehabilitation of old ones – have significant impacts on both the properties and their customers. These occur on a variety of scales:

- Internal impacts. At the center are direct capital and operating impacts on the agency cost structure (full lifecycle costs). Capital investments affect the cost of operations, costs of maintenance and repair, and frequency and costs of system failures.

- Direct customer impacts. Capital investments also impact the interaction between agencies and their users via changes in service quality, ridership and revenues. Capital investments can affect the speed, frequency, and reliability of service; the quality and safety of the passenger environment; levels of ridership and revenue; and transit fares.

- Social impacts. Finally, capital investments have external impacts on society that indirectly influence ridership and agency tax revenues. Capital investment choices ultimately affect patterns of spatial development; traffic congestion and air pollution; the efficiency of other modes of travel; and the health of the regional economy.

An unsound program of capital investment can lead to a “vicious cycle” of disinvestment or overcapitalization, producing declining system reliability, rising operating costs, falling ridership and revenues, and loss of any impetus to regional economic health. A well-designed program of capital investments can provide a “virtuous cycle” of cascading benefits, improving system reliability and customer benefits, falling operating costs, and rising ridership and revenues, while contributing to regional economic revitalization.

Evaluations of potential capital investments should calculate full lifecycle impacts in terms of net present value. They should consider all three levels of impacts (internal impacts, direct customer impacts, and broader social impacts), but separately so that each can be individually understood. In order to support these analyses, transit agencies will need to track costs and performance more systematically, so that they have the raw data they need.

5. Applicability of standards

Transit standards are being developed for both operational procedures and for equipment.[9] This section of the report summarizes a review of APTA material, interviews with transit personnel, and a meeting with APTA. It integrates information from this study and from work performed by the senior author as Chair of the Transit Standards Consortium.

The rationale for standards is to simplify transit system design, operations and practices through creation of a common language throughout the industry. Standards are expected to result in more efficient operating practices, improved safety and technological improvement. There may also be significant cost benefits, yet because standards are still in the process of being developed and implemented, little is known about actual cost benefits.

One challenge in the introduction of standards is that firms often seek a strategic advantage by introducing a unique variant of new technologies, or adding a new feature, often while lowering the price in the short-term to gain market share in the longer term. This variant usually is technically superior in some way but can potentially undermine standards. However, vendors also use these proprietary technologies or variants on standards to secure long-term sole-source relationships with their customers, with little opportunity for new competitors to break into the market. Thus, the development of standards needs to be an ongoing process.

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[9] American Public Transit Association (2004b).

Any cost-benefit evaluation of standards must consider total lifecycle costs that include not only initial procurement costs but also operating costs, maintenance costs and replacement costs. In the best-known instance of standardization in the light rail industry, the PCC car developed in the 1930s initially cost more than existing streetcars. Yet the standardized design introduced a wide range of technologies that dramatically improved operations and brought large reductions in operating costs.

Using qualitative techniques, APTA has estimated that widespread application of its current standards could bring savings of 5% in manufacturing costs; yet this captures only a small portion of the potential benefits. A standards effort underway in Europe estimates that the use of standardized tender documents could reduce firms' bidding costs for light rail vehicle procurements by 25% (AEA Technology Rail, 2000). This report also predicts that if the use of standard vehicle designs throughout Europe were feasible, it could reduce procurement costs by 10%.

Evaluating cost savings accruing over the entire asset lifecycle will best capture the full effect of different kinds of standards:

- <u>Procedural standards</u> that specify maintenance of equipment and facilities primarily affect operating costs but can reduce capital costs by increasing the mean distance between failure (MDBF) and the time between major rehabilitations.

- <u>Equipment standards</u> including standards for communications architectures should serve to dampen capital cost escalation. Much of the cost increase in equipment over the past decade has come from the addition of new technologies. Standardization would increase competition among suppliers, who would be able to invest capital for more secure and larger markets. It would also help reduce soft costs associated with designing and testing new equipment. To the extent that standards improve system reliability, they could save operating and maintenance costs in the long term.

A lifecycle approach, described in Appendix D, would evaluate the various kinds of cost savings from standardization. For example, as with the PCC car, standardization might result in an increase in short-term capital costs as new technologies are added to vehicles and rights of way.

But over the longer term, adoption of standards could cut life cycle costs and reduce capital costs on successive procurements.

Finally, it is important to note that standardization is but one of several closely related strategies that can help reduce project costs. Others include:

- <u>Harmonization</u>, which is the adoption of common technologies or protocols among a more limited cluster of agencies with similar needs. There could be a federal role in providing incentives for agencies to harmonize their designs and coordinate purchases.

- <u>Optimization of design</u>. Compared with their European counterparts, many LRT systems in the U.S. are over-designed. More optimally designed LRT systems might be lighter and less technologically advanced, but far cheaper to procure and maintain. The tendency to over-design projects can be a consequence of agencies that lack the internal expertise to select designs that minimize lifecycle costs, or to withstand pressures from consultants and the political process to escalate project designs.

- <u>De-specification</u>. Many procurements overspecify project elements in advance, providing no flexibility for innovation and cost savings later on. Allowing contractors greater flexibility by replacing specs with performance standards can potentially save money. However, it is not always enough: one agency reported using open, performance-based specifications, only to receive five bids, all using the same rail car manufacturer.

Areas that are particularly ripe for the development of standards include:

- <u>Signals</u>. In order to maximize the flexibility of LRT systems, signal and control systems are needed that enable LRT to operate in complex multimodal environments. If light rail could come up with a good standardized signal system, it could allow for more joint freight and light rail operations. Similarly, unique operating and signal standards are needed to enable LRT to operate jointly with buses in the same right of way.

- <u>Elevators and escalators</u>. The challenging environment of transit stations demands heavy-duty elevators and escalators. Although a new standard might imply higher capital costs, these could be recouped through lower maintenance costs.

6. Synthesis and Cross-Cutting Conclusions

6.1. Lessons learned

Prices for light rail systems have stabilized over the last decade.

- No trend is apparent in the scope and cost of construction projects. Since 1995, the average size of LRT construction projects has leveled off, after a significant decline in the preceding decade. Except for direct fixation track, which has declined in cost, there are no significant trends in the unit costs of these projects.

- Costs for light rail vehicles have leveled off since 1995, while they have grown more complex and their physical dimensions have remained constant. In the preceding decade, vehicle cost, size and weight increased.

Agencies face a number of obstacles as they work to control costs:

- Institutional capacity can play a major role in shaping capital costs. An agency with greater in-house expertise can save money by better anticipating and avoiding expensive surprises. Yet many light rail projects are being built by agencies without experience designing rail projects or managing major capital investments.

- Commodity prices can add significant volatility to project costs, but their long-term trend in recent decades has been stable or falling.

- There are significant economies of scale in LRT capital projects, because of the high fixed costs that are independent of project size.

- Regulations, such as those preventing milestone-based payments to car manufacturers, requiring 100% performance bonds, and governing safety certification can limit competition and affect overall project costs.

6.2. Recommendations

This study suggests a number of areas where FTA could pursue research and policy guidance:

A. Minimize "soft costs."

- Coordinated procurements: Development of a strategy encouraging "peer systems" with similar needs to coordinate future procurements to reduce costs.

- Contracting guidance and regulatory flexibility: Development of policies to promote alternative contracting and project management strategies, including reducing federal requirements that limit agencies' administrative and project management flexibility, allowing accelerated procurement of railroad rights-of-way, and relaxing performance bonding requirements.

- Training: Development of training and technical assistance programs to help agencies learn state-of-practice procurement, project management, lifecycle economic assessment, and risk management strategies.

- Peer reviews and cost control ratings: FTA could implement peer reviews of projects in the planning phase. It could also rate New Starts proposals based on the quality of their cost control strategies.

B. Evaluate the potential for standards

- Standards for emerging technologies. A forward-looking study identifying opportunities for standardization in the technologies and features of the LRT systems of the future.

- Reduce reliance on proprietary technologies. Policy guidance encouraging the use of non-proprietary technologies to maintain competition and reduce long-term costs.

- Lifecycle cost analysis. Information on capital and operating costs for specific components could be collected and entered into a database to allow development of lifecycle cost models. These models, as described in Appendix D, could relate cost reduction to packages of standards.

- Appropriate design. A study identifying assets and technologies that tend to be "overdesigned" (built to an unnecessarily high standard) in U.S. light rail systems, driving up project costs.

- Simpler specifications. A study addressing the problem of "overspecification" (project components defined so rigidly that opportunities for innovative cost savings are lost).

C. Develop a template for allowable costs under Federal Share:

- Standard vehicle. One approach towards realizing the benefits of standardization is to develop a "Standard Vehicle for Procurement." This might be a synthesis of recent procurements. Items and costs that arise outside this Standard become local responsibilities.

- Soft cost budget. A similar approach might be taken towards acceptable soft costs. Such costs might be capped. FTA might assist properties with soft cost reduction through appropriate training programs in design and procurement developed by NTI.

- Cap funding for land acquisition costs. For land acquisition costs, the federal government could decide that this is a local responsibility, or could fund these costs out of a revolving loan fund that state or local partners must reimburse.

In sum, this section proposes that FTA take an innovative approach to contain costs; but one that is helpful to the local properties.

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About the University Transportation Research Center

The Region 2 University Transportation Research Center (UTRC) is one of ten original University Transportation Centers established in 1987 by the U.S. Congress. These Centers were established with the recognition that transportation plays a key role in the nation's economy and the quality of life of its citizens. University faculty members provide a critical link in resolving our national and regional transportation problems while training the professionals who address our transportation systems and their customers on a daily basis. UTRC includes a dozen participating universities in New York, New Jersey, and Puerto Rico, and is led by Prof. Robert E. Paaswell, Distinguished Professor of Civil Engineering at the City College of New York.

APPENDIX A: Literature Review on Cost Drivers

Concern over the growth in costs for large public works projects such as light rail transit systems is not a new phenomenon but has impelled increased scrutiny and more rigorous analysis in recent years. Three different but related issues have surfaced:

- Cost overruns within individual projects, in which final costs exceed estimated costs;
- Cost escalation, in which costs of comparable projects rise over time; and
- Project escalation, in which the projects themselves increase in scale or complexity over time.

This appendix reviews the literature on cost trends and drivers and presents some analysis of the available data. It begins with a quick review of the literature on cost overruns, including Booz Allen's ongoing study for the Transit Cooperative Research Program (TCRP G-07). It then explores price trends in light rail projects over the last quarter century, and explores the range of factors that may have contributed to those trends or could affect future prices.

Some items that increase the capital costs of transit projects have the potential to bring savings on the operating budget, and these items are identified. This section also explores strategies that have been proposed to mitigate the effects of certain cost drivers.

A.1. Cost overruns

A.1.1. Background

Cost overruns on light rail projects in the United States have received increased scrutiny in the last quarter century with construction of a number of new systems and expansions. The early literature on cost overruns for public works projects showed that rail transit appeared to be particularly susceptible to this problem. Recent studies by Flyvbjerg, Booz Allen, and others have enabled systematic analysis of the magnitude and causes of the problem.

In the broadest study, Flyvbjerg *et al.* (2003) explored cost overruns in a study of 258 rail, highway, bridge, and tunnel projects worldwide. Ninety percent of these projects experienced cost overruns. When adjusted for inflation, cost overruns averaged 45% for rail, 34% for tunnels and bridges, and 20% for road projects. A smaller study by Menendez (1993) looked at cost overruns on nine U.S. rail transit projects in the 1980s. Cost overruns ranged from 12% to 77% in constant dollars, and seven of the projects had cost overruns of 50% or more. Pickrell (1990) studied ten rail transit projects built in the U.S. in the 1970s and 1980s and found that the median cost overrun exceeded 50%.

A.1.2. Types and causes of cost overruns

Cost overruns occur when the final cost for a project exceeds the forecast cost. The source of the overrun can be seen as a question of insufficient control of costs during execution of the project, or it can be framed as underestimation of the actual costs. This section first looks at the individual project elements whose costs most frequently grow during project development, and then explores deeper explanations for the mismatch between forecast and final costs.

Booz Allen & Hamilton’s TCRP G-07 project, currently underway, explores the drivers of cost overruns on twenty recent U.S. rail projects. The interim report (2004a) identifies a number of specific areas where costs grew on the surveyed projects:

- Alignment modifications: planned at-grade guideway converted to subway or elevated guideway; tunnels added; location of alignment changed;
- Structured parking or park-and-ride lots added;
- Costs underestimated: soft design costs increased; costs for demolition and utility relocation demolition added;
- Additional right-of-way purchased;
- Environmental mitigation: landscaping; “3rd party agreements,” hazardous material removal; fireman’s ventilation; lawsuits and claims;
- ADA upgrades;
- Station entrances added;

- Unforeseen soil conditions;
- Additional storage tracks; additional costs for yards and shops;
- Increased electrification.

The interim report also notes changes in unit quantities during the course of the projects. In general, as projects moved to completion, alignments were shortened and stations were dropped but the number of vehicles purchased increased. The table below shows the number of projects for which unit quantities changed between planning and project completion.

Item	Quantities increased	Quantities decreased
Alignment (track miles)	1	6
Stations	3	8
Vehicles	10	2

Source: Booz Allen & Hamilton (2004a)

Figure A-1. Changes in project scope between planning and project completion.

Pickrell (1990) similarly found that on ten rail transit projects built in the 1970s and 1980s, the number of guideway miles, stations, and vehicles remained fairly constant from inception to completion.

Delays, which are common on large public works projects, can result in higher costs as financing is stretched out and inflation devalues the originally budgeted dollars. For rail transit projects built in the 1970s and 1980s, Pickrell found that the inflationary of delays typically accounted for 20 to 50 percent of total cost overruns. (As inflation has subsided, the significance of these effects may have diminished.)

The unpredictable factors that contribute to cost overruns or delays are frequently described as risks. Touran et al (1994) reviews several techniques for classifying risks; for transit capital projects the authors suggest a division between design and construction risks, and financial risks. For the first category, they present a checklist of fifteen general risk areas such as “contracting arrangement” and “labor.” Financial risks include market risks such as fluctuations in interest rates, and project-specific risks such as the predictability of revenue sources, contractor bankruptcy, and currency risk associated with international financing.

Much of the academic literature considers cost overruns to be a more systematic problem of underestimation of costs in the early stages of project development. Wachs (1989), Pickrell (1990), Mackie and Preston (1998) and Flyvbjerg et al (2003 and 2005) have developed a number of hypotheses to explain the mismatch between forecast and final costs. These include:

- <u>Misrepresentation</u>. In order to win approval of capital projects, backers of some projects have systematically underestimated costs. Wachs relates interviews with planners who explain that they were asked to lower cost estimates in order to make projects look more attractive.

- <u>Underestimating risks</u>. Planners may spend insufficient effort evaluating risks and the costs of mitigating those risks. For example, projects may be affected by unforeseen geological conditions that require expensive remediation (Mackie and Preston 1998).

- <u>Inflation</u>. Estimates that do not take into account the effects of inflation risk understating the actual costs, although inflation can be over-estimated, as well (Pickrell 1990).

At a more fundamental level, some writers have hypothesized that agencies are less careful when using federal dollars than local tax dollars or private funds. Pucher (1983) showed a statistically significant relationship between higher operating costs and a higher federal share of transit subsidies. As for capital projects, Pickrell's survey of ten urban rail projects in the 1970s and 1980s showed that the federal government originally planned to cover between 45 and 82 percent of project costs, with the remainder paid by state and local governments. For six of the projects, the federal government paid more than three-fourths of the cost overruns, and in some cases, it covered a higher share of the cost overrun than of the original forecast. However, there has been no systematic evaluation of the relationship between federal subsidies and cost overruns on transit projects.

Pickrell's study suggests potential mitigation techniques for cost overruns, several of which have been implemented in recent years:

- <u>More detailed engineering prior to project selection</u>. The FTA now requires detailed risk assessments on New Starts projects.

- Reasonableness check. Forecast costs should be compared against those for similar recently-constructed projects. The Booz Allen Light Rail Capital Cost Study provides a “Standard LRT” model that can be used for such comparisons.

- Expert review of estimates. Local agencies could designate a peer review panel to evaluate forecasts and the underlying assumptions and models.

- Independent oversight. Outside consultants could provide independent expertise in construction management. FTA now uses Project Management Oversight Contractors to independently evaluate the adequacy of cost estimates

- Inclusion of contingency allowances. The risks to a project should be analyzed and an appropriate contingency allowance should be included in the project budget.

Flyvjberg (2005) additionally suggests that national governments should offer block transportation grants to local governments, instead of grants for particular projects. Competition for this latter type of grant creates incentives for project backers to underestimate final costs. Pickrell (1990) notes that since the late 1980s the federal government has used Full Funding Grant Agreements to cap the government’s dollar obligation to projects. These effectively shift risk from the federal government to state and local governments and may increase local accountability.

A.2. Cost escalation

A.2.1. Background

Cost escalation can be defined as the long-term increase in costs that occurs across projects. Costs that are growing faster than inflation pose a significant challenge for agencies seeking to finance new projects. For the Federal government, rapid cost growth can mean that projects will eventually be funded at lower levels and that some projects will be unfunded. At the local level, underfunding or delayed funding of capital programs can have negative impacts on future capital and operating costs, on system users and agency revenues, and ultimately on the regional economy.

Booz Allen's study of light rail transit capital costs (2003) shows that cost per mile increased substantially between the 1980s and 1990s. Overall project costs increased 1.0% annually between the early 1980s and 2003, relative to a standard price index – the Means Construction Cost Index. The report also showed that some project elements experienced much stronger inflation than others. The most rapid category increases were seen in Yards and Shops and for Stations, which saw real increases of 3.5% and 3.4% per year (respectively). Vehicle prices rose 1.8% annually. Underground Guideway and Direct Fixation Track were the only categories that experienced declining real prices, down 2.9% and 0.6% per year, respectively.

Category	Inflation	Index	Difference
2.00 Yards and Shops	6.3%	2.8%	+3.5%
4.01 Stations: At-Grade - Center Platform	6.0%	2.6%	+3.4%
4.02 Stations: At-Grade - Side Platform	5.8%	2.8%	+3.0%
3.03 Communications	5.3%	2.6%	+2.7%
1.03 Elevated Structure Guideway	5.1%	2.5%	+2.6%
1.01 At Grade Guideway	4.9%	2.5%	+2.4%
5.00 Vehicles	4.7%	2.9%	+1.8%
3.01 Signal System	3.8%	2.5%	+1.3%
3.04 Revenue Collection	3.5%	2.5%	+1.0%
8.00 Soft Costs	3.5%	2.6%	+0.9%
7.00 Right-of-Way	3.4%	2.6%	+0.8%
6.00 Special Conditions	3.3%	2.5%	+0.8%
1.09 Embedded Track	3.2%	2.8%	+0.4%
3.02 Electrification	2.9%	2.5%	+0.4%
1.08 Ballasted Track	3.0%	2.8%	+0.2%
1.07 Direct Fixation Track	2.0%	2.6%	-0.6%
1.05 Underground Guideway	-0.3%	2.6%	-2.9%
Total Project Costs	3.5%	2.5%	+1.0%

Source: Booz Allen & Hamilton (2003)

Figure A-2. Capital Cost Growth by Category

Our analysis of the Booz Allen data shows that since the mid-1990s there has not been a statistically significant increase in prices in any individual cost category. In fact, our analysis shows that the only category to show a statistically significant change since 1995 was direct fixation track, and that unit costs *fell* in this category (See Appendix B).

The American Public Transportation Association (APTA) (2004a) maintains a database of information on vehicles, including light rail vehicles, in North American transit fleets. This database includes the year of purchase and, for some vehicles acquired since 1996, the purchase price. Analysis of this data shows that after adjusting for inflation, there has been no statistically significant increase in price since the mid-1990s.

Analysis of vehicle prices from Booz Allen's compendium of light rail vehicle specifications (2004b) shows that prices remained level in the 1980s, saw a sharp increase in the early 1990s, and have leveled off since 1995 (see Appendix B). In constant (2005) dollars, prices increased from the $1.0 - 2.0 million range in the 1980s to the $2.5 million range in the last five years. Together, these analyses suggest that vehicles costs have decreased or at least stabilized over the last few years, after a rapid increase in the early 1990s.

The literature also includes studies of cost growth for other forms of transit. Altshuler and Luberoff (2003) showed that cost per mile of new heavy rail transit systems increased at a rapid pace from the 1960s through the 1990s (see Figure A-3). San Francisco's BART system, which opened in 1972, cost $81 million per mile (in 2001 dollars), while Los Angeles built its Red Line for nearly four times the per-mile cost in the late 1980s and early 1990s.

System	Built	Cost per mile (2001 dollars)
San Francisco, BART	1960s-1970s	$81 million
Atlanta, MARTA	1970s-1980s	$152 million
Washington Metro	1970s-1980s	$197 million
Los Angeles, Red Line	1980s-1990s	$300 million

Source: Altshuler and Luberoff 2003

Figure A-3. Cost Per Mile of New Heavy Rail Systems

Other types of transportation projects have also seen rapid cost growth in recent decades. A study of freeway construction costs in California over the last few decades showed that costs per mile were stable until the early 1960s. In that decade, freeway development costs rose 8.2% per year versus average annual inflation of 2.4%. In the 1970s costs rose 12.1% annually while general inflation was 8.7%. In the 1980s, freeway construction costs per new mile increased 700% in California and 500% nationally.

These analyses suggest that cost growth for light rail systems has slowed or indeed stopped in recent years, and that prices of some components have decreased over the last ten years. However, these projects still face tremendous cost pressures, as shown in the next section. Efforts to mitigate these pressures will be crucial to limiting future cost growth.

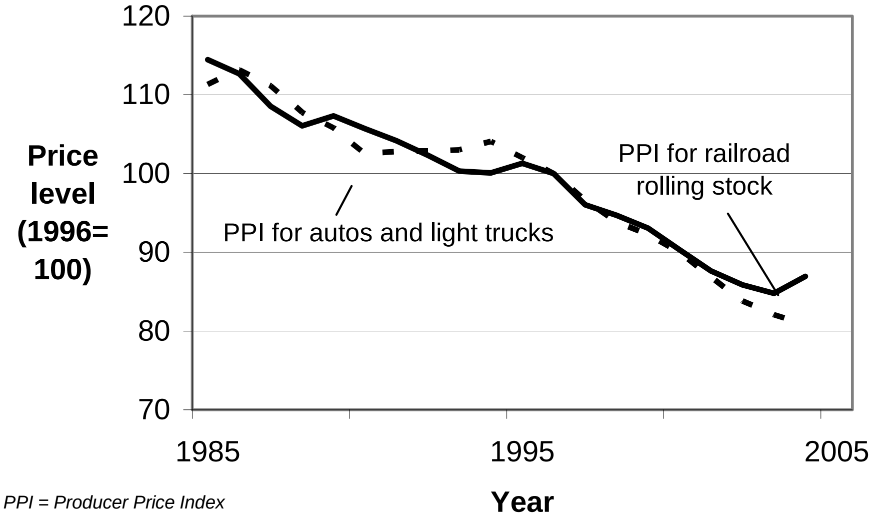
A.2.2. Types and causes of cost escalation

A wide range of factors have been suggested as driving cost growth across projects. The literature reviewed below explores a number of explanations, from the cost of raw materials, to the inclusion of advanced technologies, as well as the costs of customized specifications.

A.2.2.1. Factor costs: labor, raw materials, land and other inputs

An obvious potential source of cost growth is growth in the cost of the underlying inputs. If the costs of the raw materials and labor that go into transit projects are rising faster than general inflation, these rising costs could be passed through to the projects themselves and push total project costs higher. The literature and our data analysis suggest that until recently, the costs of these inputs have been rising *less* rapidly than inflation and have not been the source of any growth in costs. In the last two years, prices for steel and other raw materials have increased at a rate greater than the general price level and may contribute to escalation of overall project costs.

The FTA's Transit Capital Cost Index Study (Booz Allen 1995a) developed a composite cost index that tracked the prices of the inputs into typical light rail projects – labor, commodities such as steel and concrete, and manufactured inputs. The study found that the prices of these inputs increased at a rate below that of the Consumer Price Index (CPI) between 1985 and 1994.



PPI = Producer Price Index
Source: Bureau of Labor Statistics

Figure A-4. U.S. Vehicle Prices, Relative to Consumer Price Index

The Bureau of Labor Statistics' Producer Price Index (PPI) for Railroad Rolling Stock Manufacturing tracks the prices received by vendors for manufacturing and rehabilitation of light and heavy rail cars as well as parts. According to the index, prices increased at a rate below that of the CPI from 1985 (when the index began) to 1995 and since then have remained flat. The Producer Price Index for Automobiles and Light Trucks similarly increased during the 1980s and has been flat since 1996. When these indices are compared with the CPI, they show that prices for railroad rolling stock and for new motor vehicles have been falling in real terms for the last two decades (see Figure A-4). Since many of the inputs for automobiles and railroad rolling stock are similar to those for light rail vehicles, this analysis suggests that any increase in LRV prices is not due to increasing input costs.

In the last two years, rising steel prices have been a cost concern at many transit agencies (FTA 2004). After years of level or falling prices, iron and steel prices increased by 48% between 2001 and 2004. Given the widespread use of steel throughout all components of transit capital projects, such an increase could have an important impact on total project costs. According to our analysis of cost data from projects built in the 1980s and early 1990s, iron and steel products typically comprise at least 12% of the cost of light rail capital projects (see Appendix B). Steel prices are only one factor in the price of these products but if the price increase of the raw materials was passed through and less expensive alternatives were not substituted, the effect on total project costs could be an increase of several percentage points. (Since early 2005, steel prices have fallen sharply, though they remain well above the 2001 level.)

Right-of-way (ROW) costs are one area where costs have been shown to be increasing faster than the general price level. The Index study (Booz Allen 1995a) found that the inputs to ROW acquisition increased at twice the rate of other capital cost inputs from 1985 to 1994. Taylor (1995) argues that freeways increase the value of surrounding land by improving accessibility. Acquiring the ROW to expand these systems, then, becomes much more expensive than acquiring the original ROW. "Metropolitan freeways become victims of their own success," he writes. Light rail projects that require real estate purchases along existing lines may face similar cost pressures.

A.2.2.2. Procurement practices

Procurement and construction management methods and policies may also have a large effect on overall project cost. Some ways that these can impact costs include:

- Delivery schedules: capitalization costs, options, volume discounts
- Risk: Contractor risk, Inflation and currency risks, Warranties
- Extras: Spare parts, Testing and maintenance equipment, Renovation/modernization of existing assets
- Degree of customization and specification
- Contracting practices: Design-build; design-bid-build; design-build-operate-maintain; In-house versus contracted work

A.2.2.2.1. Contracting procedures

Transit agencies typically must follow state procurement guidelines that in many cases require them to choose the lowest bidder for contracts and procurements. In comparison with other contract management methods, however, low-bid procurements can increase project risk and result in higher soft costs and longer delays.

The traditional method for managing large construction projects separates design and construction into two contracts, with design completed before construction begin. In this system, known as design-bid-build, the designer is chosen using a qualifications-based approach, while the construction contractor is selected based on low bid (Trombly and Lutrell 2000). States typically mandate the low-bid method in order to minimize the influence of politics on the contracting system. Yet awarding contracts based on low-bid does not necessarily result in low overall project costs. On three different contracts, Portland’s Tri-Met saw large cost overruns on low-bid projects (Irwin 2003). On a $29 million contract, the agency received a $13 million claim late in construction. On a $104 million contract, costs increased $75 million; and on an $8 million contract, the agency was forced to delete certain work and let a separate contract for $2.5 million to complete the work.

For projects that involve new technologies and where advance completion of the final design is not possible (as with many ITS projects), or where communication between designer and contractor is a major issue, new contracting processes may be more appropriate. Some states have developed waiver processes to allow for alternative contracting methods. Irwin evaluates the advantages and disadvantages for transit agencies of a number of contracting methods, including low-bid, design-bid-build, request-for-proposal process, construction manager at risk, design-build, and sole source. He explains the scoring process that Portland developed to select an appropriate contracting method for each component of a $350 million expansion project. The process involved rating each project on a range of criteria, such as complexity and schedule constraints, and selecting a contracting method that best managed the items determined to be most critical for the project. (The project was completed under budget and on-schedule in 2004.)

State highway departments have also begun to experiment with a variety of contracting procedures. Carpenter et al (2003) review several types of performance-based contracts, including warranties, design-build, cost plus time (also known as A+B), and lane rental. Design-build, in which a single contractor is responsible for the entire project, has been noted for speeding up project delivery and reducing cost growth. One state found that highway projects that used innovative contracting methods experienced lower cost overruns and delays than projects that used traditional low-cost bidding.

Looking beyond the transportation industry, Kashiwagi (2004) compares low-bid, best-value, and negotiated bid procurement practices for general construction projects. He argues that where competitors are not all high-performing, a low-bid procurement shifts risk to the client and increases the need for management and oversight. A major consideration in designing a procurement process is that it deliver best value for the client and maximum profit for the contractor.

Kashiwagi (2001) has developed an alternative contract management technique, the Performance Information Procurement System (PIPS), which uses measures of contractors' past performance as selection criteria. Potential contractors are required to identify risks and propose mitigation measures, a step that eliminates inexperienced contractors. The facility owner is relieved of the task of micro-managing contractors to minimize risk. The contracting system has been used to select contractors for roof installations in Hawaii, for storm damage repair projects in Hawaii and California, and for construction of part of the 2002 Olympic Village in Utah. The author reports a very high success rate in completing projects on time and on budget.

A.2.2.2.2. Warranties

Warranties are a relatively new innovation in capital construction of transit projects. While a search of the literature did not find any analyses of such warranties, there is discussion of warranties for road construction projects. Warranties are seen as a way of improving quality and reducing maintenance and inspection costs. The contractor is responsible for maintenance work that may occur over the warranty period and has the freedom to use materials and techniques that will achieve the specified performance.

A survey of state departments of transportation by Bayraktar (2004) found that warranties typically added 5-15% to initial project costs. This did not necessarily translate into savings over the warranty period: nearly half of the surveyed states expected higher life-cycle costs on warranted projects, and only one state expected to see significant cost savings. Maintenance costs were estimated to drop by 10% or less. Furthermore, requiring contractors to provide warranties may reduce bid competition as surety companies are unwilling to underwrite warranties from small companies.

A.2.2.2.3. Degree of customization and specification

Transit agencies frequently face pressure to incorporate unique designs that will establish a system’s identity. Peterson (1995) explains that Los Angeles’ originally chose a driverless vehicle for its Green Line because the city “deserved a world class transportation system and therefore should specifically not install an extremely simple and low-cost system like San Diego’s.”

Customization of vehicles and systems effectively divides the market for those components into smaller markets for each agency. In such an environment, where manufacturers have no assurance of additional orders from other customers, they are forced to recoup their fixed costs on the initial order, driving up prices (Silien and Mora 1975). Efforts to promote standard design, with the potential for cost savings, began as far back as the 1930s with the Presidents’

Conference Committee (PCC) design for a standard light rail vehicle. In the early 1970s, the Urban Mass Transit Administration promoted development of a uniform standard for vehicles to be purchased for systems in Boston and San Francisco. This program resulted in the Standard Light Rail Vehicle produced by Boeing Vertol but was less successful than the PCC as Boeing lost money on its contract and eventually left the business.

More recently, several U.S. agencies have chosen de facto standards in the form of off-the-shelf designs for vehicles. O'Brien (1995) reported on operating savings achieved by San Diego and Sacramento as a result of their selection of a common Siemens design. California's newer LRT properties (including San Jose and Los Angeles) also standardized on self-service fare collection. Los Angeles had at one time planned custom vehicles for each line but later promoted standardization, in part to achieve greater economies of scale (Peterson 1995). New Jersey has also explored standardizing elements of its three light rail systems (Aurelius 1995).

FTA data on 9 recent orders suggest a wide cost disparity between orders for off-the-shelf and customized units (FTA 2005a). Salt Lake City purchased 28 standard Siemens units in 1999 for a base price of $2.13 million and a final price, including spare parts and "other," of $2.15 million. Seattle received bids for 31 custom bi-articulated vehicles to be delivered in 2007, with a base price of $2.44 million but a final price of $4.25 million. This final price covered millions of dollars in engineering, testing, bonds, insurance, management, contingency, and other fixed costs associated with development of a unique design.

APTA has developed a number of standards for transit systems including components of light rail systems (APTA 2004b). Safety is a prime motivator for standards, but the APTA report suggests there could be significant cost savings, too. It notes that a high degree of standardization in the avionics industry allows airlines to install components from any supplier without rewiring, and estimates savings to the airline industry of $291 million annually (1999). The report argues that such standardization increases the size of markets, encourages competition, and drives down prices. Standardization in the transit industry could bring additional savings as agencies reduce their inventories of custom spare parts and eliminate custom maintenance manuals and training programs.

APTA's consultant attempted to estimate the financial benefit of standards through interviews with vehicle (bus and railcar) manufacturers. Executives at these companies were asked to estimate the cost savings from application of all existing APTA and IEEE (Institute of Electrical and Electronic Engineers) standards. The maximum (and median) savings indicated by the interviewees was 5%. Assuming that these savings could be achieved for light rail vehicles and that savings were passed through to buyers, this would translate into a reduction of $125,000 - $150,000 for the typical $2.5-$3.0 million vehicle.

The European Union has launched a technical standards program for light rail vehicles (European Commission 2005). Working groups are addressing functional areas ranging from electromagnetic compatibility to accessibility and will propose procurement standards and maintenance best practices. The project is expected to cut procurement costs for new vehicles by as much as 25% and result in lower operating and maintenance costs.

A.2.2.3. Regulatory requirements

Transit agencies are subject to a range of federal, state and local regulations that affect capital costs. Some of these mandate specific technical designs to improve safety or allow increased accessibility. Others relate to the way the agency conducts its business, such as low-bid procurement requirements and prevailing wage (Davis-Bacon) laws. The following reviews changes in regulations that may have affected recent capital cost trends.

A.2.2.3.1. Americans with Disabilities Act

The Americans with Disabilities Act (ADA) was passed by Congress in 1991 and established standards for accessibility in public places, including transit systems. Agencies responded with a range of technologies including elevators, vehicle or platform lifts, high or mini-high platforms, vehicle ramps, and low-floor vehicles.

The cost of compliance with the law depended on a system's existing configuration. Sacramento's existing stations, for example, already incorporated many required elements such as elevators (Cross 1995). The cost of upgrading most elements of its 30 stations to ADA standards was estimated at $1.3 million. This included expanded use of detectable warning strips, improved lighting, new graphics, Braille signs, and new elevator controls. The one station that did not already provide disabled access in both directions would have to be rebuilt, at an estimated cost of $1.0 million. In San Jose, the transit agency explored several accessibility options to bring its existing and planned system into compliance; these ranged in cost from $67 million to $152 million (Weiss 1995). Finally, improving accessibility by specifying low-floor vehicles can add as much as $250,000 to the price of a vehicle.

A.2.2.3.2. Domestic and local manufacturing requirements

A potential contributor to cost escalation is the strengthening of domestic content mandates since the late 1980s. These Buy America regulations are designed to support employment and industry in the U.S. by requiring that agencies purchase products made wholly or at least in part in the U.S. Before 1987, the law required transit agencies to use domestic suppliers unless the price would be more than 10% above that offered by foreign suppliers. Vehicles were subject to a less stringent standard: a vehicle qualified as domestic if at least 50% of its parts were of domestic origin (Johnson 2001).

In 1987 Congress increased the cost differential to 25%, such that a foreign supplier could only be chosen if domestic supplies would cost 25% or more than the foreign equivalent. For vehicles, the domestic content minimum was increased to 60%. The law requires that final assembly of vehicles take place in the U.S.

The effect of these regulations on price is not clear, but in other industries such as automobiles, manufacturers have increasingly moved their plants outside the U.S. to cut costs. Requiring manufacturers to maintain LRV assembly plants inside the U.S. may contribute to faster cost growth for LRVs.

Transit agencies must also comply with state and local manufacturing mandates that have the potential to increase project costs. (States are barred from mandating local content or assembly for federally-funded projects.) In 1992, for example, the Los Angeles County Transportation Commission added job-creation conditions for bidders on a new order of railcars. The region was suffering a significant recession and the board had been forced to rescind its decision to award the order to a foreign supplier (Peterson 1995). The conditions included:

- A requirement to partner with local high-technology companies to develop advanced transit products that would be used on two prototype cars, with the potential for marketing new products in the worldwide market. The Commission set aside $10 million to fund development of the prototypes.

- Bidders were required, as part of the bid scoring process, to engage new businesses, or businesses never involved in the transit business, in an attempt to jump-start creation of a transit vehicle industry.

- The Commission stipulated that ten percent of the vehicle content should be provided by Small Minority Business Enterprises.

A.2.2.4. Market conditions

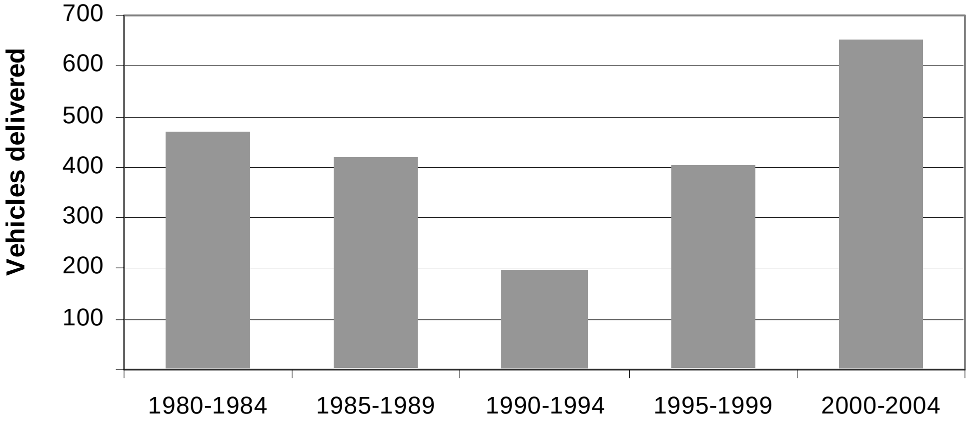
In any industry, competition can be an important force controlling cost growth. When there are many vendors vying for the same business, they are forced to keep prices down. In the light rail industry, however, competition is limited by a number of factors and since 1995, three vendors have accounted for 80% of U.S. LRV vehicle deliveries.

Customization is an important factor limiting competition. If an agency develops a custom design for its vehicles, it may limit the number of vendors who will bid on a procurement, particularly if the order is small. Furthermore, the agency may find it difficult to purchase spare parts for its custom system from any but the original manufacturer, and therefore has limited leverage in negotiations over price. Conversely, when standardized vehicle parts are used, an agency may be able to choose from multiple vendors to get the best price.

An additional constraint on competition is the large fixed cost associated with manufacturing light rail vehicles. Foreign manufacturers are required to establish assembly plants in the United States. These startup costs give an advantage to established suppliers who already have plants in the U.S. and may deter entry into the market by any but the largest companies.

Finally, the size of the U.S. market for light rail vehicles is small and relatively volatile. Since 1995, agencies have purchased an average of 105 vehicles annually, with the size of orders typically ranging from 10 to 40 vehicles (APTA 2004a and FTA 2005). Of course the U.S.

market is only part of a larger global market – worldwide annual shipments recently averaged 585 units – but the domestic content and assembly requirements may effectively isolate the U.S. market from that larger market and limit the number of manufacturers willing to bid on U.S. orders (Wright 2004).



Source: APTA (2004a)

Figure A-5. U.S. LRV Deliveries, 1980-2004

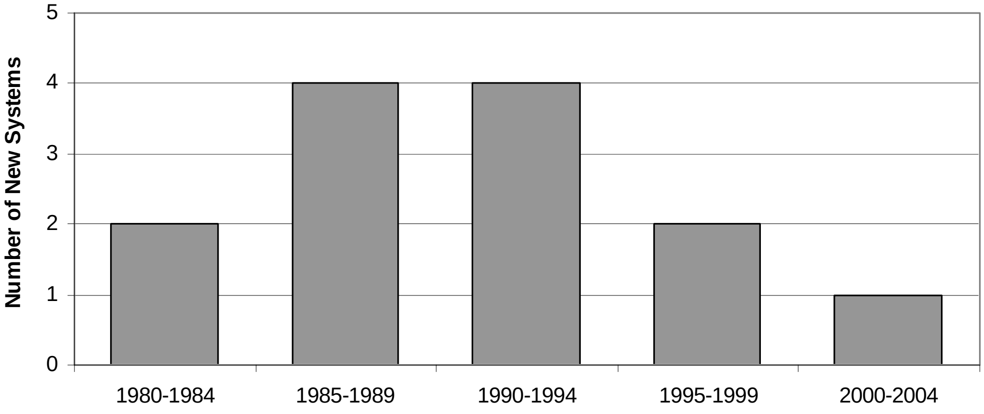
Over the last quarter century, several major suppliers have left the market and been replaced by others. Bombardier acquired two Canadian manufacturers, and Kawasaki has not delivered any U.S. LRVs in over 20 years. Only one manufacturer, Siemens, has maintained a consistent level of deliveries since 1980. Since 2000, Siemens, KinkiSharyo, and Ansaldobreda have been the largest suppliers. Although all have assembly plants in the U.S., all are foreign-owned.

As Figure A-5 shows, the size of the market for U.S. light rail vehicles in the 1990-1994 period was half that of any other five-year period in the last quarter century. Several manufacturers exited the market in the late 1980s and one manufacturer, Siemens, accounted for 70% of the deliveries. Further exploration would be necessary to understand the market dynamics during this period and any relationship between market structure and price.

In small markets dominated by a few firms, such as local contracting markets and possibly the market for light rail vehicles, prices may reflect market strategy of the bidders rather than actual production costs. Sclar (2000) explores the market behavior of public works contractors. He points to a decision by Fort Lauderdale, Florida, to close its pipe-laying department and rely on private contractors. The city estimated its in-house cost at $90 per linear foot. Contractors reportedly began preparing bids of up to $130 per foot. After the city revised its in-house cost estimates to $43 per foot, the contractors revised their bids to the $50 to $60 range. Sclar points out that much public contracting takes place in uncompetitive markets where bidders are quite aware of each other's interests and may submit bids with an eye on the needs of their rivals.

A.2.2.5. Technical capacity

A factor that may have contributed to the moderation of cost growth in recent years is the maturation of technical capacity at transit agencies. Since 1980, new systems have opened in thirteen cities in the United States. Most of these began operations in the late 1980s or early 1990s; only two systems (Salt Lake City and Houston) have opened since 1996. Nearly all of these agencies have since embarked on one or more expansion projects.



Source: APTA (2004a)

Figure A-6. Openings of New U.S. Light Rail Systems, 1980-2004

Agencies have used lessons learned from development of their initial system to improve practices on these subsequent projects. As indicated in section A.2.2.2 above, Portland's Tri-Met used its experience on earlier projects to develop more successful procurement practices for its latest expansion. In Los Angeles, experience with two different light rail standards on its first lines impelled the local agency to focus on using a standardized design for its third line (section A.2.2.2.3.). These and other measures applied by increasingly experienced technical staff may have contributed to the leveling of costs over the last ten years.

A.3. Project Escalation

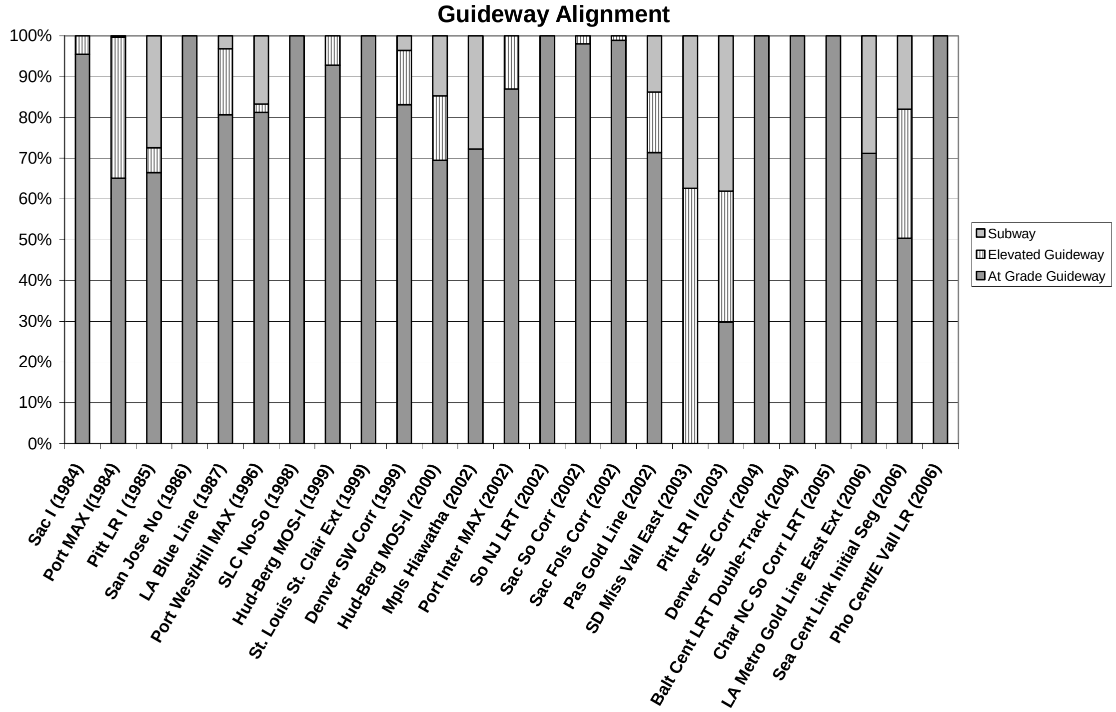
Some trends in project costs may not be due to an escalation of costs among comparable projects, but rather to qualitative changes in the nature of the projects themselves.

A.3.1. Local conditions

As light rail systems around the country mature, changes in project location conditions could contribute to cost growth. For example, the first line in a new system frequently takes advantage of an existing railroad corridor, while expansion projects may require expensive construction of new guideway along a new right-of-way. Pilgrim (2000) notes that Portland paid nearly twice the price per meter paid by Salt Lake City and Dallas for construction of at-grade ballasted double-track guideway. The source of the disparity, he suggests, is that the two latter lines were constructed in former railroad corridors, while Portland's line went through a variety of unprepared areas.

If newer projects are being designed with a more expensive mix of components such as tunnels or elevated structures, this trend could potentially drive costs higher. Pilgrim looked at fifteen light rail projects developed in the 1980s and 1990s and assessed the sources of unit cost variation. The type of guideway was a key cost driver, with subway costs far higher than at-grade construction. The cost per mile of at-grade work ranged from $10 million to $30 million, while tunnel sections ranged from $60 million to $89 million. At-grade stations cost an average of $1.7 million, while underground stations averaged $19.9 million (1998 dollars). Booz Allen (2003) found that such variations accounted for 30% of the variance in unit costs across projects.

Our analysis of the 19 projects surveyed by Booz Allen shows, however, that there has not been a statistically significant trend toward more expensive mixes of guideway alignments. The percentage of projects that is built at-grade has not changed in any meaningful way since the 1980s for the projects surveyed (see Figure A-7), and in fact four recent projects are entirely at-grade. Since there is no trend, changes in the mix of guideway alignment do not appear to be contributing to long-term cost trends.



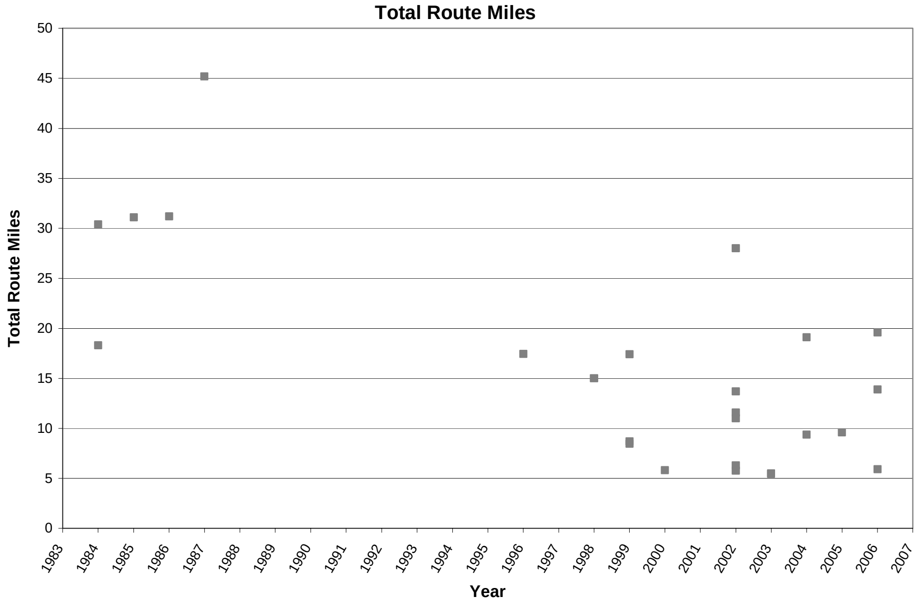
Source: Booz Allen & Hamilton (2003)

Figure A-7. Percentage of Guideway That Is At-Grade, Elevated, or Underground

Expansion projects must also cope with constraints imposed by the operational requirements of the existing system. Additional costs may be incurred to provide alternate service or to develop designs that minimize the impact on riders, and work may be carried out on nights or weekends, resulting in higher labor costs. These costs are likely to figure most prominently on projects such as double-tracking where construction takes place in close proximity to existing lines.

A.3.2. Economies and Diseconomies of Scale

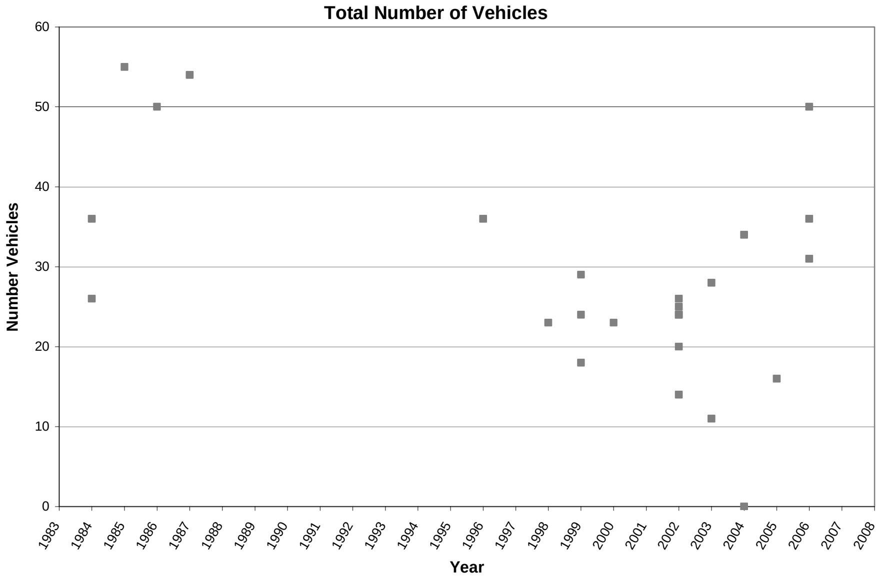
On the other hand, Booz Allen documented a trend towards smaller projects since the 1980s (see Figure A-8). The study also found significant economies of scale in many asset categories. For categories with large fixed costs, per-unit costs increase as project size decreases. The study determined that fully half of the increase in unit costs between the mid-1980s and the late 1990s-early 2000s could be accounted for by smaller project size.



Sources: Booz Allen & Hamilton (2003), FTA (2005b)

Figure A-8. Size of Transit Capital Projects, in Route Miles

Similar economies of scale apply to purchases of light rail vehicles. Manufacturers must recoup certain fixed costs with every order, and the larger the order, the more vehicles over which they can spread these costs. Our analysis of Booz Allen's compendium of vehicle specifications (2004b) shows that the size of orders has decreased significantly since the 1980s (Figure A-9). Regression analysis does not find a statistically significant trend since 1995. Thus changes in order size may have contributed to higher prices in the mid-1990s but do not appear to have had an effect since then.



Sources: Booz Allen & Hamilton (2003) , FTA (2005b)

Figure A-9. Size of Vehicle Procurements

A.3.3. Incorporation of new technologies

Technology has been an important cost driver for light rail systems in recent years. New systems and vehicles incorporate advanced technical features such as communications-based train control, low floors, AC traction motors, and real-time customer information systems, some of which can add significantly to capital costs. These new features can drive up the cost of new systems but promise to improve safety or service. Some features such as low-floor vehicles may increase capital costs in one asset category while saving costs in another; and others such as AC motors promise operating budget savings through reduced maintenance costs and lower energy consumption.

Swanson (2000) identifies twenty-five significant trends affecting light rail system design. These include system configuration changes such as a shift from single-unit to multiple-unit operations; the adoption of technologies such as air-conditioning and AC motors; requirements for improved accessibility; stricter procurement requirements; and more advanced security and safety systems. The article also suggests future trends that are likely to affect LRT design. These include:

- new power transmission systems (contactless pickups, energy storage systems);
- more diverse power sources (dual diesel-electric, fuel cells, natural gas);
- maximum possible low-floor area in vehicles;
- driverless operation;
- variable vehicle configurations;
- individual wheel drives without bogie (truck) frames;
- flexible interior layouts;
- increased collision protection inside vehicles;
- convergence on technical standards; and
- mandatory recycling by manufacturer.

Additional research is required to understand the potential effect of these trends on cost. The remainder of this section reviews the existing literature on specific cost drivers. Further research could identify the extent to which each of these factors has actually affected the cost of light rail capital projects.

A.3.3.1. Intelligent transportation systems

A report by Mitretek Systems (2000) identifies a range of intelligent transportation systems (ITS) technologies that have been implemented or are being considered for passenger rail systems. A later report and database developed by Mitretek (2003) identify cost ranges for individual components in typical ITS systems.

One prominent ITS technology is communications-based train control (CBTC), a set of train control technologies that replaces or augments existing fixed-block control systems. It includes communications technologies that track the exact location of trains and allow the possibility of shorter headways between trains. The most advanced CBTC technologies promise fully-automated operation. CBTC has the potential to increase the capacity of rail lines, improve safety, and reduce labor costs. San Francisco Muni spent $80 million and over eight years retrofitting its existing system with CBTC and New York has spent more than $250 million adding CBTC to one subway line; the cost of implementing the technology in a new system is not known.

From the rider's perspective, one of the most visible technological advances is the provision of real-time information. Wireless technology, satellite communications, and the Internet have allowed agencies to provide up-to-date information to their customers about vehicle arrival times. The benefits of such systems are increased customer satisfaction and higher ridership. Agencies have responded by implementing automatic vehicle location systems and adding electronic displays to their vehicles and stations. Mitretek (2000) cites an FTA study that estimated a 1-3% ridership increase from implementation of traveler information systems.

The Mitretek database suggests cost ranges for some of the components in a typical information systems. A TCRP report on bus information systems (Schweiger 2003) gives total system costs for Portland's Tri-Met Transit Tracker system, which provides customers with real-time information on bus and light rail arrivals. Tri-Met reported a total cost of $7 million to implement an automatic vehicle location system; the cost associated with each vehicle was $4,500. The agency spent an additional $700,000 for its real-time information system, and about $4,000 for each electronic display board.

On a more basic level, our preliminary analysis of light rail vehicle specifications provided by Booz Allen (Booz Allen 2004b) confirms the trend toward more advanced technologies. Over the last quarter century, agencies have increasingly specified electronic signs, prerecorded announcements, and outside public address systems for their vehicles. Further research could identify the incremental capital cost of these items.

A.3.3.2. Low-floor vehicles

Low-floor vehicles (LF-LRVs) were first used in France in the 1980s and have been ordered by a number of U.S. systems since the mid-1990s. These vehicles provide easier street-level boarding and help solve accessibility problems. In new systems, they may eliminate the need to build high-level platforms and allow customers to board from existing sidewalks. An early study of technical designs for low-floor streetcars suggested that low-floor vehicles were costing at least 20% more than high-floor designs (Hondius 1993). A TCRP report (Booz Allen 1995b) used cost comparisons and anecdotal evidence to argue that low-floor designs should add no more than 10% to vehicle costs and that the cost premium would disappear "in the near future."

Analysis of the APTA vehicle database shows that low-floor vehicles cost approximately $250,000 more than high-floor vehicles.

The TCRP report identified potential capital and operating benefits from low-floor designs, including the following:

- Lower capital cost for platforms. On new lines or systems, platforms for LF-LRVs are much less expensive and intrusive than for conventional LRVs.

- Faster boarding times. Low floor designs could result in faster boarding times and round-trip times and thus savings in the size of the active fleet and number of operators and maintenance personnel. A report on Portland's early experience with low-floor vehicle (Porter and Heilig 2000) found that such savings were "incipient" but had not yet been realized two years after the fleet was put into service.

A.3.3.3. Larger vehicles

Changes in vehicle size could drive costs higher; however, analysis of the APTA database shows that vehicle size has remained fairly constant over the last decade. Vehicle lengths have typically ranged from 72 to 95 feet and seating capacity between 60 and 76. Nearly all vehicles have a single articulation. Regression analysis shows that variations in size (as measured by vehicle square footage) account for 25% of the variation in price between vehicles, but over the last twenty years there is no discernible trend toward larger or smaller vehicles.

In two specific cases, variations from these norms may have affected cost. Seattle's new cars, at $4.25 million, are well above the $2.5-3.2 million price seen in other recent orders. They are also the only bi-articulated cars, though they fall within the norms for length and seating capacity. San Diego's North County Transit District diesel cars, to be delivered in 2006, are priced at $4.22 million. They are much larger than any other light rail vehicle, with a length of 137 feet and a seating capacity of 140.

A.3.3.4. AC motors

An important motivation for incorporating new technologies is the promise of lower operating costs. AC traction motors are an example of such a technology. Agencies have in recent years specified these motors in place of the older DC chopper motors. AC motors offer significant energy cost savings and require less maintenance, although the relationship between higher capital costs and operating savings is unclear (U.S. Congress Office of Technology Assessment 1991, Allen and Aurelius 2003). The Chicago Transit Authority cited a more competitive market for the new motors as part of the justification for upgrading its rapid transit fleet to AC propulsion (Chicago Transit Authority 2001).

A.4. Summary

A significant conclusion that may be drawn from the literature and data analysis is that prices for light rail systems have stabilized over the last decade. Prices of some components, notably direct fixation trackwork, appear to have fallen since 1995. These trends suggest a reversal of the cost growth seen during the 1980s and early 1990s.

While there is insufficient data to fully explain these trends, the literature review and data analysis point to possible sources for the earlier increase and indicate the range of cost pressure that agencies face today. The slowing of cost growth in recent years also hints at the possibility that some of the mitigation measures reviewed here have been successful.

Among factors that may have driven light rail costs higher in the early 1990s, a few stand out:

- A number of new systems were developed during those years. Agencies with less experience on transit capital projects may be less effective at managing costs than older agencies. There may also be political pressures that are particular to development of new systems, such as the desire to build a custom design that establishes a system’s uniqueness.

- The Americans with Disabilities Act came into force in 1991 and required transit agencies to develop more accessible systems. Adoption of low-floor vehicles alone may have added $250,000 to the price of vehicles, although these vehicles brought the potential for savings in other areas.

- Congress strengthened Buy America requirements in the late 1980s and early 1990s, potentially increasing the prices of many foreign- and domestically-produced components.
- One supplier dominated the vehicle market in the early 1990s.

Since the mid-1990s, the cost of light rail systems has remained relatively stable; yet agencies face a number of obstacles as they work to control cost growth:

- Commodity prices, stable or falling for many years, have surged upward in the last two years as worldwide demand has grown rapidly.
- While starter systems at new agencies may have been able to take advantage of old railroad corridors, expansion projects may require expensive acquisition and construction of new right-of-way.
- Projects are smaller than they were twenty years ago and agencies are not able to obtain the same economies of scale as with larger projects.
- There is continued demand for the use of new technologies such as customer information systems and automatic train control that can add significantly to system cost.

The literature also points to the potential cost benefits of technical standards. Widespread adoption of vehicle standards could bring savings of 5% in costs (APTA); when the benefits of increased competition are considered the savings could be much greater, as suggested by the European Commission’s estimate of a 25% reduction.

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APPENDIX B: Statistical Analysis of Cost Trends

B.1. Introduction

This appendix describes the research team's analysis of light rail transit project cost trends. It focuses on four different areas. First, it identifies capital asset categories that represent a substantial proportion of total costs. Second, it examines overall total project costs trends as well as cost trends for steel which is a major component of light rail projects and estimates steel's contribution to light rail project capital costs. Third, it analyzes capital asset category unit costs. The final section is an analysis of the scale and complexity of light rail projects in general and light rail vehicles in particular.

B.2. Analysis of Capital Asset Categories in terms of their Proportion of Total Costs

This analysis is based on the data provided in the Booz Allen report, "Light Rail Transit Capital Cost Study Update" (2003), which breaks down the costs for 19 light rail transit capital projects into 25 specific asset categories. The percentage of total cost represented by each category was calculated and the results are shown for the post-1995 projects in Figure B-1 and for all 19 projects in Figure B-2.

The most substantial factor is Soft Costs, which includes planning/feasibility studies, preliminary engineering and design, final design, construction management, project management, and project mitigation. The next most significant is Revenue Vehicles, which account for 13.7% of the total costs for the post 1995 projects. At-Grade Guideway, which accounts for 10% of the total costs, is also very significant. Other leading factors (5% or more of total costs) include Stations, Right-of-Way, Special Conditions, and Electrification.

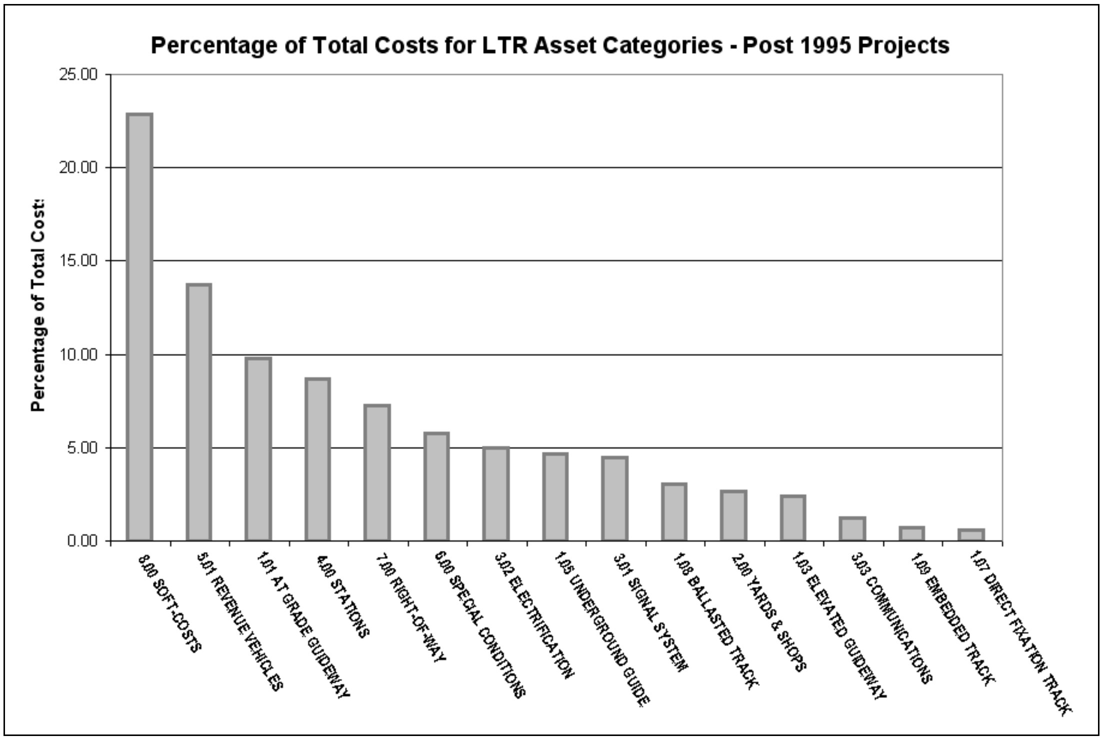


Figure B-1: Percentage of total cost for 14 post 1995 projects.

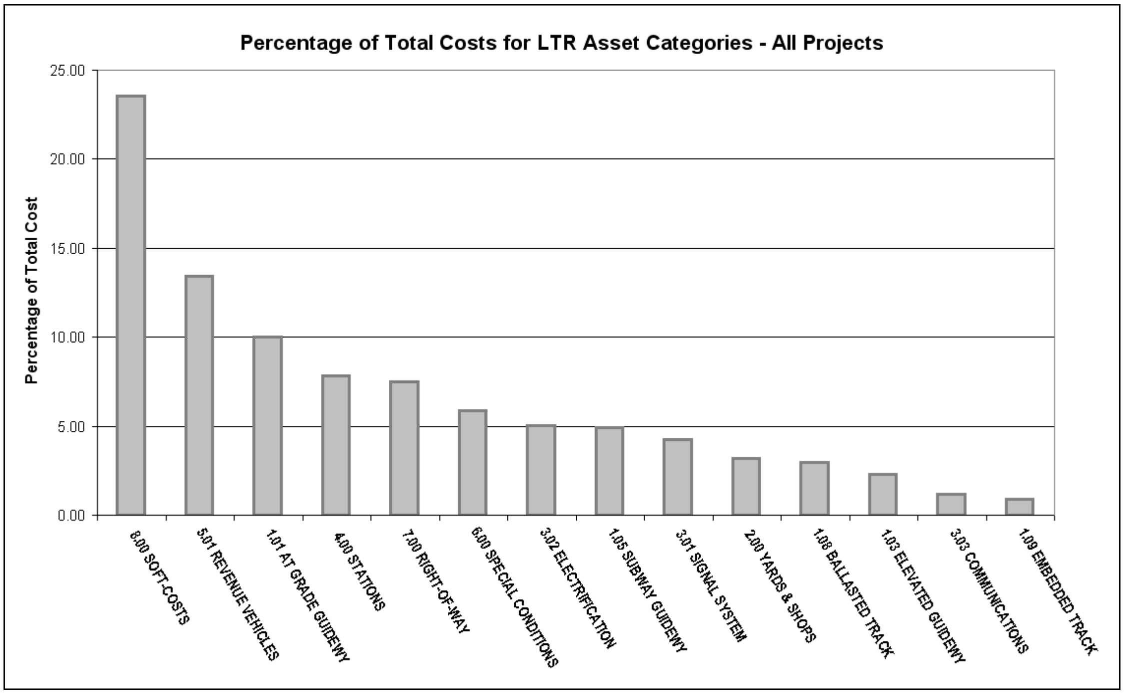


Figure B-2: Percentage of total cost for 19 projects from 1984 to 2003.

B.3. Overall Cost Trends

B.3.1. Total Project Costs

The actual total project costs for the 19 light rail transit projects covered in the Booz Allen report are shown below in Figure B-3. The adjusted total project costs over the same period (taking into account Booz Allen's methodology for adjusting these costs to account for differences in location and other factors) are shown in Figure B-4. Finally, the total project costs per unit length of guideway are shown in Figure B-5.

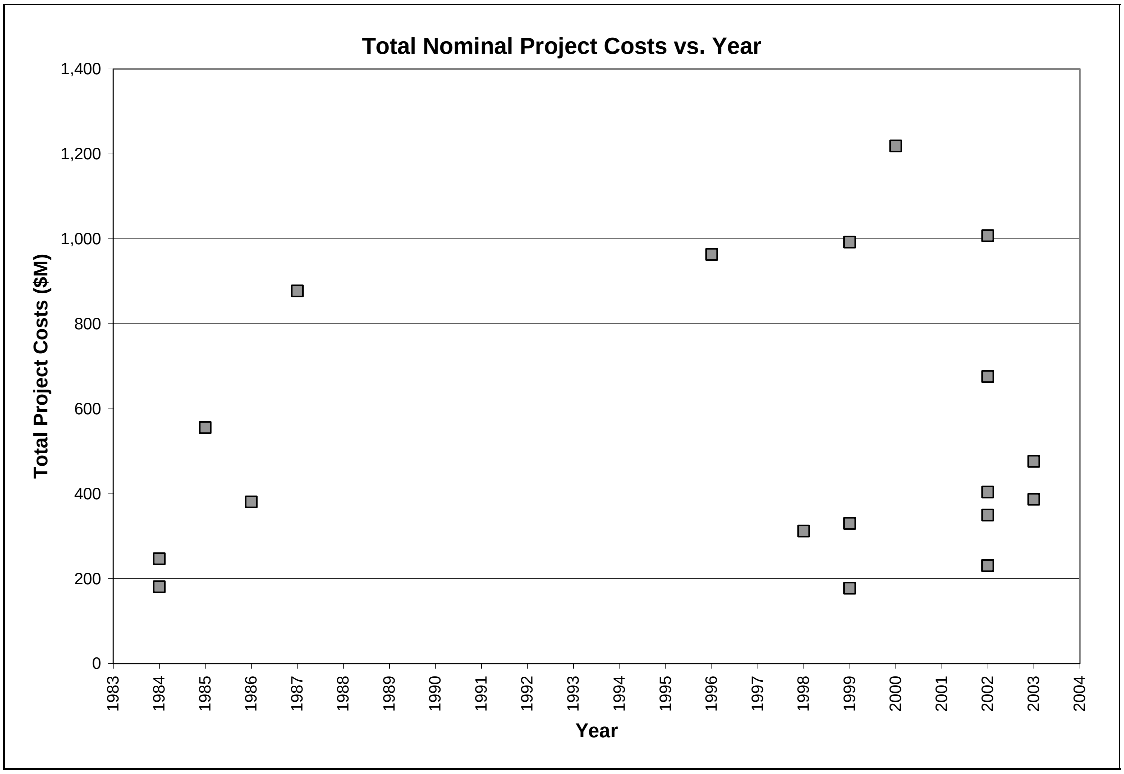


Figure B-3: Total project costs vs. year for all 19 projects.

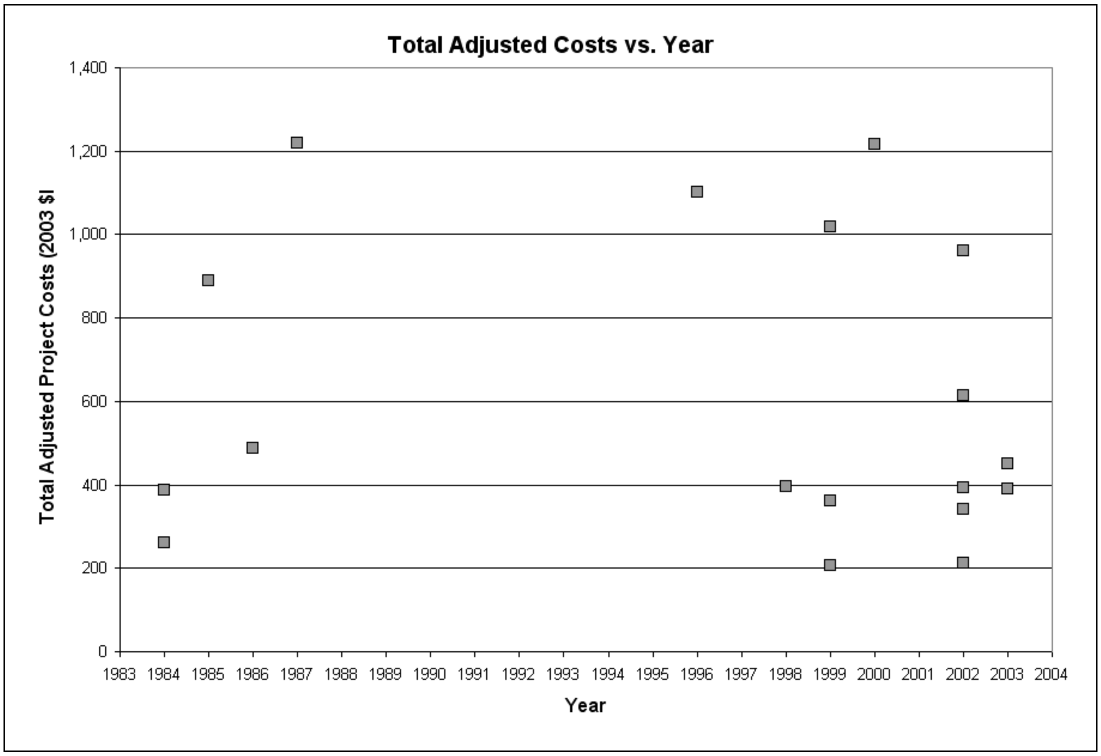


Figure B-4: Total project costs adjusted for inflation and regional cost factors.

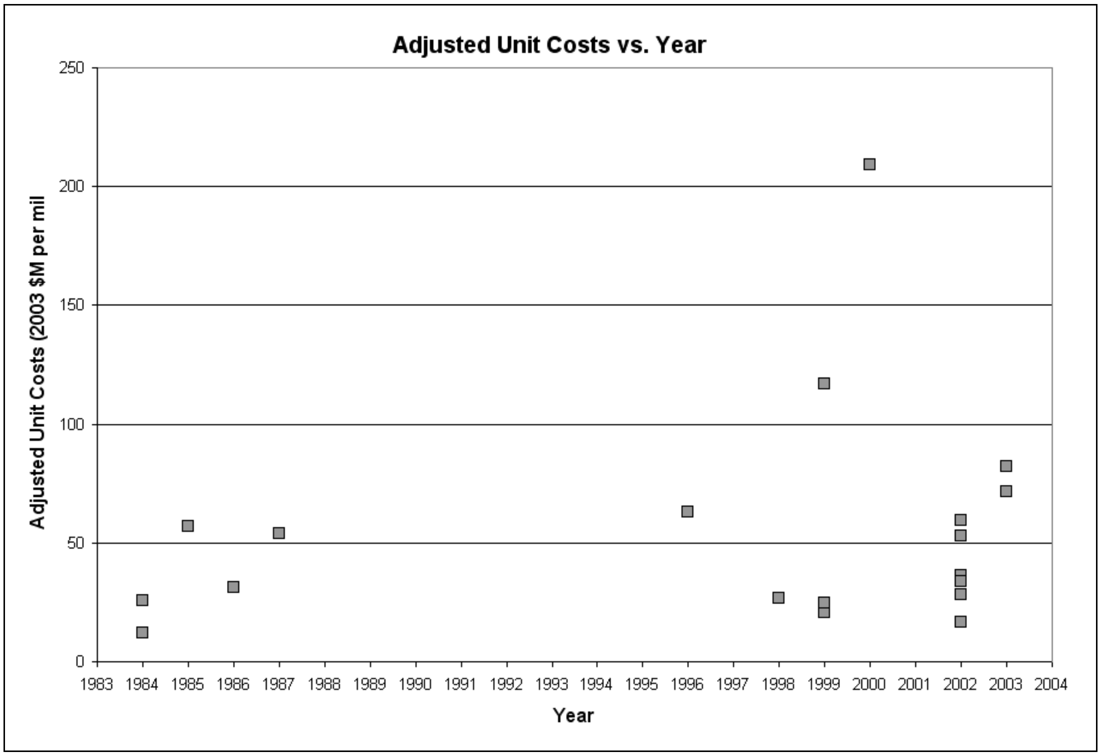


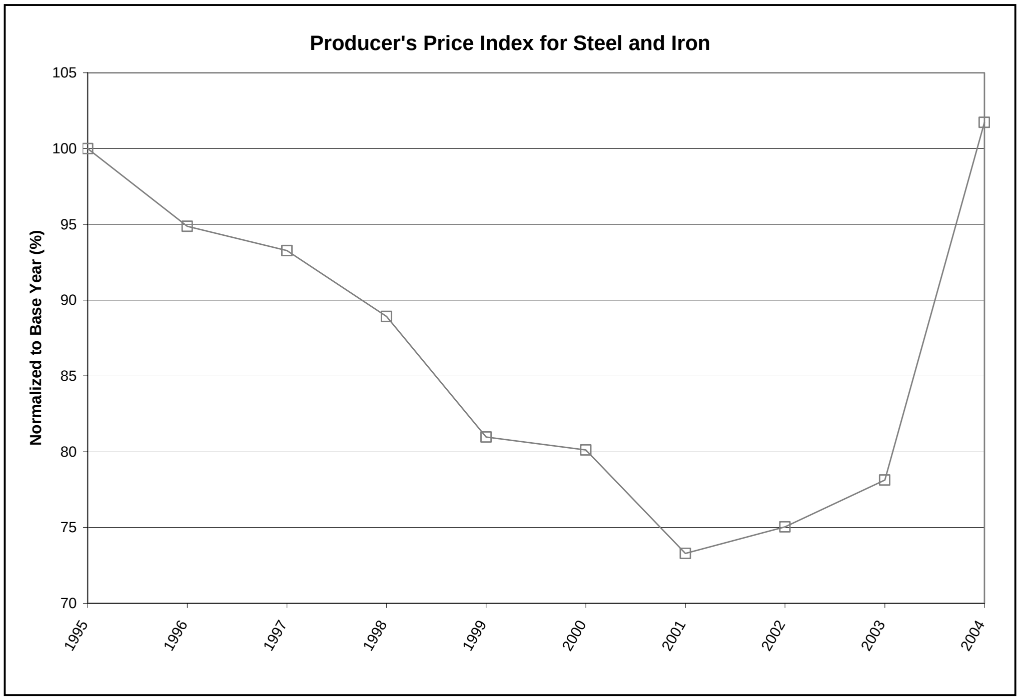
Figure B-5: Total adjusted project costs per mile of guideway.

B.3.2 Analysis of steel price trends and steel's contribution to project costs

Steel prices have been rising rapidly in the past few years and, since steel is a significant component of most light rail projects, rising steel prices could play a significant role in rising light rail project capital costs. This section documents changes in the price of steel over the last ten years and estimates the contribution that steel prices make to light rail capital costs. This analysis indicates that steel makes up 12.1% of total project costs when soft-costs are included and 15.7% when soft-costs are excluded.

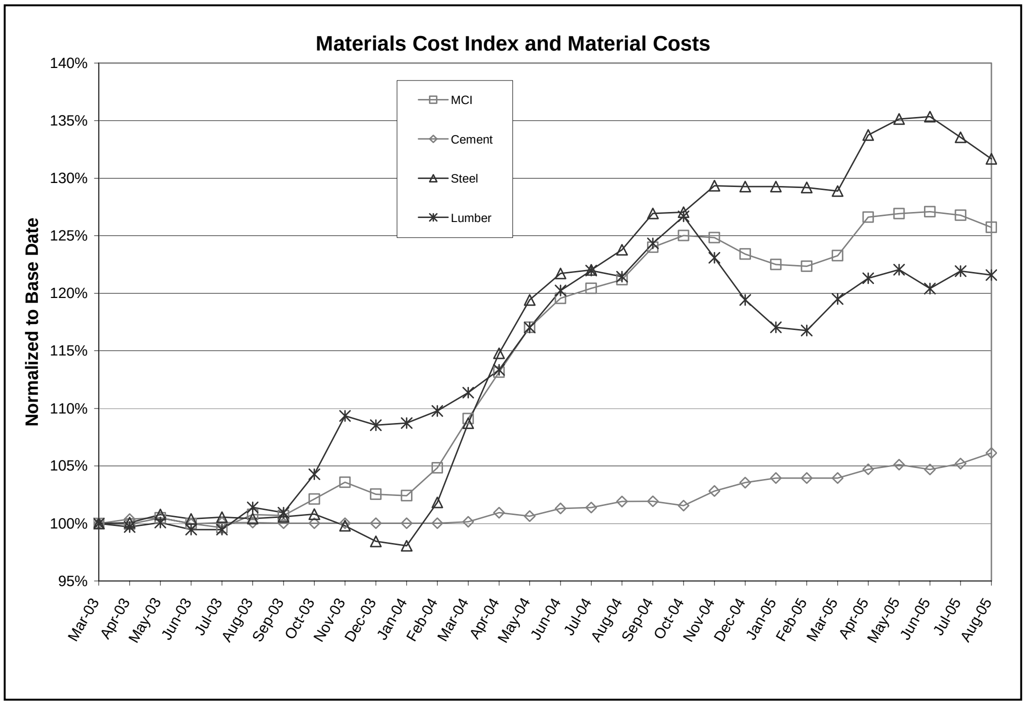
To document the price of steel in real terms over the last ten years, the producer's price index (PPI) for iron and steel from 1995 to 2004 was adjusted to 2005 dollars using the consumer's price index. The PPI is an index calculated by the Bureau of Labor Statistics which measures the average change over time in selling prices received by domestic producers of goods and services, that is, it measures price change from the seller's perspective. To track more finely what has happened to the price of steel in the last couple of years, the monthly materials cost index and steel costs reported by the Engineering News Record are also presented in this report. Both sets of data have been normalized by reporting them as a percentage of the base date value, that is, the respective value for the earliest date in each case.

Figure B-6 shows the producer's price index for iron and steel from 1995 to 2004 and Figure B-7 shows the materials cost index as well as the cost for steel, lumber, and cement from March 2003 to August 2005. Figure B-6 shows that the price of steel decreased from 1995 to 2001, but then began to increase from 2001 to 2003 and to increase dramatically since then. Figure B-7 shows that, from March, 2003 until September, 2003, the materials cost index and the cost for steel, lumber, and cement remained quite constant, but that after that, each item fluctuated quite a bit, with the exception of concrete which remained fairly constant. After a decline into January, 2004, the cost of steel increased the most and only recently has it decreased slightly.



Source: Bureau of Labor Statistics

Figure B-6. Producer Price Index for iron and steel (base year = 1995).



Source: Engineering News Record

Figure B-7. Materials cost index and costs of steel, lumber, and cement adjusted for inflation and normalized to the base date of March, 2003.

The estimation of the size of steel’s contribution to light rail capital costs is based on data from an FTA sponsored study by Booz-Allen, “The Transit Capital Cost Index Study” (1995). This study breaks light rail project costs down into the eight top-level categories shown in Figure B-8. The Booz-Allen study estimates the percentage of total costs that each category represents. It also estimates the percentage of costs that are represented by labor, equipment, and materials, including steel products, for each category. Steel products include structural metal, fabricated platework, nuts and bolts, and rebar. Most of these steel products are manufactured and the commodity price is only part of their cost, which also includes labor and manufacturing costs.

Cost Element
1.00 GUIDEWAY ELEMENTS
2.00 YARDS & SHOPS
3.00 SYSTEMS
4.00 STATIONS
5.00 VEHICLES
6.00 SPECIAL CONDITIONS
7.00 RIGHT-OF-WAY
8.00 SOFT-COSTS

Figure B-8. Light rail capital cost categories used by Booz-Allen.

To estimate the percentage of total cost within each category represented by steel, the category’s percentage of total costs is multiplied by steel’s percentage of the category’s cost as shown in Figure B-9. Summing up these percentages over the eight cost categories, steel makes up 12.1% of total project costs when soft-costs are included and 15.7% when soft-costs are excluded.

Cost Element	**Element's % of Total Costs**	**Element's % of Total Cost (w/o soft costs)**	**Steel's % of Element's cost**	**Steel's % of Total Cost**	**Steel's % of Total Cost (w/o soft costs)**
1.00 GUIDEWAY ELEMENTS	25.65	33.06	8.80	2.26	2.91
2.00 YARDS & SHOPS	5.56	7.16	26.49	1.47	1.90
3.00 SYSTEMS	11.37	14.65	11.38	1.29	1.67
4.00 STATIONS	5.81	7.48	9.89	0.57	0.74
5.00 VEHICLES	13.86	17.87	40.70	5.64	7.27
6.00 SPECIAL CONDITIONS	6.36	8.19	14.20	0.90	1.16
7.00 RIGHT-OF-WAY	8.99	11.59	0.00	0.00	0.00
8.00 SOFT-COSTS	22.40	0.00	0.00	0.00	0.00
TOTAL				**12.14**	**15.65**

Figure B-9. Estimation of steel’s percentage of total project costs.

B.4. Analysis of Unit Cost Trends

To identify the asset categories whose costs were increasing the fastest, a regression analysis was done which looked at the cost rates of change over time. Before describing the results of this analysis, the process used to standardize and adjust the asset category cost values will be briefly discussed.

The Booz Allen report analyzes each type of capital asset (or project component) on a unit cost basis. For example, the guideway elements were analyzed in dollars per linear foot, while the vehicle elements were given in dollars per vehicle. To facilitate a comparison across a number of different projects located in different parts of the country and completed at different times, two further adjustments to the unit cost values. First, to account for general price inflation, individual unit costs were inflated from their year-of-expenditure values to a constant 2003 dollar value using the Consumer Price Index. Second, to account for regional price level differences, these 2003 constant dollar values were adjusted to a normalized national average basis. Since rail vehicles are a commodity not subject to local construction conditions, this second adjustment was not performed on vehicle costs.

To identify the cost elements that have been increasing the most rapidly, a regression analysis was performed which looked at the relationship between the asset category costs and the project year. The costs which were analyzed in the Booz Allen report were unit costs in which the total cost for a particular element is divided by the relevant unit. The unit costs which were adjusted for inflation and regional price level differences as described above were normalized to deal with the fact that the different asset category costs were given in different units. For each asset category, the mean and standard deviation were calculated and the normalized unit costs were calculated using the following formula:

$$Normalized\_Unit\_Cost = (unit\_cost - mean)/standard\_deviation$$

Where *mean* is the mean cost of a given category for all projects being analyzed and *standard_deviation* is the corresponding standard deviation.

A regression analysis was then used to examine the relationship between the normalized unit costs and project year. For each asset category, the regression equation has the form:

$$Normalized\_Unit\_Cost = \alpha_0 + \alpha_i Year$$

Where α_0 is a constant and α_i is a coefficient that represents the change in the normalized unit cost over time.

This regression analysis produced an estimate of the relative rate of change in costs over time for each asset category as well as a measure of significance for that estimate. These rates of change are shown for the post-1995 projects in Figure B-10 and for all projects in Figure B-11.

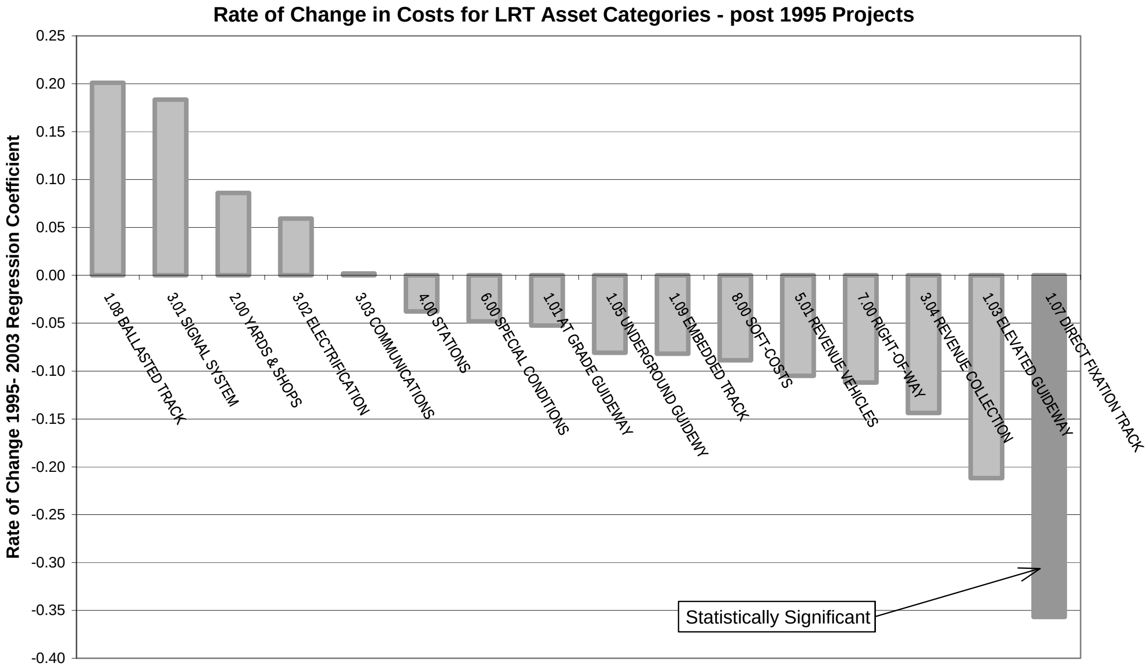


Figure B-10: Relative changes in cost by asset category, for 14 post-1995 projects.

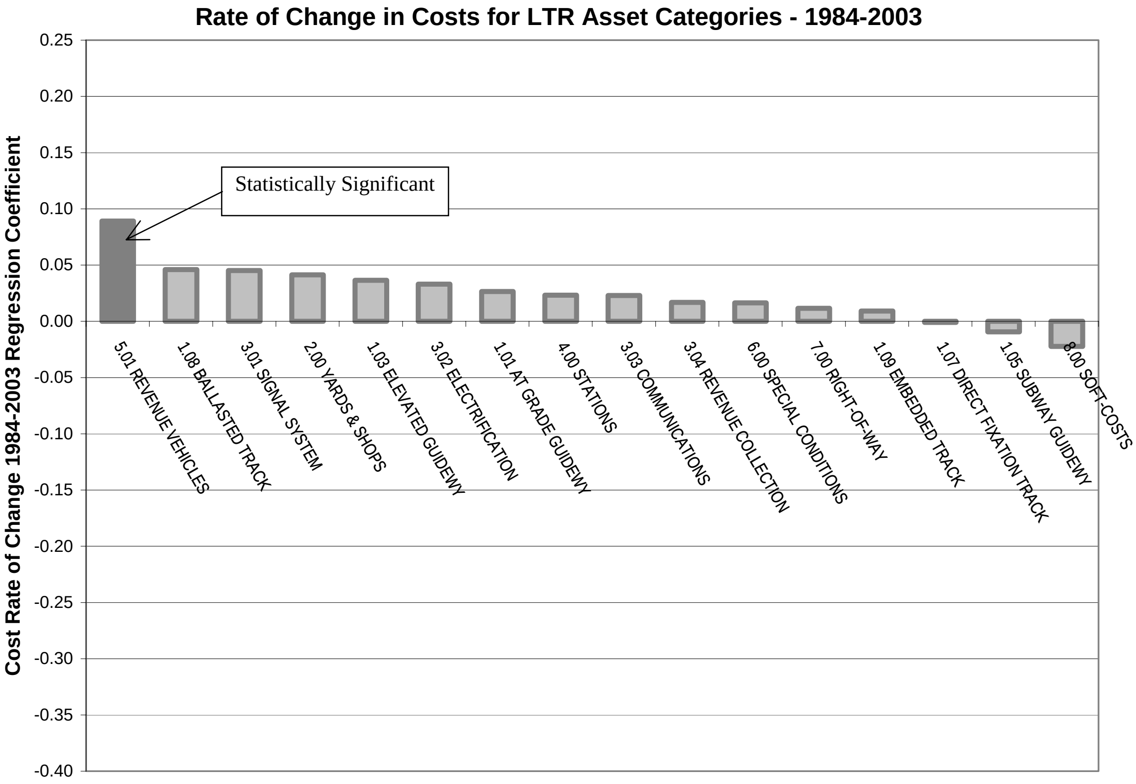


Figure B-11: Relative changes in cost by asset category, for all 19 projects.

The coefficient values associated with the independent variable *year* and corresponding p-values as well as the average percentage of total costs for the post 1995 projects are listed by asset category in Figure B-12 and in descending order of cost rate change in Figure B-13. There were some projects which had no costs in specific asset categories which reduced the number of observations which could be analyzed for several of the cost elements. For some elements, the number of observations was too low to analyze at all. For each category, the number of observations is indicated.

Figure B-13 shows that only five elements showed an increase in cost in the post-1995 projects – ballasted track, signal systems, yards and shops, electrification, and communications, and that none of these increases were statistically significant. The only asset that showed a significant cost trend at a 95% confidence level was Direct Fixation Track, which decreased in cost. This category accounted for less than 1% of the total project costs.

ANALYSIS OF POST 1995 PROJECTS	**Year**		**%**	**# of**
Cost Element	**Coefficient**	**P-value**	**of Cost**	**cases**
1.01 AT GRADE GUIDEWAY	-0.0526	0.765	*9.8*	*12*
1.03 ELEVATED GUIDEWAY	-0.2118	0.201	*2.4*	*10*
1.05 UNDERGROUND GUIDEWY	-0.0809	0.757	*4.6*	*4*
1.07 DIRECT FIXATION TRACK	**-0.3568**	**0.018**	**0.6**	**11**
1.08 BALLASTED TRACK	0.2010	0.179	*3.0*	*14*
1.09 EMBEDDED TRACK	-0.0819	0.633	*0.7*	*9*
2.00 YARDS & SHOPS	0.0860	0.633	*2.7*	*10*
3.01 SIGNAL SYSTEM	0.1835	0.163	*4.4*	*14*
3.02 ELECTRIFICATION	0.0592	0.688	*5.0*	*13*
3.03 COMMUNICATIONS	0.0019	0.990	*1.3*	*12*
3.04 REVENUE COLLECTION	-0.1437	0.367	*0.5*	*13*
4.00 STATIONS	-0.0377	0.812	*8.7*	*14*
5.01 REVENUE VEHICLES	-0.1050	0.337	*13.7*	*14*
6.00 SPECIAL CONDITIONS	-0.0480	0.755	*5.8*	*14*
7.00 RIGHT-OF-WAY	-0.1121	0.455	*7.3*	*14*
8.00 SOFT-COSTS	-0.0887	0.535	*22.9*	*14*

Note: The categories with significant rates of change are shown in bold and those with insignificant rates of change are shown in italics.

Figure B-12: Regression results for 14 most recent projects listed by asset category

ANALYSIS OF POST 1995 PROJECTS	**Year**		**%**	**# of**
Cost Element	**Coefficient**	**P-value**	**of Cost**	**cases**
1.08 BALLASTED TRACK	0.2010	0.179	*3.0*	*14*
3.01 SIGNAL SYSTEM	0.1835	0.163	*4.4*	*14*
2.00 YARDS & SHOPS	0.0860	0.633	*2.7*	*10*
3.02 ELECTRIFICATION	0.0592	0.688	*5.0*	*13*
3.03 COMMUNICATIONS	0.0019	0.990	*1.3*	*12*
4.00 STATIONS	-0.0377	0.812	*8.7*	*14*
6.00 SPECIAL CONDITIONS	-0.0480	0.755	*5.8*	*14*
1.01 AT GRADE GUIDEWAY	-0.0526	0.765	*9.8*	*12*
1.05 UNDERGROUND GUIDEWY	-0.0809	0.757	*4.6*	*4*
1.09 EMBEDDED TRACK	-0.0819	0.633	*0.7*	*9*
8.00 SOFT-COSTS	-0.0887	0.535	*22.9*	*14*
5.01 REVENUE VEHICLES	-0.1050	0.337	*13.7*	*14*
7.00 RIGHT-OF-WAY	-0.1121	0.455	*7.3*	*14*
3.04 REVENUE COLLECTION	-0.1437	0.367	*0.5*	*13*
1.03 ELEVATED GUIDEWAY	-0.2118	0.201	*2.4*	*10*
1.07 DIRECT FIXATION TRACK	**-0.3568**	**0.018**	**0.6**	**11**

Figure B-13: Regression results for 14 most recent projects listed by cost rate of change

This regression analysis was repeated for all 19 projects described in the Booz Allen report, including the five pre-1995 projects (listed by asset category in Figure B-14 and in descending order of cost rate change in Figure B-15). The results in Figure B-15 show that all asset categories experienced an increase in cost over the past 20 years except for direct fixation track, underground guideway, and soft costs. However, again, none of these cost increases were statistically significant at a 95% confidence level. Of the 22 elements analyzed, the only one which experienced a significant change was Revenue Vehicles, which significantly increased.

ANALYSIS OF ALL 19 PROJECTS	**Year**		**%**	**# of**
Cost Element	**Coefficient**	**P-value**	**of Cost**	**cases**
1.01 AT GRADE GUIDEWY	0.0266	0.451	*10.0*	19
1.03 ELEVATED GUIDEWY	0.0364	0.333	*2.3*	19
1.05 SUBWAY GUIDEWY	-0.0094	0.881	*4.9*	19
1.07 DIRECT FIXATION TRACK	-0.0010	0.981	*0.5*	19
1.08 BALLASTED TRACK	0.0462	0.162	*3.0*	19
1.09 EMBEDDED TRACK	0.0091	0.821	*0.9*	18
2.00 YARDS & SHOPS	0.0414	0.255	*3.2*	14
3.01 SIGNAL SYSTEM	0.0451	0.172	*4.2*	19
3.02 ELECTRIFICATION	0.0332	0.330	*5.0*	4
3.03 COMMUNICATIONS	0.0230	0.548	*1.2*	18
3.04 REVENUE COLLECTION	0.0169	0.626	*0.6*	13
4.00 STATIONS	0.0232	0.491	*7.8*	15
5.01 REVENUE VEHICLES	**0.0891**	**0.003**	**13.4**	**19**
6.00 SPECIAL CONDITIONS	0.0164	0.628	*5.9*	16
7.00 RIGHT-OF-WAY	0.0117	0.730	*7.5*	11
8.00 SOFT-COSTS	-0.0223	0.509	*23.6*	15

Figure B-14: Regression results for all 19 projects listed by asset category

ANALYSIS OF ALL 19 PROJECTS	**Year**		**%**	**# of**
Cost Element	**Coefficient**	**P-value**	**of Cost**	**cases**
5.01 REVENUE VEHICLES	**0.0891**	**0.003**	**13.4**	**19**
1.08 BALLASTED TRACK	0.0462	0.162	*3.0*	19
3.01 SIGNAL SYSTEM	0.0451	0.172	*4.2*	19
2.00 YARDS & SHOPS	0.0414	0.255	*3.2*	14
1.03 ELEVATED GUIDEWY	0.0364	0.333	*2.3*	19
3.02 ELECTRIFICATION	0.0332	0.330	*5.0*	4
1.01 AT GRADE GUIDEWY	0.0266	0.451	*10.0*	19
4.00 STATIONS	0.0232	0.491	*7.8*	15
3.03 COMMUNICATIONS	0.0230	0.548	*1.2*	18
3.04 REVENUE COLLECTION	0.0169	0.626	*0.6*	13
6.00 SPECIAL CONDITIONS	0.0164	0.628	*5.9*	16
7.00 RIGHT-OF-WAY	0.0117	0.730	*7.5*	11
1.09 EMBEDDED TRACK	0.0091	0.821	*0.9*	18
1.07 DIRECT FIXATION TRACK	-0.0010	0.981	*0.5*	19
1.05 SUBWAY GUIDEWY	-0.0094	0.881	*4.9*	19
8.00 SOFT-COSTS	-0.0223	0.509	*23.6*	15

Figure B-15: Regression results for all 19 projects listed by cost rate of change.

B.5. Analysis of the Scale and Complexity of Light Rail Investments

The analysis above shows that, with the exception of light rail vehicle costs over the 1984 – 2003 projects, the unit costs for specific light rail asset categories were not significantly increasing. The analysis in this section looks at the nature of light rail new starts and vehicles to identify whether the character of projects has been changing in ways that increase total project costs. Data on the scale and complexity of light rail projects comes from two sources, the Booz Allen report, "Light Rail Transit Capital Cost Study Update" (2003) and FTA's "Annual Report on New Starts: Proposed Allocations of Funds for Fiscal Year 2006" (2005). Data on the scale and complexity of light rail vehicles comes from the Booz Allen report, "North American Light Rail Vehicles 2004".

This analysis indicates that, overall, the size of projects has significantly decreased in terms of total route miles, number of stations, and number of vehicles, but that this trend has leveled off since 1995. In the period before 1995, a declining number of projects were "starter systems;" since then, a new trend has emerged in which projects are relying on an increasing percentage of new right-of-way. The analysis of vehicle scale and complexity indicated that, overall, vehicle weight has significantly increased, while vehicle order size has significantly decreased. However, when narrowing the focus to post 1995 projects, it was found that the cost of vehicles, order size, and vehicle weight have not significantly changed. There appears to be a significant trend towards more complex vehicles as the newer the vehicle the more likely it was to have a number of characteristics such as LED or LCD signs, handicapped accessibility, and prerecorded announcements.

B.5.1 Scale and complexity of light rail construction projects

A project's size and complexity can be measured in a number of ways. The following variables for size were chosen because they were contained in both the Booz Allen and New Starts reports: total route miles, number of stations, and number of vehicles. A variable indicative of a project's complexity is the percentage of guideway alignment that is at-grade as opposed to elevated or underground. Other variables concerning a project's complexity are whether it is a starter system or an expansion of an existing system and the extent to which its right of way is newly constructed. The Booz Allen report has data on 19 projects and the New Starts report has data on 6 projects. The name and year of the 25 projects that were analyzed are shown in Figure B-16.

Project Name	Year
Sacramento Stage I	1984
Portland MAX Segment I	1984
Pittsburgh Light Rail Stage I	1985
San Jose North Corridor 1	1986
Los Angeles – Long Beach Blue Line	1987
Portland Westside/Hillsboro MAX	1996
Salt Lake North South Corridor	1998
Hudson-Bergen MOS-I	1999
St. Louis St. Clair Cnty Extension	1999
Denver Southwest Corridor	1999
Hudson-Bergen MOS-II	2000
Hiawatha Corridor	2002
Portland Interstate MAX	2002
Southern New Jersey Light Rail Transit System	2002
Sacramento South Corridor	2002
Sacramento Folsom Corridor	2002
Pasadena Gold Line	2002
San Diego Mission Valley East	2003
Pittsburgh Light Rail Stage II	2003
Denver Southeast Corridor LRT *	2004
Baltimore Central LRT Double-Track *	2004
Charlotte NC South Corridor LRT *	2005
LA Metro Gold Line East Side Extension *	2006
Seattle Central Link Initial Segment *	2006
Phoenix Central Phoenix/East Valley Light Rail *	2006

*Note: An * indicates the data are from the FTA new starts report.*

Figure B-16. Light Rail Projects

To help identify the most recent trends, the analysis also focused on the 20 projects that were undertaken after 1995. The following pages show trends for the total route miles for each project (Figure B-17), the number of stations (Figure B-18), and the number of vehicles (Figure B-19).

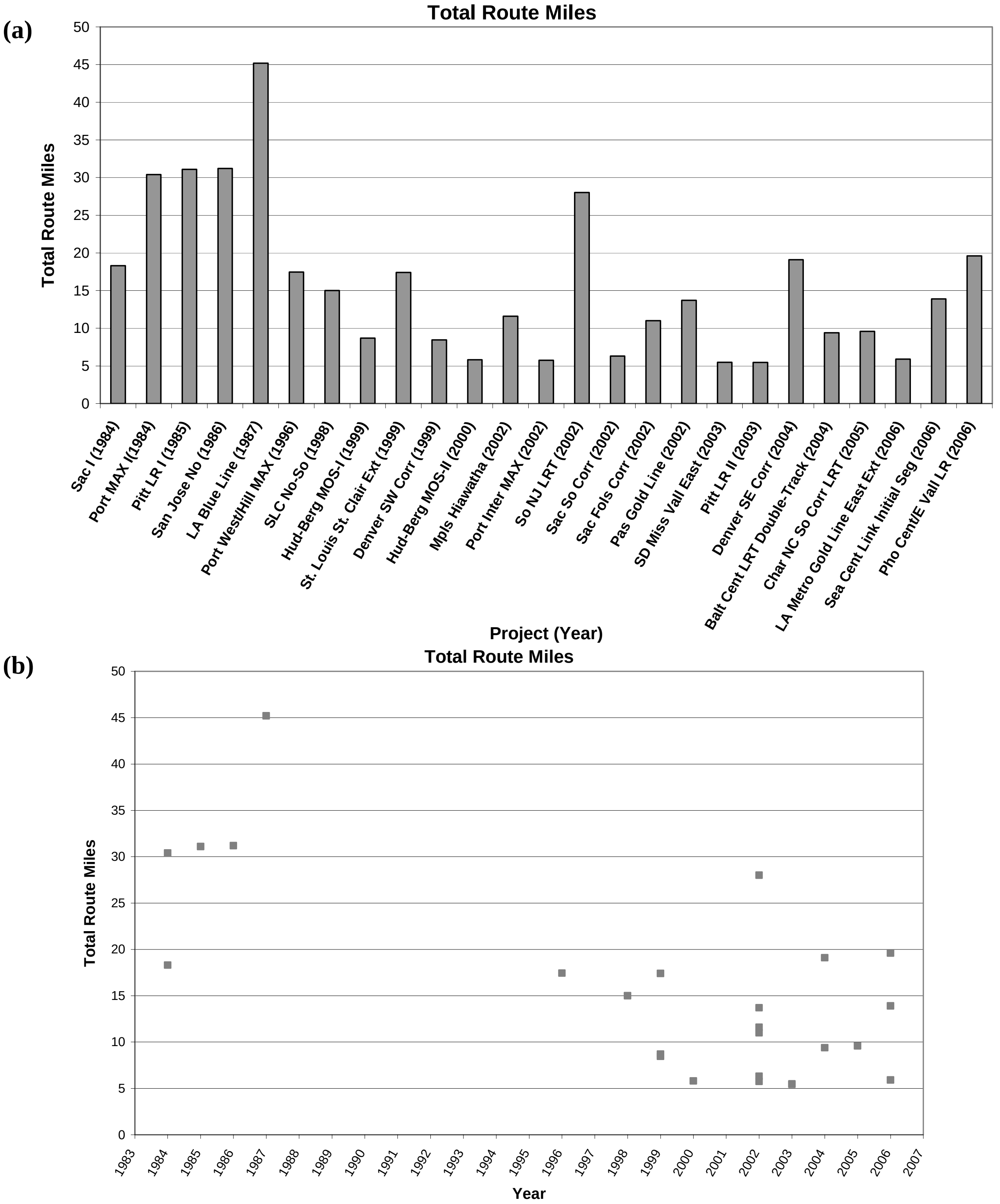


Figure B-17. Total route miles for all 25 projects: **(a)** bar graph and **(b)** scatter plot.

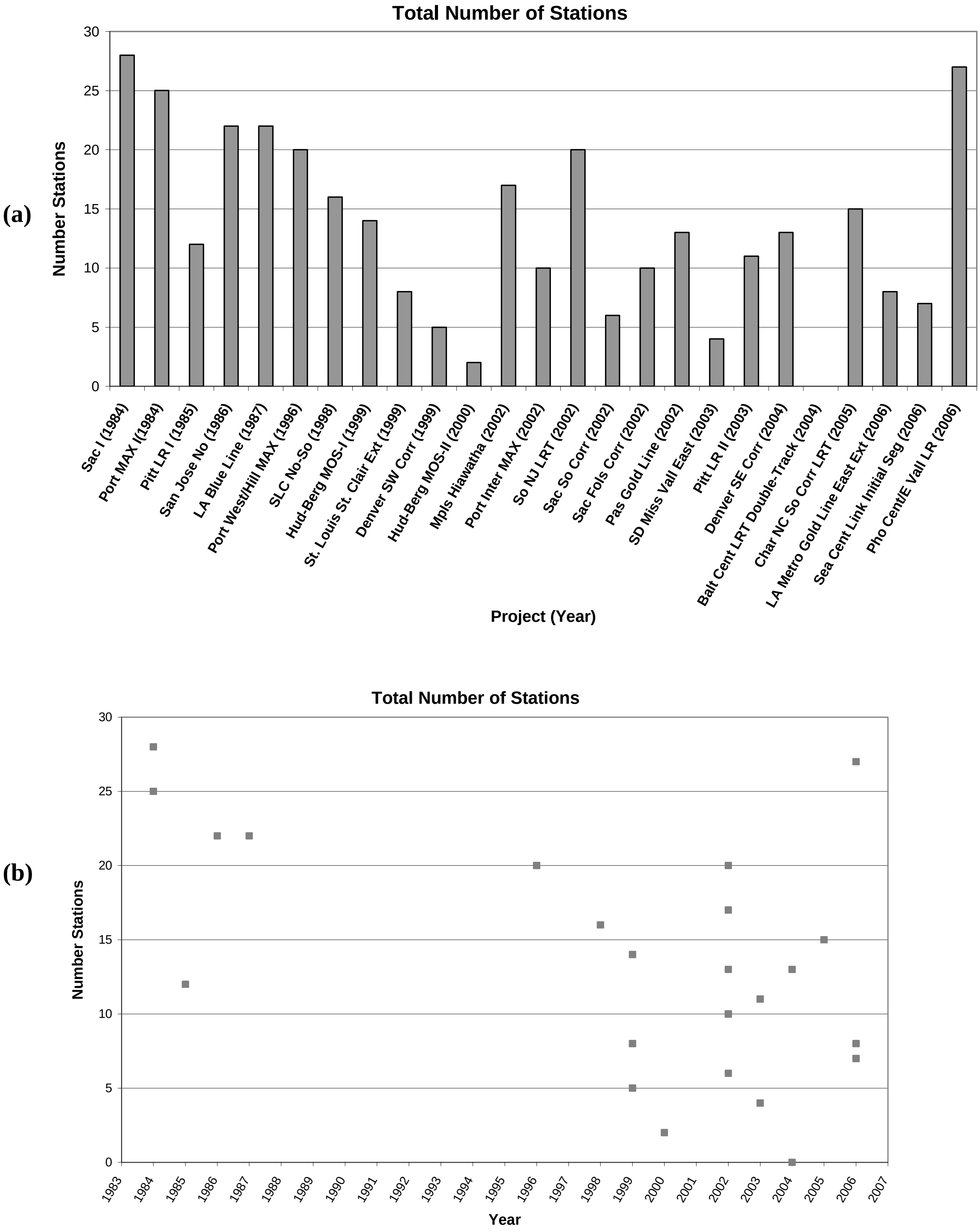


Figure B-18. Number of stations for all projects: **(a)** bar graph and **(b)** scatter plot.

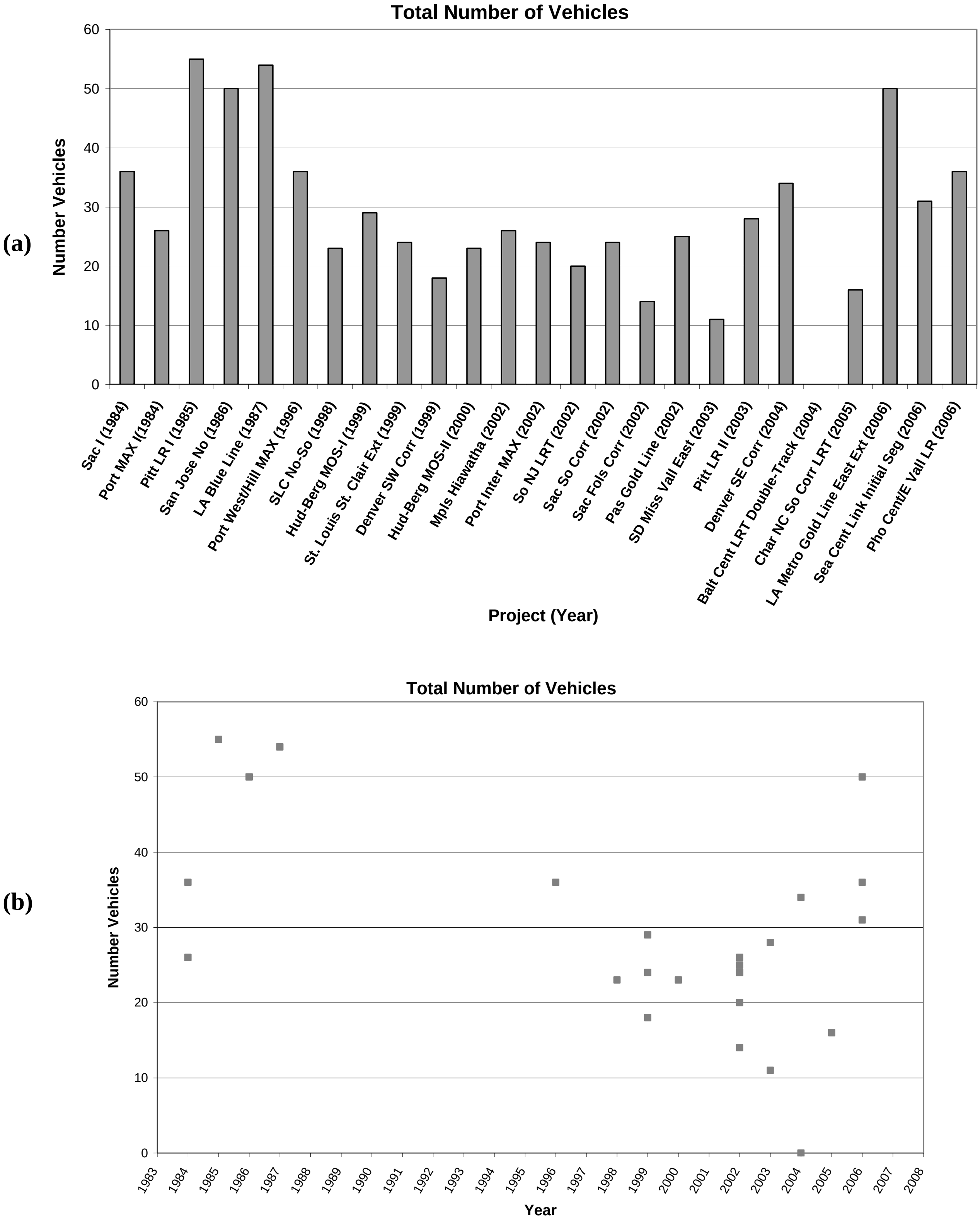


Figure B-19. Number of vehicles for all projects: **(a)** bar graph and **(b)** scatter plot.

The figures for all of the projects indicate that, over time, projects have tended to decrease in size. Thus, they lend support to the trend noted in the Booz Allen capital cost report that more recent projects have tended to become smaller and, because of economies of scale, have thus had higher unit costs. The figures for the projects undertaken since 1995 do not show any real observable trends. A regression analysis was performed which looked at the relationship between the size variables and project year. For each project size variable, the regression equation has the form:

$$Project\_Size\_Variable \;=\; \alpha_0 + \alpha_i \, Project\_Year$$

The results of this analysis for all projects and for the post 1995 projects are shown in Figure B-20. This table shows that the coefficient for project year in the regression equations for total route miles, number of stations, and number of vehicles are negative which indicates that all of these variables have decreased over time. This table also indicates that, in each case, the *t* statistic is less than -1.96 (and the P value is less than 0.05) which means that, in each case, the decrease is statistically significant.

The same analysis was repeated with only the post 1995 projects and Figure B-20 shows that the coefficients for total route miles and number of stations are negative, thus both of these variables decreased over time. The coefficient for the number of vehicles is positive, thus this variable increased over time. However, the absolute value of the *t* statistic is less than 1.96 (and the P value is greater than 0.05) which means that none of these changes are significant.

All Projects	**Adj. R^2**	**Year**	**T stat**	**P value**
Route Miles(*)	0.4779	-0.999	-4.792	0.0001
Stations(*)	0.2555	-0.567	-3.039	0.0058
Vehicles(*)	0.2328	-0.941	-2.878	0.0085
Post 1995 Projects				
Route Miles	-0.0490	-0.171	-0.3351	0.7414
Stations	-0.0537	-0.100	-0.1775	0.8611
Vehicles	-0.0451	0.373	0.4239	0.6766

*Note: an * indicates that the coefficient is statistically significant.*

Figure B-20. Regression analysis of total route miles, number of stations, and number of vehicles and project year for all projects and for post 1995 projects.

Turning from the issue of the size of projects to their complexity, Figure B-21 shows the percentage of guideway alignment that is at-grade, elevated, and underground. Figure B-22 shows the following data for a large subset of the projects:

- the percentage of guideway that is at-grade, elevated, and underground
- whether the project is a starter system
- the percentage of route miles which were newly constructed as opposed to using existing rail lines
- a guideway index which is calculated as:

  guideway index = 0 x at-grade guideway + 0.5 x elevated guideway + 1.0 x underground guideway

  with *at-grade quideway*, *elevated guideway*, and *underground guideway* expressed as proportions

The idea behind the guideway index is that construction of at-grade guideway is generally the least complex and costly, followed by elevated guideway, and underground guideway is the most complex and costly.

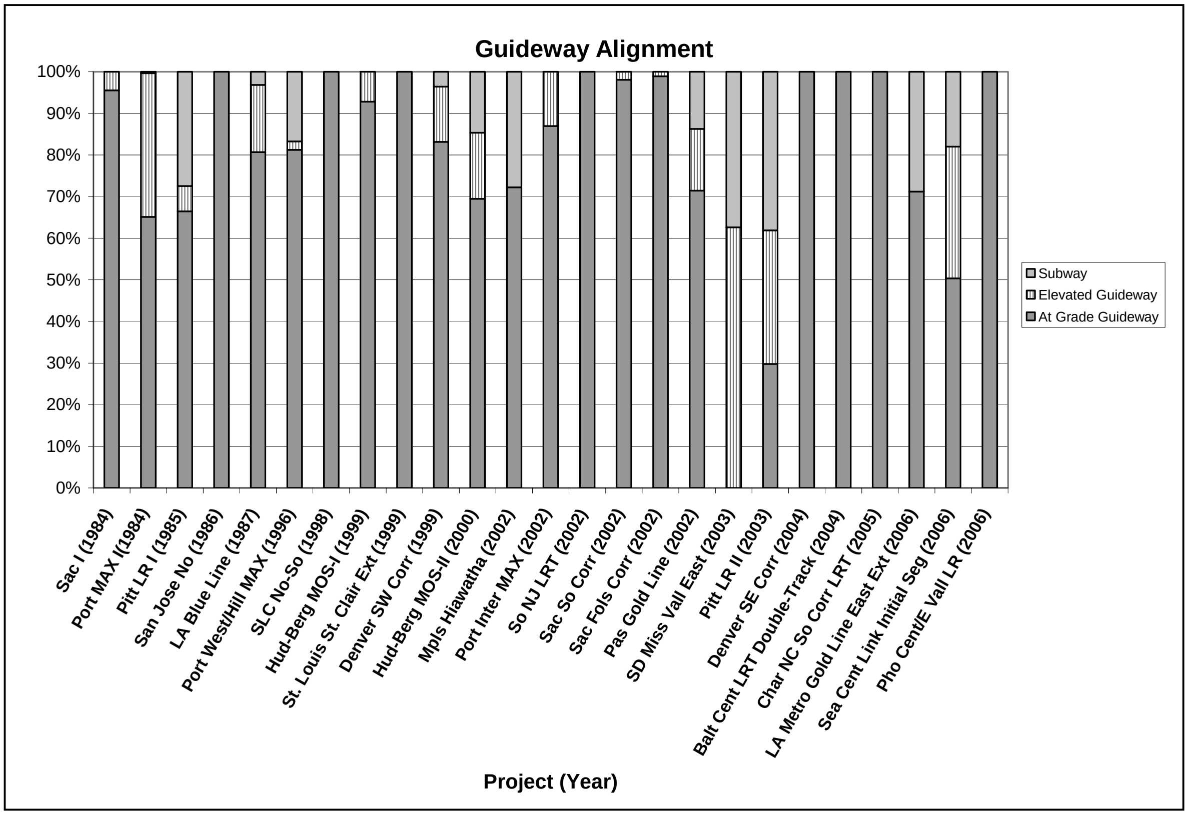


Figure B-21. Percentage of alignment that is at grade, elevated, and underground.

	Year	Percent Guideway			% New ROW	Starter System	Guideway Index	Index * % New
		At Grade	Elevated	Subway				
Sacramento Stage I	1984	95.52	4.48	0.00	37.70	Yes	0.0224	0.00845
Pittsburgh Light Rail Stage I	1985	66.46	6.10	27.44	40.19	Yes	0.3049	0.12256
San Jose North Corridor	1986	100.00	0.00	0.00	0.00	Yes	0.0000	0.00000
Los Angeles – Long Beach Blue Line	1987	80.69	16.13	3.17	22.22	Yes	0.1124	0.02498
Portland Westside/Hillsboro MAX	1996	81.20	2.03	16.77	0.00	No	0.1778	0.00000
Salt Lake North South Corridor	1998	100.00	0.00	0.00	12.67	Yes	0.0000	0.00000
Hudson-Bergen MOS-I	1999	92.81	7.19	0.00	28.74	Yes	0.0359	0.01033
St. Louis St. Clair Cnty Extension	1999	100.00	0.00	0.00	0.00	No	0.0000	0.00000
Denver Southwest Corridor	1999	83.13	13.32	3.55	0.00	No	0.1021	0.00000
Hudson-Bergen MOS-II	2000	69.48	15.85	14.67	0.00	No	0.2259	0.00000
Hiawatha Corridor	2002	72.24	0.00	27.76	100.00	Yes	0.2776	0.27756
Southern New Jersey Light Rail Transit System	2002	100.00	0.00	0.00	0.00	Yes	0.0000	0.00000
Sacramento South Corridor	2002	98.05	1.95	0.00	4.76	No	0.0098	0.00047
Sacramento Folsom Corridor	2002	98.90	1.10	0.00	0.00	No	0.0055	0.00000
San Diego Mission Valley East	2003	0.00	62.65	37.35	100.00	No	0.6868	0.68675
Pittsburgh Light Rail Stage II	2003	29.78	32.11	38.11	0.00	No	0.5416	0.00000
Denver Southeast Corridor LRT	2004	100.00	0.00	0.00	100.00	No	0.0000	0.00000
Baltimore Central LRT Double-Track	2004	100.00	0.00	0.00	0.00	No	0.0000	0.00000
Charlotte NC South Corridor LRT	2005	100.00	0.00	0.00	61.46	Yes	0.0000	0.00000
Seattle Central Link Initial Segment	2006	50.36	31.65	17.99	90.65	Yes	0.3381	0.30651

Figure B-22. Project complexity data

Figure B-23 shows the results of a regression analysis looking at the relationship between the complexity variables and project year and adjusted project cost. For all of the projects, the only significant relationship was between starter system and project year. The coefficient for the starter system variable was negative, which means that, over the years, projects were less likely to be starter systems. No significant relationship was found between the percentage of guideway at-grade and project year and, as shown in Figure B-21, four of the six most recent projects are completely at grade. Thus, the trend noted in the Booz Allen report that more recent projects tended to have more elevated and underground alignments appears not to apply for the projects that have been undertaken since that report was written. For the projects since 1995, the percentage of newly constructed right of way has increased significantly.

The results of the regression analysis of complexity variables and adjusted project cost in Figure B-23 show that, for all of the projects and for the post 1995 projects, the percentage of at-grade guideway has a negative relationship to total project costs, while starter system and percentage of newly constructed right of way are both positively related to total project costs. However, none of these relationships are significant.

ALL PROJECTS		Coefficient		
PROJECT YEAR	Adj. R^2	Year	T stat	P value
At-Grade Guideway %	-0.038403	-0.237	-0.3353	0.7405
Starter System (*)	0.1281	-0.028	-2.1274	0.0443
Newly Constructed ROW	0.0038	1.310	1.0355	0.3142
Guideway Index	-0.0330	0.004	0.6268	0.5386
ADJUSTED TOTAL COSTS		Cost		
At-Grade Guideway %	-0.0139	-0.008	-0.8188	0.4213
Starter System	0.0119	233.360	1.1352	0.2680
Newly Constructed ROW	0.0599	0.024	1.4870	0.1543
POST 1995 PROJECTS				
PROJECT YEAR		Year		
At-Grade Guideway %	-0.0138	-2.498	-0.8921	0.3874
Starter System	-0.0489	0.026	0.5487	0.5919
Newly Constructed ROW(*)	0.2214	1.109	2.2948	0.0377
Guideway Index	-0.0249	0.016	0.7970	0.4388
ADJUSTED TOTAL COSTS		Cost		
At-Grade Guideway %	-0.0199	-0.011	-0.8410	0.4145
Starter System	0.0865	0.000	1.5555	0.1421
Newly Constructed ROW	0.1271	0.004	1.7842	0.0961

*Note: an * indicates that the variable's coefficient is statistically significant.*

Figure B-23. Regression analysis of complexity variables, project year and adjusted total cost

B.5.2 Scale and Complexity of Light Rail Vehicles

The Booz Allen report on light rail vehicles gives vehicle characteristics for 40 different acquisitions by various transit agencies in the United States, Mexico, and Canada. Eight of these acquisitions involved multi-year deliveries thus providing a total sample size of 48. The name and year of the projects are shown in Figure B-24.

Vehicle characteristics were given for 14 different categories many of which have a number of subcategories. The characteristics which are most indicative of vehicle size are the vehicle's total cost, length, and empty weight as well as the number of vehicles ordered in each acquisition. The characteristics which are indicative of vehicle complexity are as follows: LED/LCD signs, elderly/handicapped accessibility, prerecorded announcements, outside PA system, articulation, more than 3 doors per car, IGBT state of the art propulsion control, passenger activated doors, more than 3 signs per car, train to wayside communication, cab signals, event recorder, trip stops, brake assurance, and automated train control.

Project	Year	Project	Year
Cleveland	1982	Los Angeles (Siemens)	1999
Edmonton	1982	Newark Subway	1999
Philadelphia (City Transit)	1982	Newark/Hudson Bergen	1999
Philadelphia (Red Arrow)	1982	Salt Lake City	1999
Toronto (CLRV)	1982	St. Louis (II)	1999
Buffalo	1985	Dallas	2000
Boston (Kinki-Sharyo)	1986	Portland (Trimet II)	2000
Portland (Trimet I)	1986	Calgary	2001
Pittsburgh (Siemens)	1987	Portland (Streetcar)	2001
Toronto (ALRV)	1987	Santa Clara (Kinki-Sharyo)	2001
Santa Clara (UTDC)	1989	St. Louis (III)	2001
Los Angeles (Nippon Sharyo) Blue Line	1990	Tacoma	2001
San Diego (U2)	1990	Calgary	2002
Sacramento (Siemens)	1991	Denver	2002
Baltimore (ABB)	1993	Sacramento (CAF)	2003
Monterrey	1993	San Francisco	2003
St. Louis (I)	1993	Houston	2004
Guadalajara	1994	Minneapolis	2004
Dallas	1995	Pittsburgh (CAF)	2004
Los Angeles (Nippon Sharyo) Green Line	1995	Boston (AnsaldoBreda)	2005
Denver	1996	Los Angeles (AnsaldoBreda)	2005
San Diego (SD100)	1996	San Diego (SD70)	2005
Boston (Kinki-Sharyo)	1997	Charlotte	2006
Baltimore (Bombardier)	1998		

Figure B-24. Light Rail Vehicle Procurements

The cost per vehicle figures given in the vehicle report appeared to be very approximate, thus the vehicle cost data from the light rail capital cost study were analyzed instead. The following pages show total cost per vehicle obtained from the second report adjusted to 2003 dollars (Figure B-25), vehicle length (Figure B-26), empty vehicle weight (Figure B-27), number of vehicles ordered (Figure B-28). Data for Figures B-26 to B-28 were drawn from the light rail vehicle report.

These graphs show that the cost per vehicle is increasing, as is the vehicle size in terms of length and weight, but that the order size is decreasing. This last trend is in agreement with the Booz Allen capital cost report which noted that more recent projects are smaller in size.

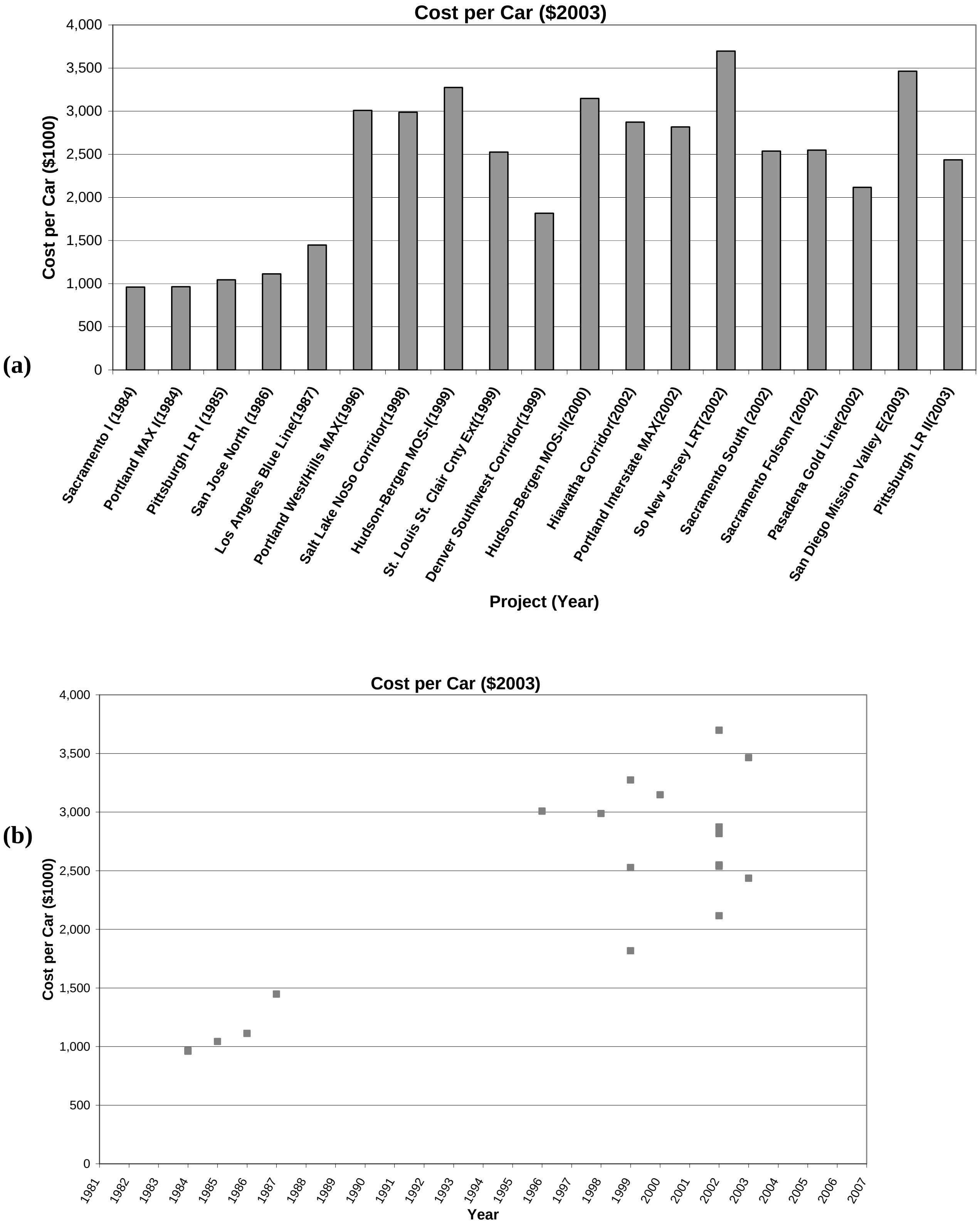
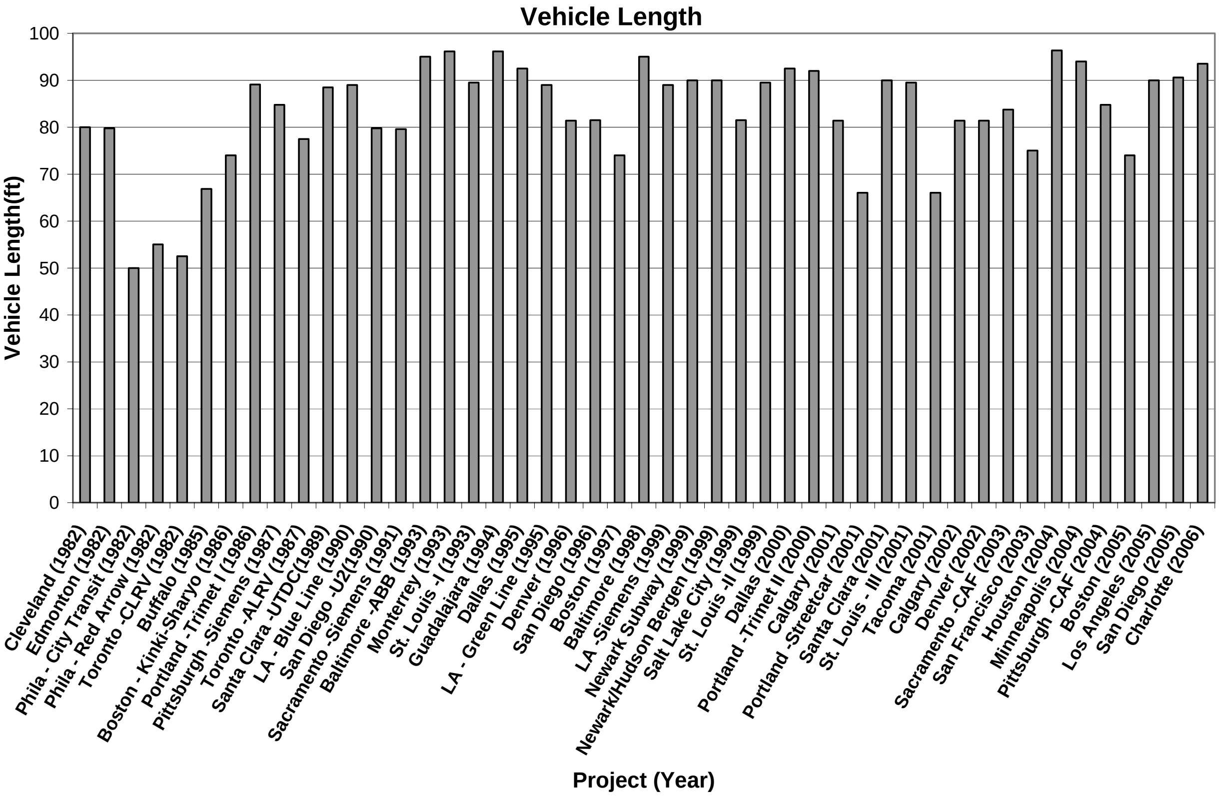


Figure B-25. Cost per vehicle in 2003 dollars: **(a)** bar graph and **(b)** scatter plot.

(a)



(b)

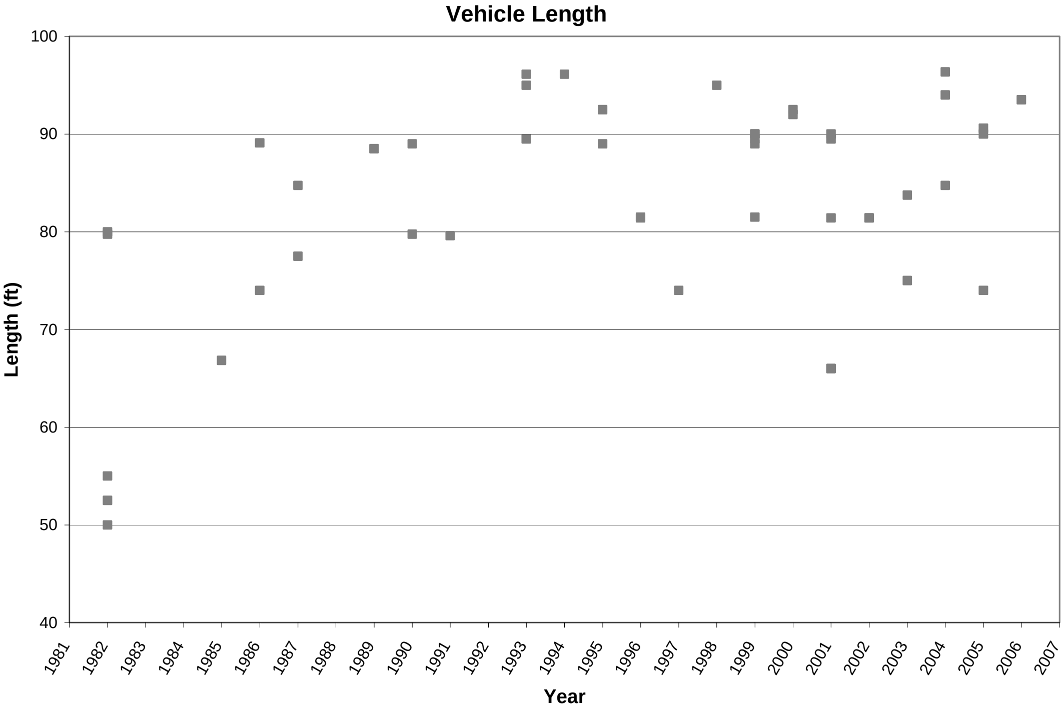


Figure B-26. Vehicle length for all projects: **(a)** bar graph and **(b)** scatter plot.

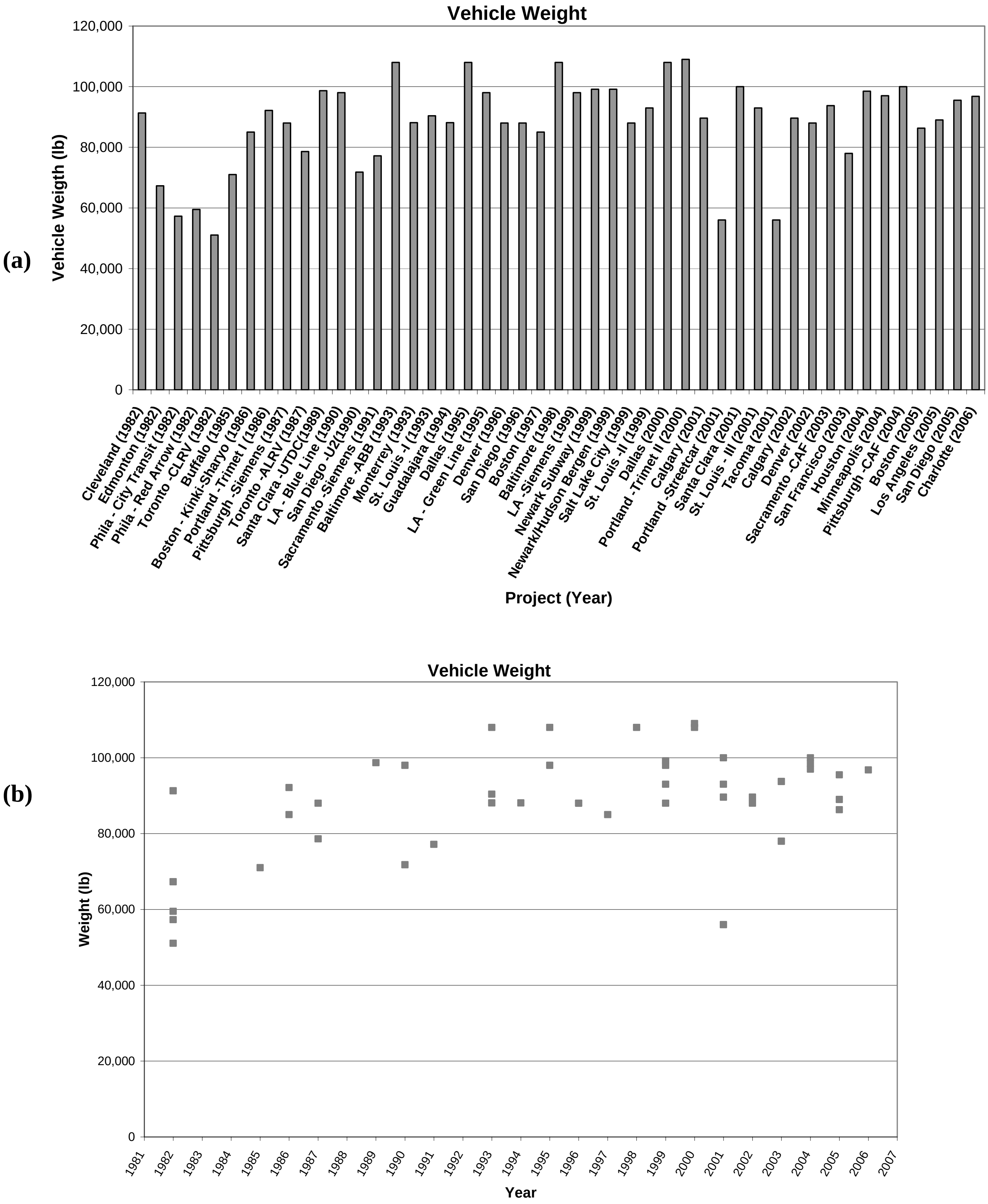


Figure B-27. Vehicle empty weight for all projects: **(a)** bar graph and **(b)** scatter plot.

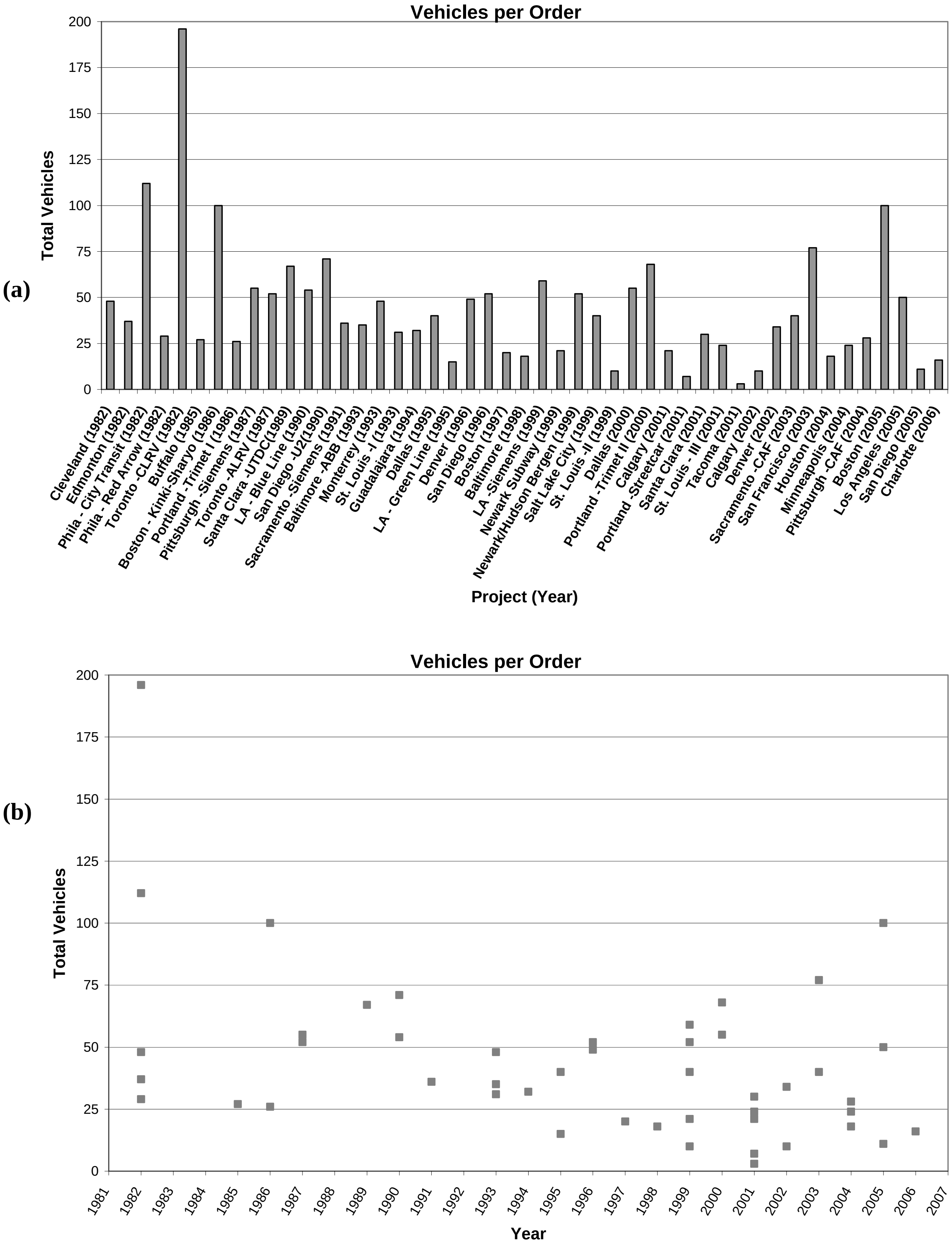


Figure B-28. Number of vehicles ordered for all projects: **(a)** bar graph and **(b)** scatter plot.

A regression analysis was performed looking at the relationship between the size variables and project year. The results of this analysis for all projects and for the post 1995 projects only are shown in Figure B-29. This table indicates that, for all projects, vehicle size in terms of length and weight has experienced a significant increase, and that vehicle order size has significantly decreased. However, an examination of the vehicle length graph in Figure B-26 shows three data points for the year 1982 which appear to be outliers. A regression analysis without these points indicates that the change in vehicle length is no longer significant.

The results for the post-1995 projects indicate that no item has experienced a significant change. It should be noted that, as discussed in the unit costs section above, revenue vehicle cost has significantly increased from 1984 to 2003. However, when looking at projects since 1995, revenue vehicle cost has not significantly changed.

ALL PROJECTS	**Adj R^2**	**Year**	**T stat**	**P value**
Vehicle Length(*)	0.1936	0.700	3.471	0.0012
Vehicle Length (minus outliers)	0.0130	0.232	1.252	0.2174
Empty Vehicle Weight(*)	0.1802	877.877	3.333	0.0017
Number of vehicles ordered(*)	0.1521	-1.858	-3.041	0.0039
POST 1995 PROJECTS				
Vehicle Length	-0.0368	0.039	0.078	0.9387
Empty Vehicle Weight	-0.0188	-529.736	-0.694	0.4934
Number of vehicles ordered	-0.0360	0.231	0.163	0.8717

*Note: an * indicates that the variable's coefficient is statistically significant.*

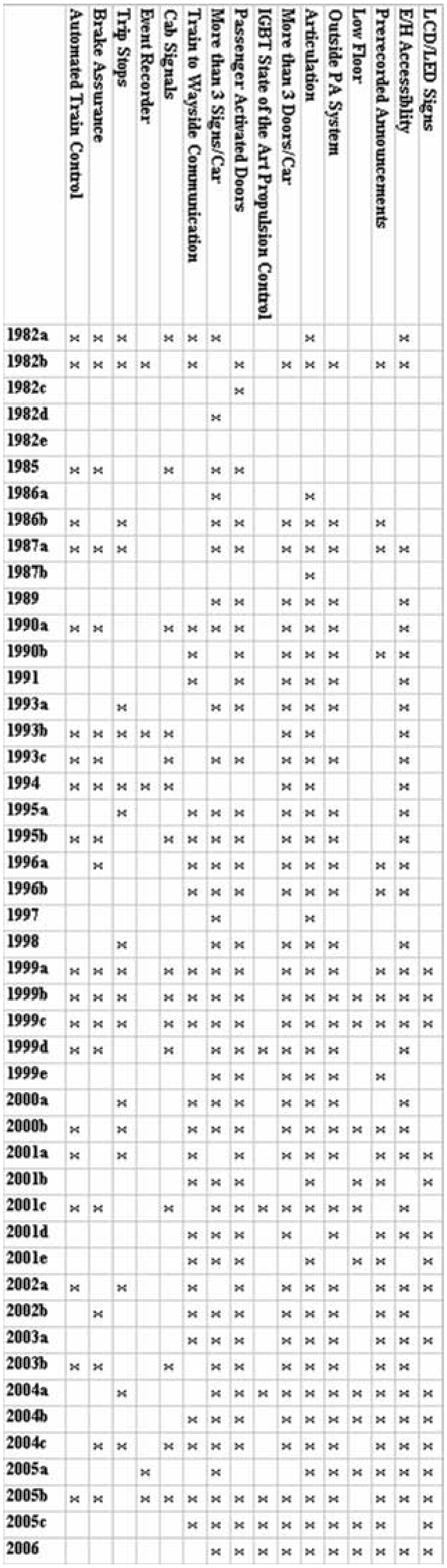
Figure B-29. Regression analysis on vehicle characteristic trends.

As mentioned above, sixteen of the many characteristics listed in the Booz Allen light rail vehicle report were selected as indicative of vehicle complexity. A regression analysis was performed looking at the relationship between these variables and project year. If the coefficient for a particular characteristic is positive, then newer vehicles are more likely to have that characteristic. The results of this analysis are shown in Figure B-30. The following variables were found to be statistically significant for all procurements : LED/LCD signs, elderly/handicapped accessibility, prerecorded announcements, outside PA system, articulation, more than 3 doors per car, IGBT state of the art propulsion control, passenger activated doors, more than 3 signs per car, and train to wayside communication. For the post 1995 procurements, only changes in the use of LED/LCD signs, IGBT state of the art propulsion control, and event recorders were found to be significant. The coefficients corresponding to these characteristics are all positive meaning that the newer the car the more likely it is to have these characteristics. Figure B-31 shows the vehicle characteristics for each of the 48 procurements.

ALL PROCUREMENTS	Adj R^2	Year	T statistic	P value
LED/LCD Signs (*)	0.4307	0.0428	5.983	0.00000
E/H Accessiblity(*)	0.2831	0.0264	4.377	0.00007
Precorded Announcements(*)	0.2828	0.0084	4.374	0.00007
Low Floor(*)	0.2331	0.0287	3.871	0.00035
Outside PA System(*)	0.2331	0.0296	3.871	0.00035
Articulation(*)	0.1685	0.0181	3.213	0.00243
More than 3 Doors per Car (*)	0.1596	0.0243	3.120	0.00315
IGBT State of the Art Propulsion Control (*)	0.1421	0.0062	2.936	0.00522
Passenger Activated Doors (*)	0.1301	0.0074	2.807	0.00736
More than 3 Signs per Car (*)	0.1165	0.0205	2.658	0.01083
Train to Wayside Communication (*)	0.0726	0.0206	2.145	0.03742
Cab Signals	-0.0204	0.0026	0.281	0.78017
Event Recorder	-0.0221	0.0004	0.058	0.95438
Trip Stops	-0.0219	-0.0012	-0.124	0.90193
Brake Assurance	-0.0195	-0.0034	-0.345	0.73163
Automated Train Control	-0.0117	-0.0068	-0.683	0.49780
POST 1995 PROCUREMENTS				
LED/LCD Signs (*)	0.3077	0.1027	3.543	0.00158
IGBT State of the Art Propulsion Control (*)	0.1517	0.0645	2.377	0.02543
Event Recorder(*)	0.1244	0.0376	2.166	0.04001
Precorded Announcements	0.0976	0.0511	1.953	0.06214
Low Floor	0.0860	0.0618	1.857	0.07516
E/H Accessiblity	0.0483	0.0199	1.523	0.14026
Outside PA System	-0.0046	0.0210	0.939	0.35668
More than 3 Doors per Car	-0.0397	0.0022	0.084	0.93392
Passenger Activated Doors	-0.0399	0.0011	0.057	0.95516
Articulation	-0.0399	0.0005	0.039	0.96890
Cab Signals	-0.0400	0.0005	0.016	0.98713
More than 3 Signs per Car	-0.0384	-0.0038	-0.199	0.84392
Train to Wayside Communication	-0.0366	-0.0097	-0.284	0.77842
Brake Assurance	-0.0265	-0.0199	-0.574	0.57138
Automated Train Control	-0.0262	-0.0204	-0.579	0.56776
Trip Stops	-0.0191	-0.0247	-0.716	0.48083

*Note: an * indicates that the variable's coefficient is statistically significant.*

Figure B-30. Regression analysis of vehicle characteristics and project year for all procurements and for the post 1995 procurements.



	Automated Train Control	Brake Assurance	Trip Stops	Event Recorder	Cab Signals	Train to Wayside Communication	More than 3 Signs/Car	Passenger Activated Doors	IGBT State of the Art Propulsion Control	More than 3 Doors/Car	Articulation	Outside PA System	Low Floor	Prerecorded Announcements	E/H Accessiblity	LCD/LED Signs
1982a	x	x	x		x	x	x				x				x	
1982b	x	x	x	x		x		x		x	x	x		x	x	
1982c								x								
1982d							x									
1982e																
1985	x	x			x		x	x								
1986a							x				x					
1986b	x		x				x	x		x	x	x		x		
1987a	x	x	x				x	x		x	x	x		x	x	
1987b											x					
1989							x	x		x	x	x			x	
1990a	x	x			x	x	x	x		x	x	x			x	
1990b						x		x		x	x	x		x	x	
1991						x		x		x	x	x			x	
1993a			x				x	x		x	x	x			x	
1993b	x	x	x	x	x					x	x				x	
1993c	x	x			x		x	x		x	x	x			x	
1994	x	x	x	x	x					x	x				x	
1995a			x			x	x	x		x	x	x			x	
1995b	x	x			x	x	x	x		x	x	x			x	
1996a		x				x	x	x		x	x	x		x	x	
1996b						x	x	x		x	x	x		x	x	
1997							x				x					
1998			x				x	x		x	x	x			x	
1999a	x	x	x		x	x	x	x		x	x	x		x	x	x
1999b	x	x	x		x	x	x	x		x	x	x	x	x	x	x
1999c	x	x	x		x	x	x	x		x	x	x	x	x	x	x
1999d	x	x			x		x	x	x	x	x	x			x	
1999e							x	x		x	x	x		x		
2000a			x			x	x	x		x	x	x			x	
2000b	x		x			x	x	x		x	x	x	x	x	x	
2001a	x		x			x		x		x	x	x		x	x	x
2001b						x	x	x			x		x	x		x
2001c	x	x			x		x	x	x	x	x	x	x		x	
2001d						x	x	x		x		x		x	x	x
2001e						x	x	x			x		x	x		x
2002a	x		x			x		x		x	x	x		x	x	x
2002b		x				x	x	x		x	x	x		x	x	
2003a						x	x	x		x	x	x		x	x	x
2003b	x	x			x		x	x		x	x	x		x	x	
2004a			x				x	x	x	x	x	x	x	x	x	x
2004b						x	x	x		x	x	x	x	x	x	x
2004c		x	x		x	x	x	x		x	x	x		x	x	x
2005a				x			x				x	x	x	x	x	x
2005b	x	x		x	x	x	x	x	x	x	x	x		x	x	x
2005c						x	x	x	x	x	x	x	x	x		x
2006							x	x	x	x	x	x	x	x	x	x

Figure B-31. Vehicle characteristics for 48 vehicle procurements.

APPENDIX C: Interview Report

Quantitative data analysis conducted as part of this study has revealed many aspects of costs and cost drivers, but such data do not necessarily tell a complete story. Qualitative information was also collected for this study through interviews with transit agency staff at various different locations throughout the country. An interview questionnaire was developed by UTRC staff (see Annex 1). Interviews, lasting around ninety minutes each, were conducted by conference call (except for one face-to-face meeting) with personnel from four agencies of differing sizes, age of operation, and geographic location. All four were medium-to-large agencies with experience operating multiple modes of rail transit. Respondents were encouraged to reflect on the experiences of their own agencies, as well as other agencies they are familiar with. Interviews were also conducted with an industry expert on light rail policy and a former engineering program manager at a major rail car manufacturer. The research team also consulted the professional staff of the American Public Transit Association (APTA), though this meeting was not conducted as a formal interview.

All interviews were not for attribution. A summary of the results of interviews are provided below, organized according to the format of the questionnaire. The results below are illustrative, rather than definitive (since a random, scientific sampling process was not employed), but provide many details of light-rail costs and cost drivers that were not captured by other data.

The characteristics of the transit agencies consulted were varied. The sample included a young agency embarking on its first major project and several very experienced agencies with decades of experience. Jurisdictions were scattered across the country, from the Northeast to the Pacific Coast. The range of responses to questions thus showed some variation, and some commonality as well. Summaries of the varied responses are provided below, each question in the interview being considered in turn.

Question 1. Have you found that total light rail project capital costs are rising, staying flat, falling?

Question 2(a) Indicate the top three categories that generally make up the bulk of your agency’s light rail total project costs; (b) What components, if any, of light rail capital projects seem to have the greatest problems with cost inflation? Which, if any, have the

least problems? Which, if any, have been falling in price. Are price-increasing categories also the categories that make up the greatest bulk of total project costs?

Answers to these questions were somewhat mixed. One agency reported that costs were increasing in all categories. This agency had to impose a cap on vehicle costs. Contracts in 2004 included a steel price adjustment clause of 5% against the base price, up or down, because of the volatility in steel prices during that year. It was noted that other agencies had also considered such clauses. Steel prices have since settled down but other input costs for this agency have risen, specifically labor, cement and fuel. Another agency reported that costs were quite stable and falling in some categories.

Another agency's response to this question implied that costs are rising and a major reason is the way light rail agencies do business. This interviewee said that a light rail project is typically not designed and operated by a commuter rail organization, but by a bus organization. As such, light rail tends to be a naïve client, very dependent on consultants who tend to have heavy and commuter rail, but not light rail, experience. As a result, light rail systems are built to standards more appropriate for heavy or commuter rail systems, which are more conservative than necessary for light rail.

For example, they may include very heavy catenary system, when the system could have been tied off to adjacent buildings. Another example is a safe brake system designed to commuter rail standards, which are too conservative for light rail. This reduces the throughput of trains limiting the system to no more than 6 trains an hour. This, in turn, requires the system to add more cars to their trains and to buy more cars, all of which drives up costs. Other examples include tunnel ventilation and fire safety standards such as NFPA-130. These standards were developed outside of transit and there is room for interpretation by engineers because it is not clear what applies and what does not.

The interviewee gave an example of an agency that became tired of doing business this way. St. Louis reportedly replaced its consultants because of frustration with cost and schedule creep. They switched consultants and are now doing more work in-house.

Another example of the bus company mentality resulting in inappropriate specifications for rail systems is the use of silent alarms. Silent alarms are a necessity on buses where the driver is completely exposed to the public, but not on trains where the conductor is not out in the open. These systems are very expensive to install and difficult to maintain and, since they are considered to be a safety system, the train cannot run when this system is not operational. At one agency, the only time a silent alarm has been used on a train has been by accident.

One agency identified the cost categories experiencing the greatest increases as soft costs, vehicles, special conditions, and ROW acquisition. Soft costs have been very high: in one project, $100 million was paid to consultants.

As far as vehicles, he mentioned an example where two cities ordered the same car – a car made by Stadler. One agency ordered 20 cars at $3.5 million per car, and the other ordered 6 cars at $5.2 million per car. One way of avoiding these high prices for small orders is to use joint procurements for small orders.

As far as ROW acquisition, light rail projects in urban areas tend to go through very expensive real estate. Purchasing rights-of-way outright, or securing agreements to use ROW from freight rail operators can be extremely expensive. One agency reported having to pay $65 million every year for 3 years after which the payments decreased, but continued. The interviewee noted it was if they sold us the house and we still have to pay them rent. Meanwhile, the freight operator continues to use the lines for their freight operations. They do pay car miles to his agency but this turns out to be a very small offsetting revenue.

As far as special conditions, one project faced a horror story of environmental work having to clean up chromium, mercury, and PCPs. Older urban areas are more likely to encounter these types of problems. There are also unique issues that arise when light rail is being used as a redevelopment tool in poor areas as is the case with his agency's other project.

Another agency reported that capital costs are increasing for all types of transit covered by his agency. Two areas in which costs are rising the fastest are traction power systems and anything containing concrete. Rising costs for materials, particularly copper, account for much the cost increase in traction power systems. Another material which is commonly used in light rail and which has been increasing in cost (7% in the past two months) is concrete. The U.S. is a net importer of cement and there is a high demand for it in the global market place, especially in China. Many places, such as Phoenix, are rationing cement which has slowed down projects.

Question 3. Which factors, in your experience, are contributing to rising capital cost trends? Falling cost trends? Flat cost trends?

As one interviewee pointed out, costs vary between agencies for a wide range of reasons, including differences in physical, topographical, institutional, economic and political conditions.

Project configuration definitely affects costs. On a unit basis, larger projects can be cheaper because of economies of scale in production. Each contract includes certain fixed costs such as engineering costs, start-up, change-order and closing costs; these costs can run as high as $20 to $40 million for a procurement of new (custom) rail cars. Larger agencies have a cost advantage, since they are able to amortize these fixed costs over a larger number of units.

On the other hand, one agency reported difficulty attracting multiple bids on contracts worth more than $200 million. The agency has attempted to increase competition by adjusting contract sizes downward, although this has had the disadvantage of increasing the number of contracts, a cost-increasing factor.

Local topography plays a large role in overall costs. Large variations in elevation, for example, may demand the use of underground sections which are far more expensive to build than elevated or at-grade sections. One agency building a single light-rail segment with an exclusive ROW is having to build that segment at about 1/3 at-grade, 1/3 underground, and 1/3 elevated over its length simply because of the topography. The underground portion has by far the highest cost per foot. The difference in sub-segments means that multiple contracts may be let, which will affect the overall cost. Beyond topography, existing infrastructure places large constraints on project design. This is generally a more important factor in older cities. For example, a new line crossing underneath an existing underground line is much more difficult to construct than a line built with cut-and-cover at the surface.

Agencies mentioned a number of other drivers related to project configuration:

- Startup costs. A new agency reported that startup costs contributed to higher costs for its first project, and that it expects costs to be lower on subsequent expansions.

- Integration with commuter rail. Intermodal tie-ins for one project pushed costs higher.
- Utility relocations. Placing a segment along a heavily-used arterial increased the costs of relocating utilities.

Another cost driver pertaining to project configuration is diversions required to maintain existing service while work is being done. One agency said it spends a lot of money for diversions on the street. This agency faces local regulations which require it to keep lanes open and to provide access to surrounding businesses. When the crews are not working, people can park on the construction site. It used to be acceptable to have the contractor provide flagging service, but now it has to be done by off-duty police officers. There has to be a specialty subcontractor for traffic routing which acts as a supervisor overseeing the crews who maintain the traffic signs. This used to be done by the general contractor. While this method undoubtedly results in a better product, it costs more and the agency's representative wondered if this better product is worth the added cost. He suggested that a better approach for the city would be to mandate performance standards instead of the means for achieving those standards.

Agency technical capacity also affects costs. One agency has had to rely on consultants to develop both specifications and technical criteria. The agency has recently been weaning itself off of reliance on consultants, building up an in-house staff over the last two to three years. Other respondents noted the benefits of having in-house technical capacity and the lowered contract costs, which seemed to result because of 'working smarter, not harder.' Of course, doing as much in-house as possible adds another cost (with one agency handling staff salaries partly as capital and partly as operating costs), but using consultants can both increase costs and create difficulties of various sorts (e.g., coordination and communication between agency, specifications contractor and product contractor, as well as creating a lack of 'institutional memory'). Another agency noted the importance of having proactive staff who can get answers to contractors quickly when they have issues, questions, or problems. This helps to avoid delays which can drive up costs.

A related issue is technical specifications. One agency uses both performance and prescriptive specifications in its contracts. The specifications tend to be too prescriptive, and the interviewee expressed a preference for more performance-based specifications.

Question 4. What types of contracting/procurement methods have you used for letting construction contracts and for purchasing vehicles and systems? What effect do low-bid procurement practices have on total contract costs (raise, lower, no effect)? What effect do negotiated procurements have on total contract costs? Do they have long-range effects on operations and maintenance or on the operating budget?

There is a wide variety of experiences in the area of contracting and procurement. One agency reported a poor experience with a planned design-build procurement. The project had been estimated at $600 million but had to be terminated and the contract reconsidered when the bid came in closer to $800 million because of limited competition. The experience has made the agency reluctant to consider design-build again. Alternative practices such as general contractor/construction manager (GCCM) are, in that interviewee’s opinion, superior in many respects to design-build and competitive bids as both involve bringing the contractor in before the bidding stage. With the increasing internationalization of light-rail contractors, there is an advantage in using procedures which these contractors are familiar with overseas, very often negotiated procurements.

This same agency tends to go with negotiated procurements on the system side and also with vehicles (the latter being the industry standard). On the civil engineering side, pre-qualified bids are more the norm. Some best-value procurements have also been done for civil engineering contracts. Negotiated procurements take longer and add costs up front, but probably result in a better price. With a hard-money/low-bid process, a project can easily grow by up to 20% in total cost, especially at-grade, while with an alternate procurement approach, especially GCCM, the increase would probably be more like 8%.

Another agency also had positive experiences with negotiated contracts. They had a very bad experience with one project for which they terminated the contract because the contractor bid out the subcontracts at too high a price. After only one subcontract had been awarded, the agency bundled the remaining contracts into one package and bid that out. The one bid that was received was too high and the agency ended up negotiating a contract with that bidder. The agency believes that the back-and-forth and give-and-take involved in the negotiation results in a better understanding on the part of the contractor.

This agency shares the negative opinion of the low bid approach. It estimates that a contractor should spend one person-month on design for every $10 million of work. In a low bid situation, they usually do not have the time to do this because of the uncertainty of winning the bid. A low-bid contract is not a good deal if the contractor is losing money; the contractor will deliver lower quality or add charges in order to recoup his or her costs.

Another agency confirmed that rail car procurements cannot be bid, because each procurement is so unique. This agency pointed out that, unlike bus orders, which are really standard products to which options are added (much like private automobile purchases), every rail procurement is a custom order, each car being individually built. Costs and contract structures were different for each order of rail cars and the size of each order varied dramatically as well.

Yet another agency used the design build operate manage (DBOM) method of project delivery for both of its light rail projects. The interviewee from this agency said that this approach can increase capital costs. In this approach, the system is relinquished to a private sector consortium for the operating and maintenance phase. The client agency increases costs by not carefully considering the penalty clauses/performance incentives for the O and M phase. This phase is quite long for both of his agency's projects – 15 years for one and 10 years for the other. He felt that contractors viewed a high quality, well designed project as a way of reducing operating costs, so the projects were actually built to higher standards using very heavy rail, bigger catenary poles, and heavier gage wire. In the face of penalty clauses, the contractors mitigated their risk by over-building the system. One project had a 99.5% reliability requirement during operations, which the bidders struggled to meet. This situation was likened to wearing both a belt and suspenders.

As mentioned above, because of the current nature of the bonding market, projects often need to be broken down into several contracts simply to allow contractors to be bonded. However, the amount of interfaces between the different subprojects goes up when this happens, increasing costs. There is thus a definite trade-off between increased competition and number of interfaces. There is currently some question as to whether one needs a 100% performance bond in every contract, and if this requirement could be selectively relaxed, it would obviously reduce the importance of this trade-off, but as of yet 100% performance bonds are the rule, literally and figuratively.

The timing of the contract, and who the contractors are, makes a big difference in contract costs. Rail cars in particular are different from construction contracts in that one company can start a construction contract and another company generally can finish if need be, but this is not the case for rail car producers.

One agency has faced situations where local contractors who have performed well on other contracts suddenly decide that they want to take on a light-rail contract, even if they have never worked in the field before. On the one hand, they are known and trusted quantities, have the necessary bonding, and may be respected by local decision-makers. On the other hand, for the particular job they are being considered for they are in effect an unknown quantity, since they have no prior experience for that job. This is where a low-bid model can work against you – the local contractor may be able to bid low but then have to call in subcontractors and perhaps end up with higher overall costs or poorer quality than expected. A move towards performance indicators for contractors (e.g. on delivery and quality of prior deliverables) may alleviate this problem, as well as alternatives to low-bid contracting, at least in the opinion of the interviewee.

Sharing of risk between the contractor and the agency is at the heart of many cost issues; the particular risks involved, combined with the way that risk-sharing is structured, will determine a lot of the bottom-line costs. For example, the exposure of contractors to liquidated damages for delays and other reasons, as well as consequential damage provisions, can be handled in a variety of ways. One agency puts a cap on damages because they need the cars and so do not want to put rail car contractors out of business, but not all agencies do this and not all companies will accept caps of certain levels.

The issue of <u>bonding capacity</u> was brought up in a different interview where it was noted that the FTA requires a performance bond of 100% for construction and nothing for vehicles, but properties often require bonds for both. There can be problems with obtaining bonds because the bonding industry has shrunk in terms of number of issuing companies and is less comfortable with posting bonds for rail cars because rail cars are a unique product and the rail industry has a reputation for problems and delays. Thus bond companies tend to offer lower amounts over shorter periods. This, of course, affects the size of contracts which can be offered and the pool of contractors eligible for each contract.

One agency noted that the FTA also requires payments to be made to contractors when cars are delivered but producers incur a lot of costs before delivery and must be compensated for those costs. Letters of Credit and Advance Payment bonds are needed, which cost money. Many properties find it so hard to get FTA to approve advance payments that they forego it entirely, which leads to higher overall contract costs, either to compensate the contractor for the lower up-front payments which result, or through changes which might result to the production process which could have been avoided by an appropriate advance payment. This particular agency conducts a net present value (NPV) analysis, puts it all in the contract, and as specified milestones are reached, up to 45% of the contract price is paid. Other transit properties may not be able to do a full NPV analysis. They may have to lower their advance payment that requires financing by the contractor, the costs of which are passed back to the property.

Question 5. What effect do warranties and/or performance incentives in procurement and construction contracts have on total contract costs and lifecycle costs? (a) Do these reduce operating costs over time? (b) Have these operational benefits, if they exist, been evaluated? How?

One variable affecting project costs is the effective date of warranties (i.e., when do warranties kick in?) Beneficial occupancy can be achieved well before the final close out of a contract. That represents a substantial risk to the contractor and many contractors will price that risk into the contract. Putting in infrastructure that other agencies are going to operate before substantial completion represents an additional warranty complication.

One agency noted that the FTA has regulations that limit the amount of warranties except where it is standard in the industry. Extended warranties obviously add to costs. To cover those costs, this agency used a performance bond during the contract and typically converted it into a warranty bond after the order had been delivered. This new bond is then stepped down in amount from the old one. The contractor may also be allowed to securitize some cash flows.

Another agency argued that performance based contracts tend to result in lower quality work. Transit agencies need high quality work up front to make up for the uncertainty of funding for later maintenance. The interviewee noted that guarantees are just paper and that to enforce penalties or incentives, the contract has to be kept open at a time when everyone wants to close it and put the system into operation.

Question 6. What effect do new technologies have on total contract costs and lifecycle costs? (a) Do these reduce operating costs over time? (b) Have these operational benefits, if they exist, been evaluated? How?

One agency, which has to do significant amounts of tunneling (obviously representing a huge initial capital cost), has found that technology typically offers trade-offs to be made rather than straight cost-increasing or decreasing causalities. One business decision that this agency made concerning traction power was to use higher voltage in order to reduce the number of substations. That tradeoff is purely economic and subject to standard economic analysis. To deal with vibration during construction and operations, the agency used dampening rail systems which avoid the need to reduce speeds without disturbing ultra-sensitive entities located above the tunnel, such as a university. Ventilation security is a developing technology (which allows continuous tracking of the system) as is stray current technology on light rails, which limits the migration of current to other nearby electrical systems. All of these technologies – and one could add low-floor cars and vending machine advances as further examples – add functionality and improvement in quality, but also cost more, at least initially.

A different agency stated that new technologies always add to operating costs and also to capital costs. But the example given was a bit more ambiguous: monitoring diagnostics which include electronic, computerized trouble shooting and maintenance. Train systems are now modularized and when a module goes down, it is replaced and subjected to a very expensive bench testing process to find out exactly what went wrong. Testing is more expensive than it used to be, and there are new inventory costs as a fuller stock of modules, components, and sub-components is kept on hand. Conversely, one can now pinpoint a problem precisely and replace the problematic part, allowing the overall assembly to remain in operation longer rather than throw a whole assembly out when it broke down, as was the case in the past. Are operating costs increased or decreased by this process? It was not clear. However, this particular example may not be too relevant in light rail, which would have a very different maintenance procedure, and where complete module replacement is still the rule.

Another agency identified two new technologies that can result in operating benefits and a reduction in operating costs. One technology is closed circuit television (CCTV). The interviewee identified two operating benefits from CCTV. One relates to security. Customers tend to feel that there is no or too few transit personnel on the train and the presence of cameras can be reassuring to them. A second benefit from CCTV is that it can be used to count riders. His agency currently spends $600,000 to count riders for FTA's National Transit Database. This could be done automatically through CCTV. A second technology which can provide operating benefits is low-floor cars which can reduce dwell times. His agency works on the assumption that dwell time is 30 seconds. With low-floor cars, in reality, the dwell time is 10-20 seconds. In contrast, for a commuter line with low platforms where customers have to use steps to get on and off, the dwell time is closer to a minute.

One agency pointed to the operating impacts of GPS, communications based train control (CBTC), and traffic signal priority. GPS for tracking vehicles offers operating benefits from being able to better regulate vehicle movements. CBTC results in smaller trains with more operators (and thus higher labor costs) but improved customer convenience and shorter roundtrip times. Using shorter trains also has an operating benefit: a reduction in the coupling failures that occur when assembling longer trains. Traffic signal priority for buses and trolleys has reduced operating costs and increased competitiveness with automobiles.

The overall point of all of these examples may be that overall quality is increasing along with cost as technology advances. Quality-adjusted costs may be decreasing, though this has not been measured. In any case, even if one wanted to return to an older technology (e.g., DC motors), it would not be possible as no one is manufacturing old technology.

Question 7. The American Public Transportation Association (APTA) is leading an effort to develop technical standards for rail transit. What, in your opinion, would be the effect of national standards for transit vehicles and systems on the following: (a) costs of individual asset categories; (b) total project capital costs; (c) operating benefits; (d) operating costs; (e) other. In your opinion, what new standards could bring the largest benefits in terms of capital cost containment? Are there existing standards that could be amended to boost the potential for cost savings? How feasible would it be to implement these standards?

A common theme in the interviews was that railcars are unique and have to be engineered for every project. For example, an example was given of three agencies across the country that were using the same light-rail vehicle manufacturer, yet each car was being built with somewhat different specifications. While there is some standardization currently, and room for more, the uniqueness of rail vehicles thus far is limiting economies that could be potentially achieved through common specifications.

Why is there so much variation? A number of reasons came up. One agency, which is trying to minimize customization, nonetheless has encountered a unique aspect of its current project which involves the joint operation of both light rail vehicles and buses with stations that accommodate both modes. This joint use will require unique operating and signal standards. This agency is the only agency in the world to be doing this.

Another agency has made efforts to standardize within its fleet of rail cars. This agency is attempting to standardize what is most amenable to standardization (e.g., windows and the scheduled maintenance system) and has begun publishing standards conforming to the IEEE. Customization exacts high costs: the agency reported that it has had to maintain spares for twenty different window types, for example. Reliance on custom parts also increases an agency's dependence on a single vendor. Vendors would prefer to standardize where possible, since this results in lower production, start-up, inventory management and diagnostic costs (this last one being very large). And light-rail vehicles are the most amenable to being standardized since there is a basic car chassis.

The representative from another agency is absolutely convinced that standards would have capital cost benefits and specifically identified vehicles as an area where standards would be particularly important. He felt that if agencies stopped tweaking their specifications, vendors should be able to give a better price. Another area where standards would be appropriate is in signal systems. This interviewee's agency uses different systems in its two light rail projects – wayside signals in one and cab signals in the other. If light rail could come up with a good standardized signal system, it would avoid the need to separate freight and light rail temporally. While he said it is easy to see the benefits on the capital side, it is not so easy on the operating side.

Another area where standards would be beneficial is heavy-duty elevators and escalators. While these standards would increase capital costs, they will probably result in lower operating costs because they would result in more durable elevators and escalators than what is currently available.

There are, however, technological limits to standardization. The age of the system is one consideration. One agency would prefer to have one rail car for its entire fleet and considered standards based on a particular line, but this was not feasible because these vehicles were too small for the other lines which were developed independently. Unless one makes everything smaller, which is not cost-efficient, then one has to have different fleets, which is the case for this agency.

The continual march of technology also poses a challenge for standards efforts. Yet some standards can be drawn in a way that accommodates new technology. For example, a specification for a battery can treat the internal mechanism as a black box, only specifying the interface, the physical size, and performance characteristics. In this way, new technologies can be incorporated into the battery without compromising the standard.

Even where the same contractor for vehicles is used across jurisdictions, differences in vehicle specifications have resulted for technical reasons. For example, because of its existing power system, one agency had to tweak vehicle specifications.

According to one agency, a market dynamic sometimes emerges where, once standards might be adopted, an individual vendor will seek a strategic market advantage by introducing a unique variant of the technology, or adding a new feature, often lowering the price in the short-term to gain market share in the longer term. This variant usually is technically superior in some way but can potentially undermine standards (though it may improve the evolution of standards as well). Some vendors may resist standardization as it removes value from niche markets.

Standardization has not increased the number of vendors and there is still mostly sole-source procurement. This, of course, raises a number of issues.   In sole-source situations, standards may have a negative effect on innovation (and may, in fact, increase the likelihood of sole-sourcing longer-term). However, it regularly happens that a groundswell develops for leaving an incumbent (for quality and innovation reasons) and going with something new. This often causes the incumbent to straighten out.

Of course standards and technology, and along with them, costs, are heavily driven by specifications provided by agencies. The agencies' testing and quality assurance processes are an example. One agency has beefed up in-house static and dynamic tests of vehicles before they will be used. This will increase capital costs, of course, but should be more than covered in lowered operating and maintenance costs. A different jurisdiction decided on a design for its aerial guideway that exceeded the current seismic standard, which increased cost in order to anticipate the newer standard. This raises costs initially but should reduce them over the lifecycle after new standards are made effective.

Question 8. In your experience, what impacts does market competition have on project procurement costs?

An issue that came up repeatedly was market conditions. Respondents noted that the number of North American light-rail vendors (and in transit generally) is dwindling and that this limited competition is impacting costs. One agency spoke of the ever-falling number of North American tunneling contractors, which is resulting in an increasing dependency on international contractors. This is having two results in this particular case: fewer qualified contractors and more monopoly. This agency also noted that there are a number of emerging monopolies in the market for end devices such as ticket vending machines.

Another agency made similar observations pertaining to the light rail vehicle market, which it called an unhealthy market with too few sellers because firms keep collapsing down. One of his agency’s light rail projects received 5 bids but each one used the same Stadler car. This project used a dynamic envelope with the specification that the vehicle be diesel. It had performance-based requirements with standard gage railroad and typical platforms, which presented no unusual problems. Despite these open, very standard specifications, all five bidding teams proposed using the same car. Even Bombardier would have mounted this car on their truck. He noted that open, performance based specs are part of the DBOM process.

Other areas in which there is a lack of competition include special track work and overhead contact work. Special track work for street running involves casting and forging switches and frogs. Overhead contact work involves steel manganese casting which is a small market with very few manufacturers. The interviewee’s agency used to deal with a small company which gave good prices for 10-15 years. This company also sold to three other cities, but left the business because transit spending dropped while reauthorization was held in limbo. The plant was taken over by a bigger outfit that required multiple drawings and approvals for any work, all of which drove up costs. As a result, prices increased 50% for the same quality product that the small company used to deliver.

Decreasing competition and decreases in domestic-based sourcing are having a number of diverse impacts. In the tunneling case, international contractors do not like the bidding process as they are used to negotiated procurements (standard practice in Europe and other areas). This possibly may lead to changes in domestic procurement processes in the future. The fact that the U.S. has no domestic railcar producer introduces another type of risk: currency fluctuation. These risks are sometimes borne by contractors internally, while in other cases there are explicit provisions for handling it in the contract.

On the other hand, large sole-source contractors can achieve significant economies of scale, which lower costs and sometimes achieve significant product innovations that might not occur as readily in more fragmented supply markets. However, when sole-source contractors are good, a different problem can arise: the contractor may move to a richer, bigger contract as the marketplace develops.

Third party costs are another issue, what one interviewee referred to as “the ground rules” – dealing with community groups, utility companies, police, and fire departments. This interviewee noted that these parties have to be negotiated with to get their cooperation, and some parties, such as gas companies, have better rights than others, such as telecommunications providers. This interviewee noted that it is important to nail down project scope in preliminary engineering and that the management team has to be in place to minimize scope creep and to streamline oversight. If agencies have earned trust and receive more cooperation, that helps streamline the process. The FTA requires that all third-party agreements be nailed down through advance formal agreements and in this respect the federal requirements are probably cost-lowering. Working out third-party issues in advance, while leading to more up-front costs, is generally cheaper over the lifecycle than working out such issues during construction.

An important, though less tangible issue is culture. One agency referred to a regional culture in which the default stance by parties is to be consensual and partnership oriented. This cultural bias obviously reinforces advance coordination of third-party issues and limits unnecessary conflicts.

Unique institutional, in addition to technical and economic, considerations are important to cost as well. One community wanted to go with cut and cover to keep a station underground when it would be cheaper to go above ground earlier. The transit board members decided to go along with the community's wishes and chose the more expensive option. Of course, the fact that the board is elected obviously plays a role here too since elected members are obviously going to be responsive to local concerns, even when those concerns may add cost. In general this interviewee noted that topography can sometimes limit options, sometimes increase them, and the ultimate choice made will be a combination of engineering, economic and political/social/community considerations.

Question 9. How do regulations affect costs? Are there particular regulations that you see as problematic in that regard? Explain.

There seemed to be overall agreement that regulations and regulatory requirements added costs, but there was a lot of variability here. To meet the Americans with Disabilities Act (ADA) requirements, one agency is using low floor cars with curb service without bridge plates. Increased security costs after 9/11 have been found both during construction and operations.

One agency found that the most costly regulations were environmental, especially the National Pollutant Discharge Elimination System (NPDES) regulations. The interviewee from this agency said that the "Buy America" regulations were not too costly and the ADA has to be budgeted for, but these two regulations have been around for long enough that agencies are accomplished in dealing with them in a cost-effective manner. The same is true for diversity requirements. NPDES stands out because it is just inherently expensive to comply with, no matter how accomplished an agency might be in dealing with them in the past. Security regulations, being relatively new, are evolving, and their costs are still being determined.

Another agency said that the requirements put forth by the ADA are just part of a good project which should provide easy access to everyone. For this agency, the most problematic regulations are system safety regulations. The FTA took a systems based approach, which is an improvement over FRA's equipment based approach because it considers training and interaction between systems. However, the safety system regulations keep growing and are becoming unwieldy, too complicated, and are adding to project costs. A tremendous amount of time in the last quarter of a project is spent on the safety system certification process. For example, one light rail project has seven full-time employees dedicated to this process.

A very different experience with ADA regulations was related by an agency that has been affected by the interpretation of the legislation. For example, any work on a street corner, which is where the pole for the overhead would be installed, requires that the yellow tactile edge be completely redone. Another example is that curb ramps have to be provided at light rail stops. A third example involves platforms and ramps up to platforms. The regulations require that there has to be a landing every 15 feet, so additional landings have had to be installed. Moreover, existing landings have had to be extended. Another change is the way the requirement that no slope exceed 2% is interpreted. It used to be applied just to the cross slope of a platform, but now it's applied to the longitudinal slope as well which has required platforms to be smoothed down. This new interpretation has deterred the agency from adding stops at certain locations. These regulations are an issue for underground stations as well.

This agency also cited a number of local regulations that have significant impacts on costs. One example is a local regulation concerning the manufacture and disposal of poly vinyl chloride (PVC) that has caused the agency to use high-density polyethylene (HDPE) in the feeder cables for the traction system. This has increased the cost of the feeder system by about 3%.

Another example is a local regulation dealing with pavement damage. Any time a project has to tear up a street, the agency is assessed a pavement damage mitigation fee for shortening the life of the pavement. In addition, these regulations require a coordination effort among different agencies with projects that require the street to be torn up so that they can do the work at the same time. While this may have overall benefits over the long run, it can increase delays and costs for individual projects.

There are also local regulations pertaining to surface mounted facilities. These regulations affect traffic priority systems that require the installation of boxes on the street. The regulations require an expensive process to get permission to install these systems including the provision of 3 alternative locations for a box, the notification of all property owners within 150 feet of the proposed locations, and a hearing to show why the boxes cannot be installed on private property. Installing the boxes on private property would most likely involve paying rent to the owners.

An issue raised by several agencies concerned the different regulatory requirements of federal and local funding. One agency said that local funding tends to be much easier with less reporting and other requirements, while federal funding comes with a whole set of reporting requirements, procurement processes and ways of doing business that increase costs and tend to squelch creativity and innovation and flexibility. In particular, this agency said that there is concern that even justifiable deviation from the way that specific federally funded procurements were done in the past may lead to sanctions and criticisms from federal overseers. So the tendency is always to do things the same way for each contract, even though transit contracts are, by their nature, very individual things.

For example, one agency took a year to do all the federal paperwork for its last purchase of rail cars funded that way. In addition, the FTA required the agency to organize its workflow and work-teams in a very specific way, creating four different workgroups with specific functions and titles.

One agency said that whatever the source of funding, it does not matter whether all the funding is in-hand or whether some of it needs to be bond-financed as far as total procurement costs. However, another agency, with 80% local and 20% federal funding, made the point that any percentage of federal funding comes with more stringent reporting requirements and other strings, and these requirements and strings do not change with the amount of the federal match.

Question 10. Do you separate land and soft costs from rolling stock and right of way costs when budgeting rail capital costs? Does this have any impact on project costs, operations or decision-making?

One agency separated out land and soft costs from rolling stock and ROW costs, but said that this does not really have an impact on costs or decision-making. The agency said that its soft/administrative costs are higher than desired, but that this is a function of the maturity of the agency, not budgeting protocols.

Question 11. In general, what trends do you see in light rail project costs moving forward?

One interviewee foresees a trend of continuing increases in project capital costs. He said that every new project sets a new base line. It is getting to the point that a $500-600 million project is considered small. Light rail projects are becoming so expensive they are becoming like commuter rail projects.

Another agency expects continued upward pressure on commodity prices, particularly wood and cement, as reconstruction begins in the Gulf Coast. Local economic conditions are also creating shortages of skilled labor.

Question 12. What policies can be adopted to help anticipate, plan for, and/or mitigate capital cost increases?

Several agencies mentioned the usefulness of submitting a project to a peer review by transit engineers and managers during the planning phase. One respondent said that this can be very helpful to get a better focus on scope, schedule, and budget. Another noted that that this approach is much better than relying on consultants and that spending more time upfront thinking about problems saves more later.

One agency uses case histories to evaluate what other projects have done. This interviewee said that one area that needs more development and sharing across transit agencies is Project Management Oversight Contractor (PMOC). The formalization of risk assessment has been helpful and has been a positive outgrowth of FTA directives and suggestions. Dissemination of knowledge of this sort is desirable, and the FTA’s construction roundtable, the peer review process, and other initiatives all deserve kudos in this regard.

This same interviewee said that the full funding grant agreement (FFGA) process of the FTA has changed and approval is getting harder to get. This particular system had to eliminate a very popular and very worthwhile station to keep the cost per rider down. The new grading system does not seem to take different local conditions into account. For example, the emphasis on ridership forecasts makes it harder for projects that have significant tunneling because tunnels have higher cost, so the cost per rider is higher.

Another interviewee recommended that FTA pay a certain amount per mile or have a sliding share based on per mile costs; and rate FFGAs based on how good their plans are in terms of cost control. This interviewee also said that equipment standards could help reduce costs and that light rail needs to stop re-engineering every new project and start re-using designs.

Annex 1: Interview Questionnaire

The University Transportation Research Center (UTRC) is carrying out research on capital cost drivers and risk factors in areas such as light rail vehicles, guideway, electrification, stations, and soft costs. The goal is to better understand the underlying causes of capital cost trends and cost overruns in these areas and the relationship between capital cost drivers and operating benefits. We are also looking at the potential for cost containment through risk management, standardization, and other strategies.

General Issues:

1. Have you found that total light rail project capital costs are rising, staying flat, falling?

2. Table A contains the major categories and subcategories that research indicates make up total light rail capital costs (this is distinguished from Table B, which focuses on factors which drive, i.e., affect, the rate of change, upward or downward, of capital costs).

(a) Indicate the top three categories that generally make up the bulk of your agency's light rail total project costs.

(b) What components, if any, of light rail capital projects seem to have the greatest problems with cost inflation? Which, if any, have the least problems? Which, if any, have been falling in price? Are price-increasing categories also the categories that make up the greatest bulk of total project costs?

TABLE A: Light-Rail Capital Cost Components	
1. Guideway	At grade/in-street Elevated Underground Retained cut Trackwork, etc.
2. Yards and Shops	
3. Systems	Signal system Electrification Communications Revenue Collection Central Control
4. Stations	At-grade Subway Elevated Parking Lots/Garage Spaces Station Access Signage and graphics Elevators/Escalators, etc.
5. Vehicles	
6. Special Conditions	Utility relocations Environmental Abatement and Mitigation, etc.
7. Right-of-Way Acquisition	
8. Soft Costs	

3. Table B contains factors which our research says drive, i.e. affect, the rate of change, upward or downward, of light rail capital costs. Which of these factors, in your experience, are contributing to rising capital cost trends? Falling cost trends? Flat cost trends?

TABLE B: Cost Drivers	
1. Input (factor) costs	1.1. Labor 1.2. Commodities 1.3. Manufacturing processes
2. Project configuration	2.1. Size of project 2.2. Mix of elements 2.2.1. Starter system/expansion 2.2.2. Type of guideway 2.2.3. New or re-used corridor 2.2.4. Diversions (accommodating existing service)
3. Technical specifications	3.1. New functionality (includes new technologies) 3.2. Costs associated with customization
4. Regulatory changes	4.1. ADA 4.2. Buy America and other local content requirements 4.3. Safety and other technical standards 4.4. Security
5. Market conditions	5.1. Market size and stability 5.2. Overall economic conditions 5.3. Competition 5.4. Foreign versus domestic suppliers
6. Contracting and procurement practices	6.1. Contracting practices: 6.1.1. Design-build; design-bid-build; design-build-operate-maintain 6.1.2. In-house versus contracted work 6.2. Procurement practices (for LRVs) 6.2.1. Delivery schedules 6.2.1.1. Options 6.2.1.2. Volume discounts 6.2.1.3. Contractor risk 6.2.1.4. Inflation and currency risks 6.2.2. Warranties 6.2.3. Extras beyond the physical cars: 6.2.4. Spare parts 6.2.5. Testing and maintenance equipment 6.2.6. Renovation/modernization of existing equipment
7. Management oversight	7.1. Funding source 7.2. Experience of agency (technical capacity) 7.3. Change orders

<u>Procurement Issues:</u>

4. What types of contracting/procurement methods have you used for letting construction contracts and for purchasing vehicles and systems? What effect do low-bid procurement practices have on total contract costs (raise, lower, no effect)? What effect do negotiated procurements have on total contract costs? Do they have long-range effects on operations and maintenance or on the operating budget? Are there issues specific to your agency’s procurement practices that have an effect on capital costs?

5. What effect do warranties and/or performance incentives in procurement and construction contracts have on total contract costs and lifecycle costs? (a) Do these reduce operating costs over time? (b) Have these operational benefits, if they exist, been evaluated? How?

New Technologies:

6. What effect do new technologies have on total contract costs and lifecycle costs? (a) Do these reduce operating costs over time? (b) Have these operational benefits, if they exist, been evaluated? How?

National Standards:

7. The American Public Transportation Association (APTA) is leading an effort to develop technical standards for rail transit. What, in your opinion, would be the effect of national standards for transit vehicles and systems on the following: (a) costs of individual asset categories; (b) total project capital costs; (c) operating benefits; (d) operating costs; (e) other.

In your opinion, what new standards could bring the largest benefits in terms of capital cost containment? Are there existing standards that could be amended to boost the potential for cost savings? How feasible would it be to implement these standards?

Market Conditions:

8. In your experience, what impacts does market competition have on project procurement costs?

Regulations:

9. How do regulations affect costs? Are there particular regulations that you see as problematic in that regard? Explain.

Budgeting:

10. Do you separate land and soft costs from rolling stock and right of way costs when budgeting rail capital costs? Does this have any impact on project costs, operations or decision-making?

Concluding:

11. In general, what trends do you see in light rail project costs moving forward?

12. What policies can be adopted to help anticipate, plan for, and/or mitigate capital cost increases?

APPENDIX D: Proposed Analysis of the Impact of Standards

Standards have only recently become more rigorously and uniformly adopted in the transit industry. Standards can be applied to any of the following:

- Practices and procedures
- Operations
- Inspection and maintenance
- Design of equipment for both vehicles, structures, right of way and associated facilities and equipment
- Communications and computer interface

The rationale for such applications and adaptation by the transit industry include:

- Safety improvements
- Operational improvements
- Beneficial impacts on system life cycle cost
- Productivity improvements
- Improvements in practice

As the positive benefits of standards become clear, they will become more widely adopted. As one example, the Senior Member of the UTRC team served as an “Impartial Expert” to assist New York MTA in the establishment of times to accomplish core bus maintenance tasks. When these then became agency standards, they saved the New York City Transit Authority $11 million per year in maintenance costs.

In general, however, the potential cost savings from standards, particularly those now being adopted and proposed by APTA, are not well understood. We suggest collecting data that will make it possible to estimate these effects. The following outlines the steps that would be required for such an effort:

1. Describe and define standards and classify by area of application (e.g., operations, safety, TCIP, bus, rail, right-of-way). Identify in a qualitative fashion the types of impacts. A standards matrix would identify the types of impacts for each standard:

Standard	Impact on capital cost	Impact on operations	Impact on safety/risk

2. Identify any operational synergies between standards (e.g., TCIP).

3. Determine the fraction of initial capital costs that each standard affects

4. Determine the percent of operating costs that each standard affects or will affect over the life cycle of the application.

5. Determine the potential impact on lifespan and on replacement costs.

6. From the above, calculate total lifecycle savings. A matrix such as that below would identify the individual components of lifecycle costs:

Standard	Short term capital cost	Long term capital cost	Short term operating cost	Long term operating cost

7. Calculate the impact on overall costs. This would relate the savings from an individual standard to total system costs. For example, if a particular item represents 5% of total costs, a 10% savings in the cost of that item would cut total costs by 0.5%. Again, these savings would be computed on a lifecycle basis.

8. Calculate savings on a performance-unit basis, such as dollars saved per operating hour, or per maintenance hour, or per passenger trip.