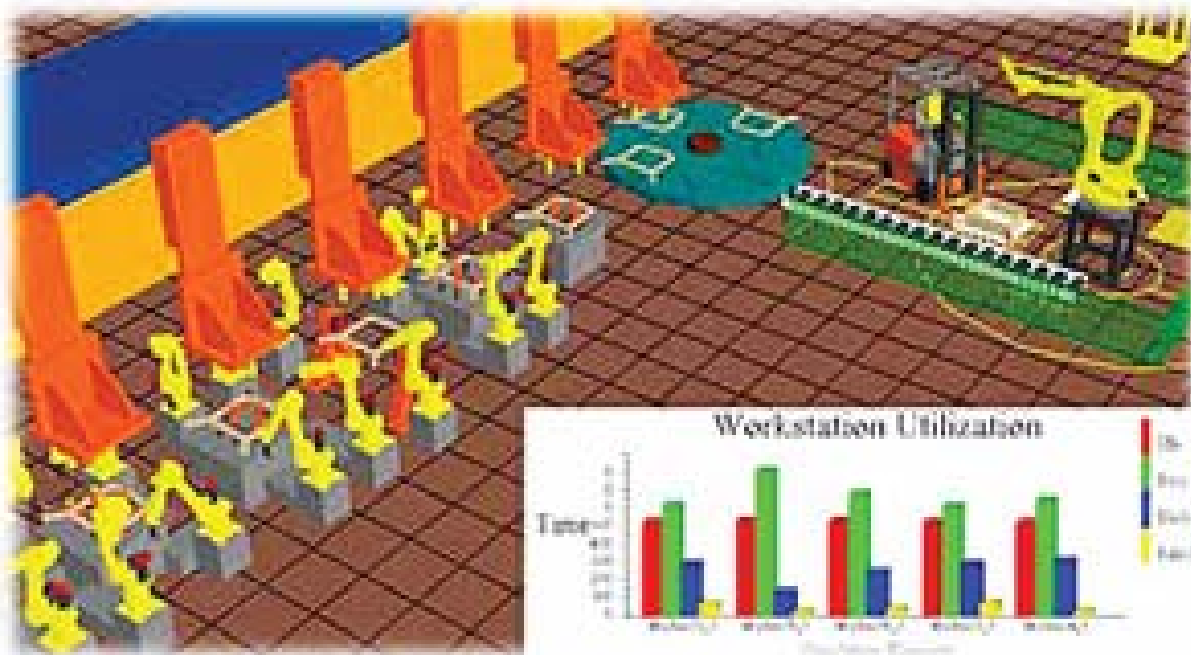


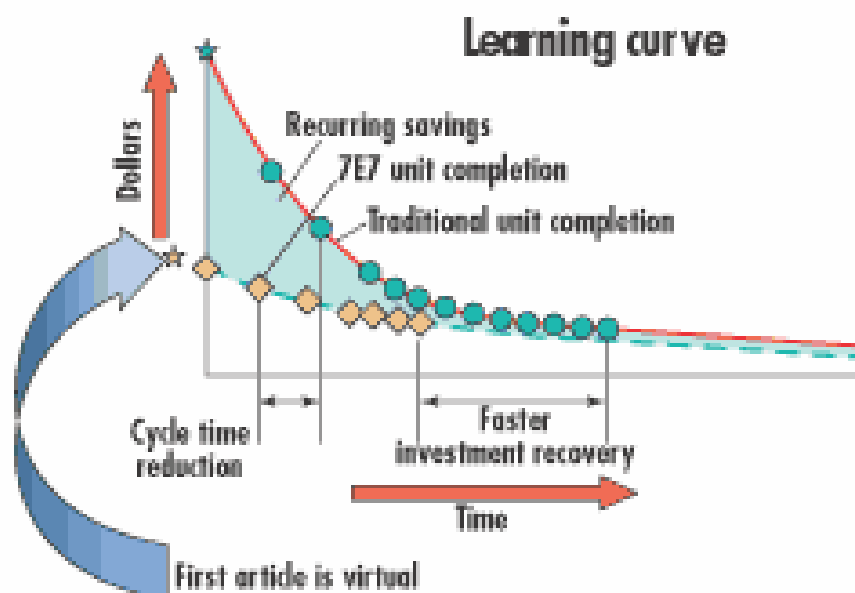
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- Japan's secret weapon – learning curves
- Toshiba color TV experience
- LHC Dipole Learning Curves
- Photovoltaic Cell Learning Curve
- Boston Consulting Group on Learning Curves

Boeing plans virtual everything before 7E7 rollout



Assembly and production cells will be modeled using Dassault's Delmia software. Simulations will include factory cells, such as this one.



For the 7E7, assembly personnel will practice on a virtual line to have skills in place for the first real plane.



Chapter 18: Japan's Secret Weapon

1. Since few journalists bother to adjust for inflation when making historical comparisons, the public is thoroughly convinced that real prices keep rising.
2. Only in brand-new industries, where explosive experience growth overwhelms inflation's distorting effects, does the price-cutting power of the learning curve become obvious to the average consumer.
3. Only Japan was prepared to exploit the incredible economic opportunities presented by the microchip. At a crucial moment in economic history, only the Japanese pursued policies that took full advantage of the learning curve's central lessons.
4. According to adherents of the "tilted-playing-field" argument, the blame for America's competitive collapse can be pinned on the machinations of the Japanese government.
5. Partisans of the "nuts-and-bolts" perspective tend to ignore the intrigues of Washington and Tokyo. Instead they focus on the workday details of life inside Japanese companies. These experts argue that the unmatched rigor of Japan's manufacturing is the ultimate source of Japan's economic might.
6. Only after the reality of the learning curve is accepted do the two paramount principles of economic competition become obvious.
 - Gaining an efficiency advantage by accumulating experience faster than competitors is the key to long-term growth and survival
 - If two firms are accumulating experience at the same pace, the more intelligent firm will prevail in the contest for economic survival.

7. Japan's triumph is partly because the Japanese government encourages smaller firms to merge and form larger firms. Also, because the Japanese live by the learning curve, they flatly reject the idea that "predatory" pricing is harmful.
8. The ultimate goal of Japanese management techniques is to create superior learning organizations. Japanese managers recognize that if two competing firms have the same rate of experience growth, the more intelligent companies will have a steeper learning curve and reduce unit costs faster.
9. In America, a favorite expression is "If it ain't broke, don't fix it." In Japan, a similarly popular saying is, "Pursue the last grain of rice in the corner of the lunch box."
10. While American employees are paid a straight salary or an hourly wage, the typical Japanese worker takes home about one-third of his or her annual compensation in the form of profit-sharing bonuses.

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5 percent, significantly lower than the 15 to 20 percent return that U.S. companies often expect on new investments. Toshiba's willingness to accept a 5 percent return reflects its consideration of the strategic value of having significant CPT production in the United States, gaining experience working with U.S. suppliers and an American work force, and having more timely access to technological developments in the United States.


Summary Observations: Toshiba Color Picture Tube Manufacturing

Toshiba's experience manufacturing CPTs in the United States prompts the following observations:

- The primary consideration in Toshiba's decision to locate in the United States was market access.
- Labor is less expensive in the United States than in Japan at recent exchange rates, but it is such a small component of production costs that it has only a small impact on the relative cost competitiveness of Toshiba's plants worldwide.
- Parts and materials are primarily procured in the United States. Extensive cooperation with its U.S. glass suppliers, including transfer from Japan of product technology, coupled with high-quality, high-yield glass supplies, has provided an important materials cost advantage to TDD.
- Despite rapid improvement, the learning curve for TDD was not as steep as a comparable Japanese plant due to higher employee turnover and a less experienced work force.
- Although the initial motivation for Toshiba's investment in American production facilities was to ensure continued market access in the face of protectionist pressures, TDD proved to be a low-cost producer once initial start-up difficulties were overcome. The United States effectively provides a favorable manufacturing environment for this product.

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CONCLUSIONS

Of the three major factors in site location consideration—access to markets, access to technologies/capabilities, and access to low-cost—the first was most significant in Toshiba's

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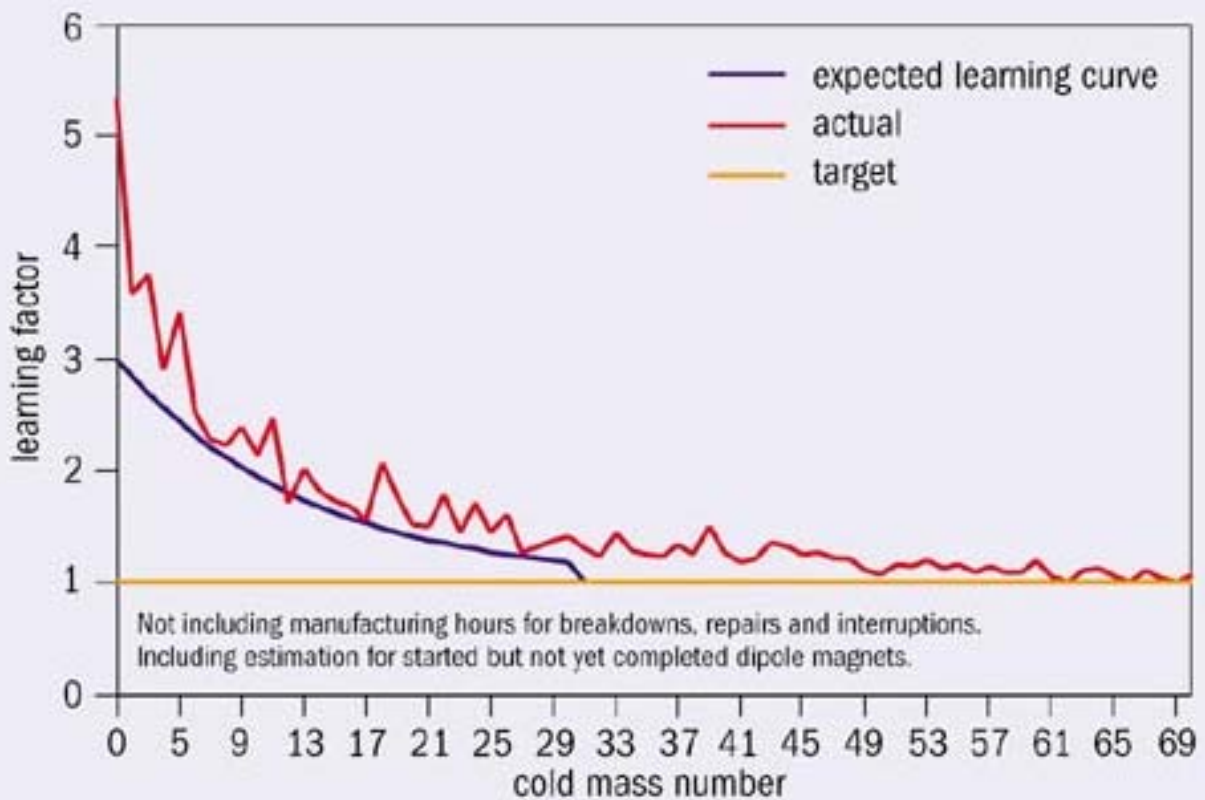
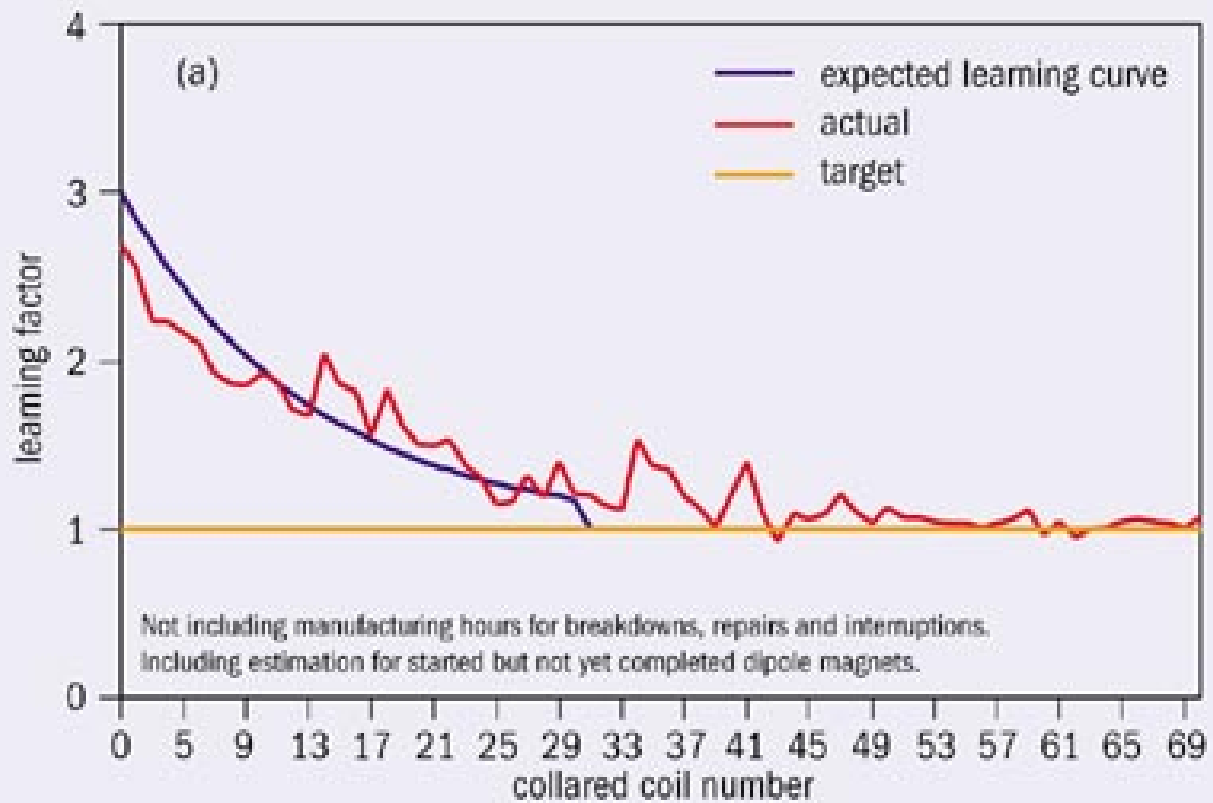
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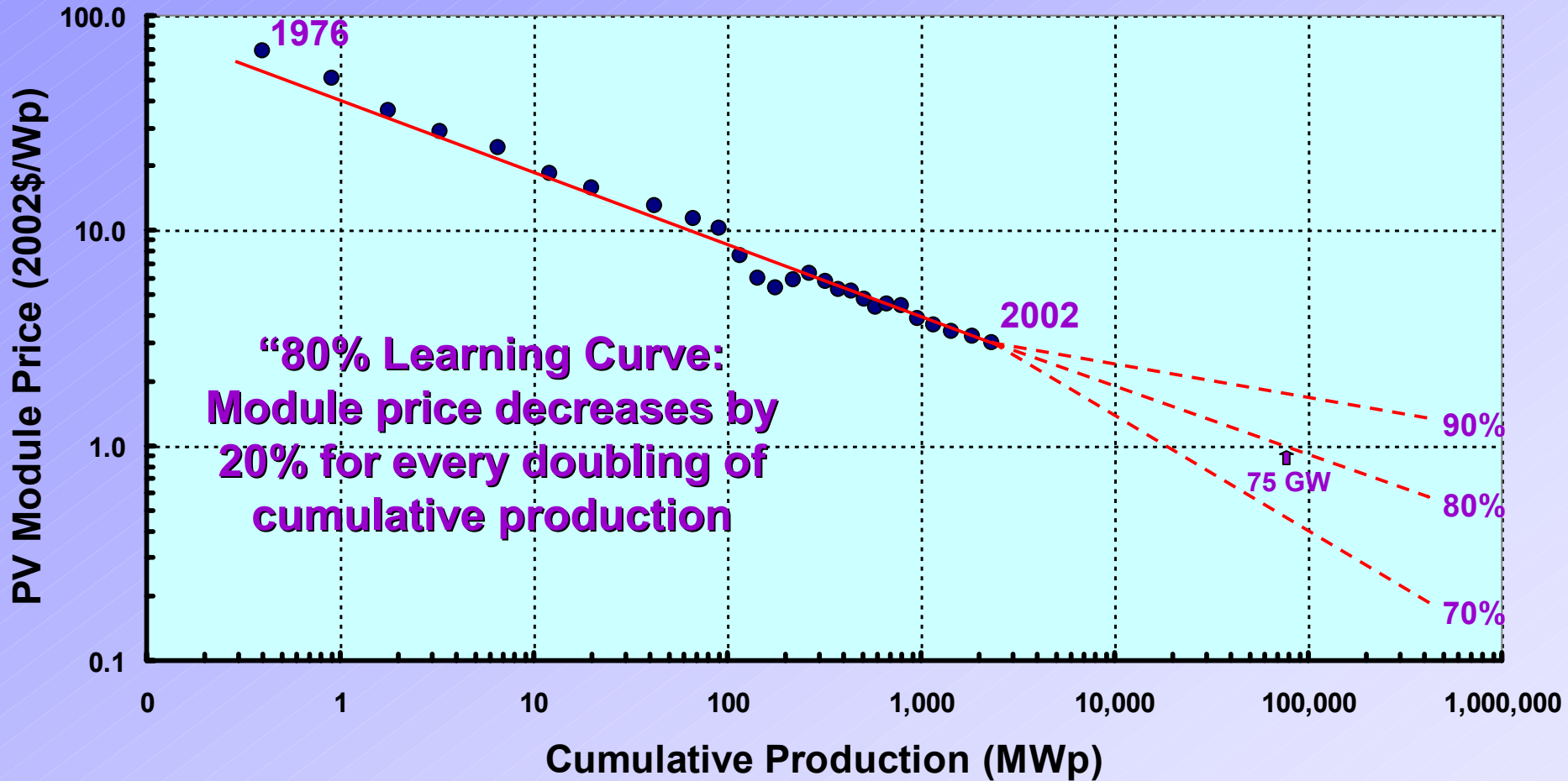
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LHC dipole production begins to take off



PV Module Production Experience (or “Learning”) Curve



BCG Publications

The Experience Curve-Reviewed - III. Why Does It Work?

Cost of value added declines approximately 20-30 percent each time accumulated experience is doubled.

This is an observable phenomenon. Whatever the reason, it happens. Explanations are rationalizations.

The whole history of increased productivity and industrialization is based on specialization of effort and investment in tools. So is the experience curve. It is a measure of the potential effect of specialization and investment.

Learning

Workers learn. If they learn to do a task better, they can do it in less time. This is equivalent to producing more in the same time. Characteristically, output can increase 10-15 percent each time total output is doubled. This is the well-known learning curve measure of man hour productivity increase. Based on the learning curve, labor costs only should decline 10-15 percent each time accumulated experience doubles.

Specialization

When scale of activity increases so that numbers of people are involved, then it becomes possible to specialize.

If two people are doing the same thing, it becomes possible to break the task into two parts. One person does all of one half. The other person does all of the other half. Each will therefore do his respective task twice as often for a given total output.

The learning curve described above predicts that with twice the experience the labor time should be reduced 10-15 percent.

Increase in scale permits such specialization. Consequently, each worker will approach a total experience at any point in time which would be twice as much as he could have achieved without specialization. Doing half as much but twice as often equals the same amount of effort but twice the experience with the task. Consequently, specialization permits 10-15 percent less time per unit or 10-15 percent more output in a given time.

If the scale doubles simultaneously with total experience, then these two effects should occur simultaneously. Costs decline 10-15 percent because of learning plus 10-15 percent because of specialization. The sum of 20-30 percent cost decline is alone an approximation of the total experience curve effect.

Where growth in output increases at any constant rate, then change in scale and change in total experience can and often do occur in parallel.

Investment

By definition, a profitable investment is one where money spent now results in a future payout that is larger than the original investment. All the return on investment comes in more output for the same total cost, but deferred.

If the cost of money is extremely high, then virtually no investment can be justified. If the cost of money

were zero, then any investment which would recover the investment and something more by eternity could be justified.

The cost decline in experience curves is a partial function of rate of investment. The control on this element is the cutoff rate on added investment. If the cutoff rate is high, costs decline slowly. If the cutoff rate is low, costs decline rapidly.

Return on investment does result in cost reduction. Without investment, capacity increase cannot occur and neither can cost reduction at constant capacity.

A significant part of the experience curve cost reduction is the result of return on investment.

Scale

The experience curve effect is the result in part of increased scale. Yet there is no justification for increased scale unless there is growth. There is no need to add capacity at all.

With growth there is constant addition of capacity. Each added increment of unit capacity becomes a smaller percent of the total capacity unless size of the increment is increased also. Both capacity utilization and scale effect are affected by growth.

The effect of scale is well known though very difficult to measure precisely. There is, however, a formula which is known to approximate scale effect in the process industries.

"Capital cost increases by the six-tenths power of the increase in capacity."

This exponential change is equivalent to an increase of 52 percent in capital cost to provide a 100 percent increase in capacity. The total capital cost became 152 percent instead of 100. The total output became 200 instead of 100. The average became $152/200 = 76$ percent of 100 percent. That is a very common and typical experience curve cost decline rate.

Average production unit size normally increases in proportion to rate of total output or even faster. If it does, then capital cost should go down as fast or even faster than in proportion to a 76 percent experience curve.

Since capital tends to displace labor over time, then this scale effect becomes increasingly important with growth in volume and experience.

There are limits on scale due to load factors and logistics provided there is a finite total market. But if the total market grows, then scale can be expected to grow too.

Scale effect applies to all operations, not just process plants. Marketing, accounting and all the overhead functions have scale effects also.

Scale effect alone is sufficient to approximate the experience curve effect where growth is constant and scale grows with volume.

For most products, a 70-80 percent slope is normal, with the steeper slope for those where the maximum value is added and where shared experience with slower growth areas is least. However, it is probable that few products decline in cost as fast as they could if optimized.

It is a known fact that costs are more certain to decline if it is generally expected that they should and will.

It must be remembered that experience curve costs are not accounting conventions. They are cash flow rates divided by output rates. Accounting data is an approximation of this but generally tends to show lower average costs since assets are deferred recognition of cash expenditures.

This means that cost of capital and return on capital from value added are both included in experience curve costs. Trading profits or losses from price levels are excluded from this cost calculation.

Experience curve costs on the above basis are probably more accurate representations of cost than any accounting convention, since they are based on cash flow only, not projections, and because such costs include the cost of capital.

The reasons for the experience curve effect are not particularly important. The important fact is that the experience curve is a universally observable phenomenon. If costs do not go down in a predictable fashion, then, and then only, do the underlying reasons become important. Analysis will usually show the reasons to be inadequate investment, improper value added definitions or occasionally just mismanagement.

Summary

The experience curve is the result of the combined effect of learning, specialization, investment and scale. The effect of each of these is an approximation, and so the experience curve effect itself is also an approximation.

The combination of these factors should permit a considerably steeper experience cost curve than is actually observed. However, some additional overhead cost is introduced by the need to coordinate and plan these changes.

All elements of cost do not have the same experience base. Also, some cost elements share experience with other products.

Consequently, only new and unique products with completely new cost elements can be expected to go down the cost experience curve with the maximum slope.

Bruce D. Henderson

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