CASE STUDY:
FORECASTING THE PRODUCTIVITY OF PROFESSIONAL SERVICES

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PREVIEW

In this case study of an architectural/engineering firm, Tonya, Ram, and Robert offer a new technique for projecting the scope and costs of professional-service projects. They utilize historical monthly data to estimate relationships between project outputs on one hand and labor inputs and prior experience on the other. Their model promises to be an upgrade for firms that traditionally develop judgmental projections without the benefit of formal statistical analysis.

THE CHALLENGE OF PRODUCTIVITY ESTIMATION

Professional-service firms (engineering, consulting, legal, architectural, etc.) provide business solutions to their clients. Productivity is measured by these firms in multiple ways. A software-engineering firm may measure productivity as the number of lines of standardized code, a consulting firm on how quickly it provides the client with effective solutions, or, as in our case study of the architectural/engineering firm, as the number of design pages it produces per unit of labor.

For these firms, estimation of productivity – prior to project specification – is a critical requirement. An accurate estimate enables the company to provide a fair and deliverable time schedule and develop realistic fees for the project. It also helps the professional-service firm budget and efficiently allocate resources to execute the project. Additionally, a critical examination of productivity metrics leads to insights on how different processes in the business can be streamlined.

Accurately estimating productivity in these companies, however, is notoriously difficult. Most projects are unique and customized to client needs. Professional-service firms also undertake numerous projects that require multiple disciplines to cooperate while seeking client solutions. Even similar-sounding projects – installations of commercial HVAC systems by an engineering firm, say – can be very different based on the client and installation site. Such a project might focus on energy efficiency in a "green building," noise and precision temperature control in a research lab, and historical conservation in architecturally protected buildings. Seemingly similar projects may have quite different project specifications and labor and materials requirements.

When professional-service managers meet potential clients, understanding productivity is a key consideration. It helps estimate how quickly and at what cost a project can be done. In these cases, however, there are few tools available to enable managers to generate rough-cut estimates of productivity and, correspondingly, the project cost and schedule. Using the architectural/engineering industry as an example, we show how managers can measure the productivity of engineers and architects with readily available data from past projects.

Key Points

1. Forecasting the productivity of professional services (engineers, consultants, lawyers, architects) is difficult because projects undertaken by professional-service firms tend to be highly variable, often require multiple types of solutions, are nonrepetitive, and are customized specifically to client needs.

2. Models that predict productivity based on historical project information can be useful. Using an architectural/engineering (A/E) firm as a case study, we developed such a model. It requires only information from past projects – readily available – that managers can use to predict the productivity of future projects.

3. The model provides estimates of project outputs (in this case, the design pages produced in a month) that came within 10% of actual design pages in the historical database. It also provides insights into how well professional-service firms learn and how they can leverage their knowledge base.

4. One key for these firms is the need for knowledge leaders – designers with the requisite expertise and knowledge of past projects – whom colleagues can approach to solve current problems.

THE CASE STUDY

The Firm. Our A/E firm provides a wide mix of architectural and engineering design services, including architectural building design; landscape architecture; mechanical, electrical, and civil/structural engineering; environmental-impact assessment; and fire protection. The firm is organized into four discipline-related units: Civil/Structural, Electrical, Mechanical, and Architectural. When a client initiates a design process, the unit with key expertise is designated as the lead and works with engineers and architects in the other disciplines. In a project to light a baseball field, the Electrical Unit will take the lead, but a civil/structural engineer will be necessary to study topographies and design the platform and structures for mounting the lights, and a mechanical engineer will be required to design storm drainage.

To begin, the engineers and architects visit the client's site, examine and evaluate design parameters and constraints, and then budget labor hours (the "input") across the multiple disciplines involved for completing the task. The team of architects and engineers works collaboratively with the client to complete the project. The product is a series of unique computer-aided-design (CAD) pages (the "output") that specify the design.

The Data. The A/E firm provided us with historical data on the total labor hours worked each month and the number of pages of output that were generated for client projects that month. The data spanned 85 months, starting in 1993 and ending in 2000.

The Model. The model employs a simple production function to estimate the number of pages (output) based on labor hours and design experience (input).

Mathematically, we can express it as:

Pages = Intercept + a* Labor Hours + b Prior Experience + Error

Pages: number of pages of design produced in a month

Labor Hours: number of hours of labor used during the month on this project

Prior Experience: total number of design pages produced up to this month

As is traditional for production-function estimation, all variables are expressed in natural log form (ln), so that the coefficients "a" and "b" represent estimates of the percentage change in output per 1-percent change in each input.

Learning

Built into this production function is the premise that experience improves productivity. Popularly called the learning curve, this phenomenon was first documented by T.P. Wright (1936) in his study of aircraft production. Wright observed that productivity increased by 20% for every doubling of output. His model has since been applied to many manufacturing industries, although there is a wide inter-industry variation in the rates at which firms learn. For a brief tutorial on the learning curve, see http://maaw.info/LearningCurveSummary.htm

In addition to requiring knowledgeable engineers and architects, the success of a design project depends on the experience and insights gathered from past projects, which have produced multiple pages of design knowledge that can now be mined. Over time, productivity gains will depend on the ability of highly trained professional engineers and architects to locate, interpret, and partially reuse or adapt prior designs.

Results

Our statistical results are shown in Table 1.

Table 1. The Estimated Production Function

Variables	Estimated Coefficients
Labor Hours	a = .8831*
Prior Experience	b = .1811*
Intercept	-4.009*
MAPE	9.7%

All coefficients are statistically significant at the 5% level

To forecast the monthly output of any project, the firm would enter monthly values for labor hours scheduled as well as the cumulative total of prior pages produced. For example, in March of 1998, the firm had scheduled its engineers for 3359 hours to work on client projects. The firm had designed 3131 pages in the 7 years of operations prior to this month. The following calculations get an estimate of the number of pages designed that month.

Estimate of *Pages* in March
1998 = -4.009 + 0.8831*ln(3359) + .1811 *ln(3131) = 4.6189
To get the estimate of pages in March 1998, we take the exponent of the logarithmic estimate:
Exp(4.6189) =101.38 pages.

The actual number of pages the firm designed in March 1998 was 98. The model in this case was off by 3.38 pages, or a percentage error of 3.5%.

Model Implications

In addition to the estimation of outputs, the model provides important clues about how A/E firms leverage their experience. The model suggests that past experience is significant in predicting productivity. Based on the value of the "b" parameter, we report that the firm improves productivity by about 12% for every doubling of experience (from the log-linear model, the savings for every doubling of design pages can be interpreted as $1\text{-}2^b$ [see Boone et al., 2008]).

Productivity gains in this firm arose from two sources: first, electronic copies of all designs were maintained in a centralized repository which was accessible to all of the firm's architects/engineers. Moreover, these projects were indexed, so an engineer working with a client could access the index and search for similar projects.

Second, this was a close-knit A/E firm. The engineers and architects knew each other well. When project teams faced specific client problems, several of the senior engineers and architects were able to steer those teams to past projects with similar challenges and to appropriate persons on the design staff for consultation.

The A/E manager can also use the model as a starting point for cost and schedule estimation. When engineers and architects are scheduled for a specified number of labor hours in the upcoming month, the model will estimate the expected output. This gives the manager an estimate of how quickly a portfolio of projects can be completed. If firms have estimates of both direct (labor) and indirect (cost of operating the firm irrespective of labor) costs, a preliminary cost estimate can be obtained.

Model Accuracy

Figure 1(a). Predictive Versus Actual Output

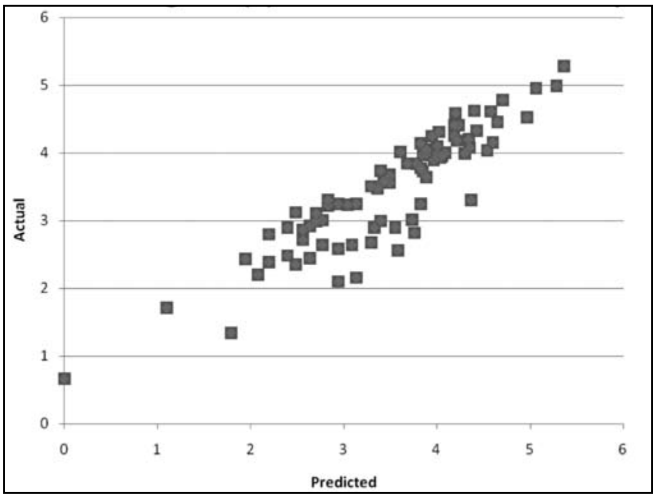


Figure 1(a) plots the model predictions of total pages/month against the actual pages on a logarithmic scale. Figure 1(b) shows the distribution of percentage errors. The model predictions are within 5% for 33 of the 85 months used in the model. This is a significant improvement from traditional methods of forecasting productivity in A/E, methods that rely on naïve forecasting models.

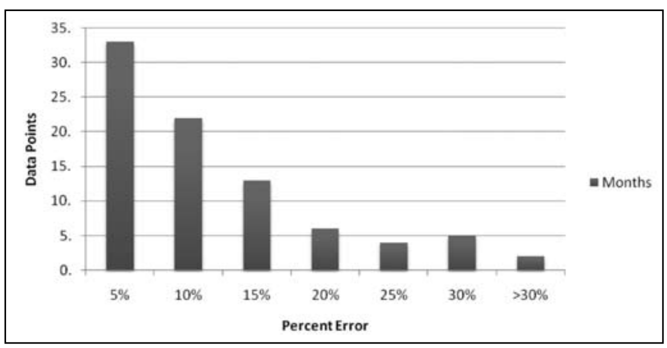
However, in 11 of the 85 months, the error is higher than 20%. These months required either a high dosage of labor for few pages of output (suggesting a small but very complex portfolio of projects in that month), or produced many pages with very little labor (suggesting the projects were easily reproduced or adapted from past designs). While our model does not specifically account for such situations, A/E managers can make ad hoc adjustments to the estimate based on the current project portfolio.

CONCLUSIONS

Implicit in our model is a strategy to improve productivity. First, a firm needs to archive and index designs and build them into a knowledge system that all staff designers can access. Then the business needs to create *knowledge leaders* – designers with the requisite expertise and intimate knowledge of past projects – who can be approached by project teams to solve current problems. Third, by tracking unit costs (either cost/page or cost/hour), the firm can monitor how efficiencies accrue and plan for them in budgeting future requirements.

We have provided a relatively simple model for service firms to predict productivity on new projects, based on the historical production function linking inputs and outputs. The model has minimal data requirements – only labor hours and design pages. In addition to estimation, this model also provides insights into how service-firm managers can think about productivity improvements.

Figure 1(b). Distribution of Percent Error



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