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Evaluating knowledge benefits of automotive lightweighting materials R&D projects

Jean H. Peretz [a,*], Sujit Das [b], Bruce E. Tonn [c]

[a] University of Tennessee, Institute for a Secure and Sustainable Environment, 311 Conference Center Building, Knoxville, TN 37996-4134, United States
[b] Energy and Transportation Science Division, Oak Ridge National Laboratory, Oak Ridge, TN, United States
[c] Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN, United States

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ABSTRACT

This paper presents a set of metrics used to evaluate short-run knowledge benefits that accrued from research and development (R&D) projects funded in fiscal years 2000–2004 by automotive lightweighting materials (ALM) of the U.S. Department of Energy (DOE). Although DOE presents to Congress energy, environmental, and security benefits and costs of its R&D efforts under the Government Performance and Results Act, DOE has yet to include knowledge benefits in that report [U.S. Department of Energy. (2007). *Projected benefits of federal energy efficiency and renewable energy programs: FY2008 budget request*. NREL/TP-640-41347 (March). Washington, DC: National Renewable Energy Laboratory for DOE Energy Efficiency and Renewable Energy. Retrieved February 12, 2007 from http://www1.eere.energy.gov/ba/pba/2008_benefits.html].

ALM focuses on development and validation of advanced technologies that significantly reduce automotive vehicle body and chassis weight without compromising other attributes such as safety, performance, recyclability, and cost [U.S. Department of Energy. (2005a). *Automotive lightweighting materials 2004 annual progress report*. Washington, DC: DOE Energy Efficiency and Renewable Energy. Retrieved March 30, 2005 from http://www.eere.energy.gov/vehiclesandfuels/resources/fcvt_alm_fy04.shtml]. The ultimate goal of ALM to have lightweighter materials in vehicles hinges on many issues, including the (1) collaborative nature of ALMs R&D with the automobile industry and (2) manufacturing knowledge gained through the R&D effort.

The ALM projects evaluated in this paper yielded numerous knowledge benefits in the short run. While these knowledge benefits are impressive, there remains uncertainty about whether the research will lead to incorporation of lightweight materials by the Big Three automakers into their manufacturing process and introduction of lightweight vehicles into the marketplace. The uncertainty illustrates a difference between (1) knowledge benefits and (2) energy, environmental, and security benefits emanating from R&D.

1. Introduction

This paper presents the results of an evaluation of research and development (R&D) projects funded during fiscal years 2000–2004 by the automotive lightweighting materials (ALM) effort of the FreedomCAR and Vehicle Technologies program of the U.S. Department of Energy (DOE). ALM focuses on the development and validation of advanced technologies that significantly reduce automotive vehicle body and chassis weight without compromising other attributes such as safety, performance, recyclability, and cost (U.S. DOE, 2005a). Funded projects range from applied materials science research to applied research in production environments. Collaborators on these projects include national laboratories, universities, private-sector firms such as leading automobile manufacturers and their suppliers, and non-profit technology organizations.

The specific goals of ALM are to develop by 2010 material and manufacturing technologies that, if implemented in high-volume production vehicles (between 50,000 to 100,000 units per year or greater), could cost effectively reduce the weight of light-duty vehicles by 50% (relative to 2002 comparable vehicles) (Carpenter et al., 2006; U.S. DOE, 2005a). The weight reduction results in energy, environmental, and security benefits, but the incorporation of lightweight materials hinges on many issues. In fact, we

* Corresponding author. Tel.: +1 865 974 4251; fax: +1 865 974 1838.
E-mail address: peretz@utk.edu (J.H. Peretz).

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contend that knowledge gained through the R&D process is a prerequisite.[1] We illustrate how knowledge may be measured qualitatively and quantitatively.

Priority lightweighting materials include advanced high-strength steels, aluminum, magnesium, titanium, and composites including glass- and carbon-fiber (U.S. DOE, 2005a). ALM activities support the lightweighting goals of the predecessor program, Partnership for a New Generation of Vehicles, as well as the on-going FreedomCAR program.

All R&D projects are *jointly* determined by the major partners in a collaborative effort. Among the partners are DOE, the national laboratories, the Big Three automakers, and automotive industry partners such as the United States Council for Automotive Research, FreedomCAR Materials Technical Team, Automotive Composites Consortium, and United States Automotive Materials Partnership (U.S. DOE, 2005a). The collaboration allows open discussion of critical needs and technical barriers. Then the teams select and prioritize projects to address these needs and barriers. It should be pointed out that the Big Three automakers are required to cost share in the funding effort (Das, Peretz, & Tonn, 2001, 2002, 2006). The intent is to carry out leveraged, high-risk research using targeted research projects that eventually transfer to the auto industry or its suppliers. Although not explicitly stated, ALM projects are contributing to the goal of an effective federal government/private sector cooperative effort to introduce new, highly fuel-efficient automobiles in the marketplace.

ALMs annual budget is around $17 million (Das et al., 2006; U.S. DOE, 2004, 2005a). DOE efforts on lightweighting automobiles have totaled more than $1.3 billion since the mid-1990s (National Research Council, 2001a). This federal expenditure continues a pattern of public-sector financial support of R&D that began in the mid to late 1800s (Nelson, Peck, & Kalachek, 1967; Scherer, 1965). While the rationale for government R&D expenditures is well-documented, there is growing interest from academia and by Congress (through legislation and hearings) for accountability on those federal R&D expenditures (Das, Tonn, & Peretz, 2004; Peretz, Das, & Tonn, 2005; Behn, 2003; Bozeman & Klein, 1999; Bozeman, Dietz, & Gaughan, 2001; Corley, 2007; Gelijns, Rosenberg, & Moskowitz, 1998; Heinrich, 2002; McLaughlin & Jordan, 1999; National Academy of Sciences, 1999; Nelson & Winter, 1982; Roessner, 2002; Scherer, 1965; Schwartz & Mayne, 2005). Calls for short-term evaluations, as is the case here, are not unusual (see, e.g., Das et al., 2004; Peretz et al., 2005; Link, 1997; National Research Council, 2000).

Section 2 of this paper presents the metrics applied by this research to evaluate the short-run knowledge benefits of ALM R&D projects. Section 3 introduces the nine ALM projects we evaluated. Results are in Section 4, and Section 5 offers conclusions and suggestions for future research in this area.

2. Evaluation methods

Economic analyses, bibliometrics, case studies, peer reviews, retrospective analyses, and benchmarking are methods commonly used for an overall evaluation of R&D projects (Bozeman, 1993; Alston & Beach, 1996; Alston, Norton, & Pardey, 1995; Ammons, 1995; Bozeman & Melkers, 1993; Brown, 1996, 1998; Chapman, 1999, 2000; Chapman & Fuller, 1996; Fischer, 1995; Fitzsimmons, 2001; Geisler, 1995; Griliches, 1998; Hamilton & Sunding, 1998; Hyde, Newman, & Seldon, 1992; Link & Scott, 1998; Martin, Gallager, & O'Connor, 2000; National Academy of Sciences, 1999; Papadakis & Link, 1997; Roessner, 2002; Rossi & Freeman, 1985; Scherer, 1965; U.S. GAO, 1997).[2] More recent evaluation literature suggests using multiple methods rather than just one, often combining quantitative and qualitative measures, such as benefit–cost ratios and peer-review judgments on the intellectual contribution of the R&D projects (Bozeman & Rogers, 2001; MacRae & Whittington, 1997).

The National Academy of Sciences' (NAS) Committee on Science, Engineering, and Public Policy (COSEPUP), after passage of the Government Performance of Results Act of 1993 (GPRA), developed a framework for evaluating both basic and applied federal R&D projects (National Academy of Sciences, 1999). The report suggests that the most effective means of evaluating federally funded R&D is through *expert review* that looks at[3]:

- *quality* of the research program in comparison with other work conducted in the research field;
- *relevance* of the research to the agency goals; and
- whether the research is at the forefront of knowledge *or* contributing to world leadership in research fields as measured through *benchmarking* by the expert panel.

With regard to evaluation methods used across DOE, it traditionally uses impact studies, peer reviews, and user assessments (Peretz et al., 2005). For example, DOE often has its R&D programs reviewed by committees of NAS's National Research Council.[4]

Selection of an evaluation method that matches the evaluation's goal is paramount to a successful evaluation (Langbein, 1980). In this effort, our goal was to measure short-run benefits of the DOE'S ALM R&D projects, with an emphasis on knowledge contributions. We define short-run as *immediate* results of an R&D effort. Although this paper focuses on short-run benefits, it should be noted that some indicators used (e.g., publications and number of graduate students participating in the R&D effort) could be considered long-run outcomes as measured through citation analysis or analysis of the career paths of undergraduate and/or graduate students (Peretz, Tonn, & Martin, 2002).

This emphasis on measuring knowledge is supported by recent evolving frameworks for evaluating DOE benefits in the R&D field, as well as the evaluation literature in general. Specifically with regard to DOE's R&D funding, in DOE's FY 2000 budget, the U.S. House Appropriations Subcommittee directed an evaluation on whether "benefits... have accrued... from the R&D..." programs funded by DOE since 1978 (National Research Council, 2001a, p. 1). The National Research Council (NRC) was charged with developing an evaluation framework that determined whether the benefits justified the expenditure (National Research Council, 2001a, p. 2).

To respond to the evaluation question posed by Congress, NRC developed a framework that attempts to systematically capture benefits that have accrued, paying particular attention to the reality that R&D occurs within a dynamic system of marketplace, technological, and societal changes. NRC developed an evaluation matrix that captures three classes of benefits: economic, environmental, and security (National Research Council, 2001a).[5] Economic net benefits are defined as changes in market value of goods

[1] Other federal agencies have also had an impact on lightweighting; for example, NASA's space program. There are other examples as well.

[2] Note that we are not focusing solely on efficiency in this discussion as one component of the Program Assessment Rating Tool federal agencies use in evaluating R&D research efforts. See National Research Council (2008) for a discussion of this evaluation.

[3] Evaluations using expert panels can be of on-going projects, prospective or ex ante, or retrospective or ex post. For example, an NRC expert panel reviewed R&D conducted on fossil energy.

[4] The National Research Council seeks reviewers who are considered "national experts" in a particular field to serve on review teams. The members may be from academia or industry research and development efforts.

[5] As Corley (2007) succinctly notes, focusing solely on productivity enhancement or economic value may shortchange the federal government's investment in R&D.