Problem

Throughout the past forty years, the learning curve has been the accepted technique to analyze manufacturing labor costs of various products. The underlying assumption is that labor hours expended per unit will decrease as the production of same-type units increases. The learning curve is a model used to predict the relationship between the amount of labor hours expended per unit and the number of units produced.

The traditional learning curve is an exponential function which takes into consideration the following: number of units produced; average cost per unit; cost of the first unit produced; and a constant representing the relationship between average cost per unit and units produced. The function is converted to a logarithm for ease of interpretation.

Applications of the learning curve have been generally limited to only one product line, therefore, in the case of aircraft production, only one aircraft model is studied. When a new aircraft model is developed, the learning curve of a previous aircraft with similar characteristics is used. This approach, while not inherently wrong, provides only limited information, since the traditional learning curve only considers units produced and the costs per unit. Clearly there are other factors besides these two variables which influence labor hours per unit.

This study modifies the traditional learning curve to incorporate: production strategy; work force experience; technological change; and initial investment factors to represent an aircraft manufacturing environment. Each factor will be described below.

The first factor, production strategy, pertains to overall policies that have affected production. For example, to meet wartime efforts, the federal government told airplane manufacturers the number of planes to be produced daily. Design or production of commercial aircraft was allowed only if it did not interfere with the much needed military aircraft. Still today, airplane manufacturers have had to change manufacturing practices to meet stricter FAA regulations while attempting to increase production to meet the demands of operators who are replacing their aging fleets.

The second factor is work force experience. Because the number of aircraft orders has fluctuated throughout the past forty years, experience levels have also fluctuated. The most obvious example of a fluctuating experience level is during World War II when women, with little to no manufacturing experience, were needed to help produce planes to meet the war effort. During the years of limited aircraft orders, the experience level of work force actually increases, since the employees with the least experience are generally the first to be laid off.

The third factor is technological change. This factor is represented in the data by the type of aircraft considered. That is, the DC1 is technologically less sophisticated than the DC8. Advances in the technology of aircraft engines, avionics, and electronics have allowed aircraft manufacturers to build larger, more powerful and fuel efficient planes.

The final factor is initial investment (or capital investment). This factor considers the effects of the amount of initial investment in engineering design efforts and plant, equipment, and tooling. Intuitively, it would seem that a large investment in development would decrease the number
of hours needed to build a plane because each design and assembly effort would be fully documented and tested. A thorough design test program lessens the chance of having to stop the production line for design changes. Erratic production rates and frequent line changes usually result in higher per unit manufacturing costs.

Nine different aircraft programs (DC1/DC2, DC3, C47, C54, B17, C124, DC6/DC7, C133 and DCB) that have been produced at the Douglas Aircraft Company during the past fifty years will be used to identify the relationships between the above four factors and labor hours per unit. With a better understanding of these factors and how they affect unit aircraft labor costs, prediction of future production costs become more reliable.

Significance of Problem--Why This is a Worthy Project?

To determine the relationship between the above factors and unit labor hours, ordinary least squares (OLS) will be used. OLS gives equal weight to the differences between programs and the differences within programs. Therefore, OLS emphasizes outliers. When trying to fit a regression line to data, OLS tends to pull the line in the direction of these outliers.

If all that was needed was to fit an individual aircraft program, then this emphasis on the outliers would be an important consideration. However, we are concerned with generalizing across programs and eventually predicting unit labor hours for future aircraft programs. Therefore, less emphasis should be given to these outliers and more emphasis given to inherent differences between program.

L2 norm estimation provides us the necessary framework to analyze the differences between programs without overemphasizing the within program differences.

Using L2 norm estimation, each program is considered to be a function. Thus since we have nine different programs, we have nine different functions which will be considered as a family of functions. In contrast to OLS which fits a line of best fit to individual points, L2 norm estimation fits a function to the nine learning curves. That is, we will be willing to make one program fit less well, if we can obtain a significantly better fit in another program.

Because L2 norm estimation is a numerical analysis technique and the equation we are trying to solve is a forth-order polynomial, too much time would be required to find a solution. Thus, PROC SYSLIN will be used to help search for a function to fit the nine learning curves. (See below for information on obtaining a program listing.)

Overall, the significance of this problem lies in how well we can fit a function to the nine learning curves using L2 norm estimation. Currently we have not been able to meet our specified criterion for convergence, but then again this project is still in its early stages.

Summary

Even though there is still work to be done on this project, this paper presented a new approach to obtaining information from previous product lines, or in this case, previous aircraft programs. This information can then be applied to existing or future aircraft programs as a tool to help predict labor hours per unit.

Clearly the most difficult task of applying this work to other manufacturing environments is the time spent specifying the factors that drive labor hours. Once the factors are determined, then the variables that can be used to measure these factors need to be decided. Of course once the variables are chosen, the most difficult task of all remains—collecting the data!
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References


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