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Acquiring advanced engineering technologies under conditions of performance improvement

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Abstract

To remain competitive, firms need to develop long-term strategies for acquiring and using advanced engineering and manufacturing technologies. In addition, technology managers are under increasing pressure to produce better results, with less time and risks, and with fewer resources. A resulting trend is a greater use of external relationships and resources to achieve the needed technological accomplishments with greater efficiency. However, there are numerous alternatives for obtaining internally and/or externally the personnel and equipment components of advanced technologies. A mathematical model which identifies the optimal means for acquiring the components for advanced engineering technology requirements, allows the engineering technology resources to be internal or external to the firm, and allows the personnel and equipment to have realistic nonlinear performance improvement (learning) or decay capabilities should be of interest and use to both technology management researchers and practicing engineering/technology managers. The nonlinear integer programming model described herein provides this capability. A comprehensive and realistically based example problem is provided and an optimal solution is obtained and compared with the results of more common, but also more expensive, solutions. Numerous future research extensions are offered.

Keywords: Engineering technology acquisition; Engineering technology management; Performance improvement; Modeling; Nonlinear mathematical programming; Integer programming

1. Introduction

A manufacturer of small gasoline engines wishes to redesign some of their models to reduce noise levels. A Midwestern firm producing heavy construction equipment desires to reduce the loping in the bulldozers it sells. A large auto manufacturer must decide how to reduce the weight of its vehicles

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without compromising safety or comfort. Finally, a company producing transmissions for trucks desires to reduce the material (and, therefore, the cost) of transmission casings by reducing their thickness, but the casings must withstand common road conditions and operate reliably. What do these seemingly dissimilar projects have in common? They all were actual and each required the use of advanced engineering analysis (e.g. finite element modeling, thermodynamic analysis, and computer simulation) to achieve a solution.

All projects involved engineers and equipment (hardware, software, testing equipment, etc.) from *both* the manufacturing company (internal) and engineering consulting firms (external). This *blending* of internal and external engineering resources is done for several reasons. Internal resources are typically less expensive per utilized time period; can be made readily available for assignments; are considered more controllable and potentially less disruptive; may pose less of a security risk; may already be familiar with the problem at hand, information sources, and organizational procedures; and may be aware of critical personnel sources (Gagnon & Mantel, 1987). However, specialized internal resources may require high capital costs and a fixed operating cost, whether they are used or not; external resources, on the other hand are contracted only when the specialized need or a lack of sufficient internal capacity is recognized (Bates & Lyle, 1979). Consultants typically market themselves as knowing the latest advanced technologies in their specialty areas and how to use them. They state that their prior experience (learning) can speed the completion of the project, thereby using less time, and resulting in a lower total project cost and an earlier achievement of project benefits (Bates & Lyle, 1979). Consultants can also be used as instructors to train the internal engineers as the project is ongoing thus preparing internal personnel to complete most, if not all, future projects (Gagnon & Mantel, 1987).

In addition, other factors tend to promote the use of external resources (or subcontracting) for portions or entire projects needing advanced engineering technologies. Harris, Insigna, Morone, and Werle (1996) write that R&D managers are under increasing pressure to enhance the productivity of their investments, i.e. accomplish more with fewer resources at a faster pace. Chatterji (1996) mentions three factors increasing the *availability* of technology from external sources: (1) scientific and engineering knowledge is growing at a more rapid rate globally in nearly all major disciplines, (2) the relative abundance of venture capital and the formation of numerous start-up companies and (3) the expanding pool of displaced talent resulting from re-engineering and corporate downsizing. A resulting trend is greater use of partnerships, collaborations and outsourcing as substitutes for in-house activities. Each of the four aforementioned projects used different combinations of internal and external engineering personnel and equipment resources. This provokes several important questions:

- What are the common alternatives (strategies) currently in use for blending internal and external engineering resources (personnel and equipment) to achieve solutions to projects requiring advanced engineering technologies?
- Since: (1) the amount of internal or external engineering resources employed for a project or set of projects can range from none to all;[2] (2) a technology consists of various personnel and equipment resource components; and (3) there are various means for acquiring each personnel and equipment resource component internally (purchase, lease, or hire) or externally (contractual arrangements, strategic alliances, acquiring controlling interest in a technologically progressive firm, or outright

[2] A project theoretically can be completed with all internal engineering resources (and no external resources), all external resources (and little or no internal resources), or numerous combinations between.