Transit Railcar Quantities: Scale Economies

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The effect of increasing size order on purchase prices of railcars is examined using data obtained from suppliers in a survey by a major transit authority. A distinction is made between short-run price and cost, the former being borne by the buyer and the latter by the supplier. The data, consisting of average price points, are converted into marginal cost curves. The analysis indicates that most economies of order size seen by the buyer as per car savings are realized by the time orders reach 60 to 90 cars. Virtually all purchasing economies are reached by the time orders reach 200 cars. Further manufacturing economies of scale, if any, will likely accrue to the suppliers. A corollary is that economies thought to result from the purchase of "off-the-shelf" cars may not exist in a significant way.

A major problem in rail passenger systems is the rapidly escalating purchase cost of railcars. In the past few years, attention has been directed toward understanding the factors in a railcar's purchase cost and how to set the parameters of these factors to minimize the cost. This effort has recently been expressed in UMTA's railcar cost containment initiatives. One such factor is the quantity of cars ordered at a single time.

The effect of order quantity, or "lot size," on the purchase cost of passenger railcars will be discussed. The degree to which the cost can be expected to decline, if it declines at all, will be determined. If the cost declines, what decision-making rules can be developed to guide car purchasers? The validity of current beliefs about the relationship between costs and order quantity and how the validity of those beliefs should govern procurement will be examined.

A review of some of the literature suggests that larger order size reduces per car costs (*1,2*). A study for UMTA by Dynatrend suggests, on the basis of a statistical analysis of historical contract prices, that costs for quantities of more than 46 cars are significantly less than for quantities of less than 46 cars (*3*). Other studies simply assume that standardization will result in lower car purchase costs, presumably because standardized (off-the-shelf) cars represent, as an aggregate, a large order (*4*).

ECONOMIES

It is reasonable to believe that increasing the order size reduces the cost of a passenger railcar. It is thought that the manufacture of railcars ought to exhibit economies of scale; therefore, the average and marginal costs of cars should decline as the quantity produced increases. The economies of scale are thought to arise from three causes:

1. For a given manufacturing technology or design, setup and overhead costs are absorbed over a greater volume.
2. For a given manufacturing technology, the "learning curve" phenomenon reduces the unit cost of additional units.
3. As order quantity increases, the manufacturing technology shifts to a higher setup cost and lower unit cost method, yielding a lower total cost for large volumes.

SURVEY AND DATA

But is this belief true? An opportunity to test the hypothesis that lower per car costs result from larger order quantities arose in the large amount of survey data gathered by the Southeastern Pennsylvania Transportation Authority (SEPTA) during its Railcar Cost Containment Program sponsored by UMTA in 1989 and 1990.

In this study, car builders, their system suppliers, and consulting engineers were surveyed to determine what they "thought" the effect of various parameters would be on the cost of cars. Each respondent was asked to estimate qualitatively and quantitatively the change in cost resulting from a change in a specific aspect of car procurement. The changes included different propulsion controls, choice of materials, and warranty duration, for example. Each respondent was also asked how the cost would vary with order size.

The response data were initially taken at face value. The data were provided by 24 firms: 11 car builders; 7 subcontractors, or systems suppliers; and 6 consulting engineering firms. Every major car builder except Kawasaki/NIAC responded to the survey. Though the sample population is not large, it encompasses the great bulk of suppliers. All respondents were asked to keep one car in mind: a 75-ft-long, stainless steel electric multiple unit with the subsystems typically used on cars of newer North American systems, such as those in Los Angeles, Baltimore, Miami, Atlanta, and Washington, D.C.

Before the survey responses are examined, a distinction between cost and price must be made. The two are not necessarily equal and, in fact, their difference is equal to profit (or loss). Increasing the quantity of cars ordered may reduce a supplier's costs, but it may not result in lower prices for a buyer. For this analysis, it will be assumed that the survey responses are in terms of prices, because that is what UMTA and SEPTA inquired about. In the long run, cost and price

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may approach one another. However, most buyers of cars place their orders in the short run.

Each respondent was asked to speculate how much the price of a car might be reduced or increased if a base order of 50 cars were changed to 100 cars, 200 cars, or approximately 30 cars. The price changes were expressed as a percentage change. Some of the changes were expressed as ranges (e.g., 3 to 6 percent or 7 to 10 percent). From the responses, the average car price for each order quantity can be calculated. The marginal price of the additional cars can be calculated from the average price. These marginal price points describe a marginal price curve. The slope of the curve is the rate at which prices change. When the slope approaches zero, most of the economies have been realized.

For example, one respondent, a consulting engineering firm, estimated percentage price changes for changes in order size as given in the following table. The price changes are expressed as a percentage change from the base price, whatever that may be, say, $1,000,000.

Order Size	*Change from Base (%)*	*Average Price of Car ($)*	*Marginal Cost of Car ($)*	*Marginal Change (%)*
30	+10	1,100,000	1,200,000	+20
50	base	1,000,000	base	base
100	−10	900,000	800,000	−20
200	−15	850,000	800,000	0

The choice of a base near the midpoint of a series creates some computational clumsiness.

ACTUAL COST CURVES

The marginal and average price curves described by these points follow the expected shape of the classic curves. Computer-generated fits of the points yield curves of declining prices best approximated by a logarithmic function. These curves are displayed in Figure 1 for one of the respondent car builders. A common computer statistical package converted them as shown in Figure 2.

A regression analysis on the entire population of respondents' points produced the following equation:

$$P_q = \$1.57 \text{ million} - \$0.137 \text{ million} \times \log Q$$

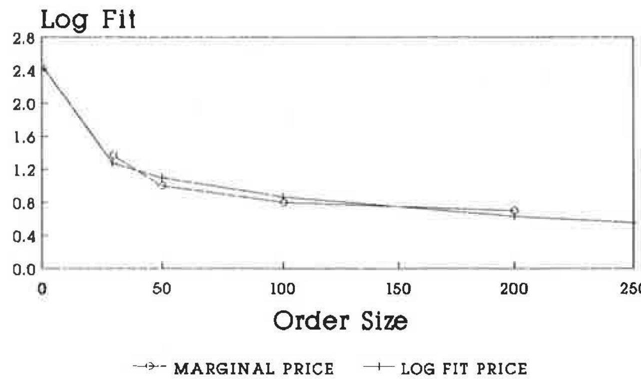

FIGURE 2 Cost curves for Car Builder A (marginal price and logarithmic fit price).

where P_q is the marginal price of the qth car and Q is the total size of the car order. The total order price is the integral of the equation over the domain of the order quantity. The R^2 of only 0.55, however, means that the predictive value of the equation is limited.

VARIABILITY IN SLOPES

However, this last result is deceiving. An inspection of the raw response data indicates the existence of two distinct populations. The first consists of firms who claim that their curves decline at a declining rate (i.e., that prices decline as order size increases, up to a point). This is expected and is shown for one car builder in Figure 1. The second consists of firms whose responses yield virtually flat curves, as shown for another car builder in Figure 3. These firms claim that prices are inelastic over order size.

A statistical averaging of the two populations is clearly inappropriate. But an inspection of the two populations is illuminating.

The difference in slopes between the car builders in Figures 1 and 3 is curious. Both firms are located in the same country. They presumably are talking about the same general car at the same time. They claim to be able to produce a wide variety of designs, and, indeed, they produced nearly identical cars at one time or another for the Philadelphia market. Why does Car Builder B claim that prices, or costs, do not vary over

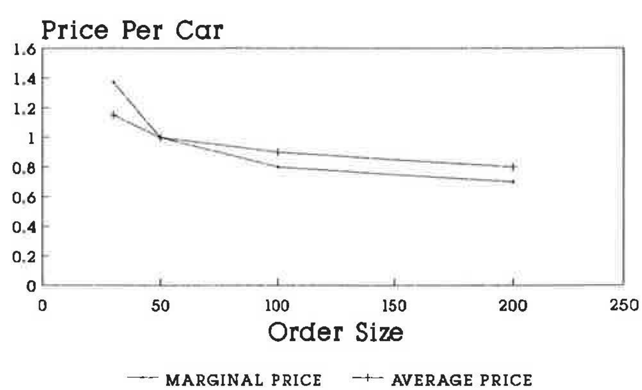

FIGURE 1 Cost curves for Car Builder A (marginal price and average price).

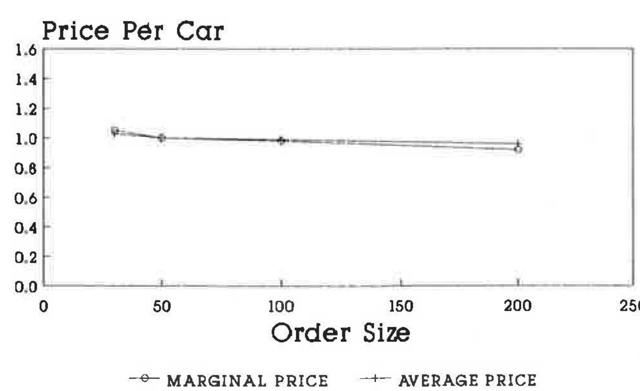

FIGURE 3 Cost curves for Car Builder B (marginal price and average price).

production runs varying by an order of magnitude, whereas Car Builder A's response yields the expected decline in price as order quantity increases?

The following explanations, however likely or implausible, come to mind to explain the horizontal response of Car Builder B:

1. Car Builder B does not intuitively or formally understand its own cost and price structure and responded in confusion (i.e., it is unsophisticated).
2. Car Builder B understands its cost structu:e but chooses not to present UMTA or a potential customer with realistic data (i.e., it is deceptive).
3. Car Builder B has no manufacturing expertise and uses no elaborate tooling. Hence, it never moves along the learning curve, or it has no setup or design cost to absorb.
4. The two firms differ in their production experience and may be describing different parts of the same production curve.
5. Some combination of the above explanations applies.

An exploration of these explanations yields a provocative conclusion: specifying an off-the-shelf car may not result in a lower car price. But before exploring the path leading to this counterintuitive conclusion, other implications of the possible explanations must be reviewed.

It is possible that the respondents do not understand the conceptual basis of the questionnaire. This is Reason 1. It is plausible. Some of the survey responses generated inconsistent data points—the average and marginal prices declined with order size and then rose. After all, strategic economic modeling has not been a strong point of the car supply industry. This may partially explain the demise of some of its members.

Reason 2, duplicity, is also possible. Regrettably, experience suggests that duplicity and commercial mendacity are accepted attributes inside some firms. Furthermore, firms may view cost structure and pricing decision making as highly proprietary information. Consequently, it would be imprudent to dismiss the possibility of a firm deliberately submitting misinformation to the client community.

Reason 3 may be partially true. The idea that a firm has no discernible learning curve or tooling costs may be dismissed. It is unlikely that such a firm would survive. However, a firm may have low design and tooling costs if it purchases existing designs or produces only designs it has made before. In these cases, product research and development costs are low to begin with, leading to fewer costs to be absorbed over volume.

This phenomenon leads into Reason 4: the two firms are actually describing different parts of the typical production curve. Car Builder B's entire output over the past 6 years has largely consisted of two designs. Both designs were purchased from other car builders that had successfully constructed these designs before. Car Builder B's efforts in manufacturing to these designs have been successful. Efforts to secure orders for other designs have been less successful. In other words, Car Builder B is well along a production experience curve. Because almost all its new orders are for cars it has already built, it may not view an order for 50 cars as 50 cars of a new type, but as 50 cars on top of the 500 or more of virtually the same type of car that it has built before or, in fact, may be in the midst of building for another customer.

This explanation is supported by an examination of the remainder of all respondents' data. Figure 4 shows the distribution of all respondents' price elasticities as approximated by the percentage change in prices from the smallest to the largest order size. Car builders typically believe that there are significant economies in order size. But their subcontractors for brakes, propulsion, door controls, and so on are less inclined to this belief. These component suppliers, however, produce more of a standard product. For example, Chicago Transit Authority (CTA), Massachusetts Bay Transportation Authority (MBTA), and SEPTA rapid transit cars use the same General Electric SCM II propulsion controls, though with minor variations. But the variation between the CTA, MBTA, and SEPTA car body structures is much greater than that between the car propulsion controls. Consequently, the car builders frequently must start at the beginning of the learning curve with each new customer's order. Suppliers like General Electric frequently do not start at the beginning, but are well along the curves.

The situation is analogous to new-home construction. Each kitchen may be customized. Each kitchen appliance is not. The building contractor believes 20 homes with the same design to be a long production run offering significant economies. However, the appliance manufacturer sees 20 appliances of the same design as routine.

The consulting engineering community's view appears to cover the entire spectrum of opinion and, taken as a group, is inconclusive. This is not surprising.

"OFF-THE-SHELF" PARADOX

It is often thought that specifying an off-the-shelf car results in paying a lower price for each car, especially if the buyer is purchasing only a small number of cars. The foregoing analysis can be further developed to show that this is not necessarily the case. It is possible to specify a general-purpose car that only approximates requirements—to obtain a lower price—and yet pay a cost close to that of a customized car.

This is how it happens. Say a car builder has an order for 100 cars from Buyer A. It bids or negotiates a price on the basis of its total cost of producing 100 cars of this design.

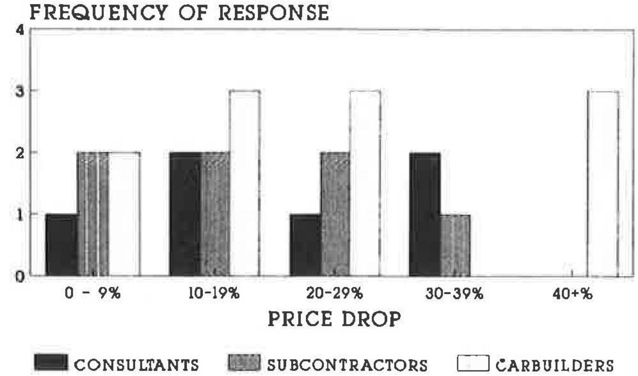

FIGURE 4 Price drop due to increasing order from 30 to 200 cars.

Buyer B wishes to order 50 cars. It wants cars customized to its unique needs. However, to economize, it solicits prices using Buyer A's design. Because the car builder can move along the cost curve to the right, that is, from 100 to 150 cars, its marginal cost declines.

But it may not pass the cost reduction along to Buyer B. It will probably charge Buyer B what it charged Buyer A, thereby retaining all the savings for itself. Recall that price does not equal cost. The difference between the two is profit, and the car builder tries to increase its profits.

If the car builder did lower the price to Buyer B, one can well imagine the protest from Buyer A. Buyer A bought 100 cars and paid more than Buyer B, which bought only 50. To Buyer A, this is manifestly unfair.

Buyer B might still save a significant amount. All things being equal, the price paid for 50 cars will be the lower price paid for 100-car orders. But the car builder's objective is to make sure all things are not equal. It wishes to push the price back toward the 50-car level. It will not try to equal the 50-car price. If it does, it opens up the market to other car builders. But it will try to raise the price to near this point.

It does so by finding a commercial pretext for making what was an off-the-shelf car suddenly customized or different. The difference may be only a routine product evolution or improvement, such as a relocated electrical apparatus locker or modernized door controls. It may be accelerated delivery. In any case, the objective of the car builder is to persuade the buyer that these differences, costing thousands, are worth tens of thousands. A capable buyer may be able to resist these commercial maneuvers if it is determined and informed.

COMPUTED PRICE BREAK POINT

A useful heuristic can be drawn from the results of the survey. The computed average prices for the 11 respondent car builders are given in Table 1, in which each car builder is identified by a letter.

Inspection indicates that most car builders see a leveling in average prices around an order size of 100 cars. This is not surprising. Most orders are for less than 100 units, and these are frequently not 100 identical units. Often the order is composed of cabs and trailers, married pairs, or other assortments of a design. Therefore, if a car builder cannot achieve most production economies before 100 cars, it is reduced to bidding on only a few rapid transit car orders a decade. To survive, suppliers must evolve a manufacturing approach that flattens the cost curve before 100 cars of a design is reached.

TABLE 1 CAR BUILDERS' AVERAGE PRICE (BASE ORDER PRICE = 1.00)

	Order Size			
Carbuilder	30	50	100	200
A	1.15	1.00	0.90	0.80
B	1.03	1.00	0.99	0.96
C	1.21	1.00	0.95	0.89
D	1.15	1.00	0.90	0.80
E	1.07	1.00	0.92	0.88
F	1.07	1.00	0.92	0.90
G	1.08	1.00	0.91	0.89
H	1.06	1.00	0.96	0.94
I	1.06	1.00	0.97	0.95
J	1.02	1.00	0.96	0.95
K	1.02	1.00	0.98	0.97

As a practical matter, increasing the size of car orders to 100 cars can substantially reduce the price, perhaps by 10 to 30 percent. Increasing the order size from 100 to 200 may reduce the price by up to another 10 percent. Orders of more than 200 cars will not result in significantly lower prices, although they may result in significantly higher profits (or disastrous losses) for the supplier.

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