

# In Search of Strategic Operations Research/Management Science

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We define strategic OR/MS as “OR/MS work that leads to a sustainable competitive advantage.” We found evidence of strategic OR/MS in the literature of strategic information systems (SIS) and OR/MS. We examined 30 early examples of SIS, many of which contained OR/MS work. Many of the most successful had high OR/MS content, while the least successful contained none. The inclusion of OR/MS work may be a key to sustaining an advantage from information technology. We also examined the Edelman Prize finalist articles published between 1990 and 1999. We found that 13 of the 42 private sector applications meet our definition of strategic OR/MS.

(Strategy: Professional, OR/MS implementation)

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The importance of linking information technology (IT) and corporate strategy is broadly accepted. The idea of strategic IT was presented as early as 1983 (Parsons 1983), and it was popularized by the work of Porter and Millar (1985) on IT and competitive advantage. Porter and Millar defined IT as “. . . the information that businesses create and use as well as a wide spectrum of . . . technologies that process the information” (1985, p. 149). Information systems (IS) researchers capitalized on the idea of strategic IT, resulting in high-level managers with an IS focus (chief information officers) and in the *Journal of Strategic Information Systems*.

Operations researchers and management scientists, however, have been slow to realize the strategic importance of OR/MS, even though Porter and Millar’s definition of IT includes “technologies that process the information.”

OR/MS is often used to address strategic problems (Ormerod 1996, Williams 1994) but operations researchers have not developed a literature on OR/MS as a corporate strategic asset: there is no journal of strategic OR. Some examples in the information-systems-research literature, however, show that firms have

used OR/MS strategically. For example, as part of the Harvard Business School’s management-information-systems history project, Mason et al. (1996, p. 33) concluded:

FedEx is an archetype of a company that has succeeded by applying the scientific method to its operations. Models and analysis have informed many of [FedEx’s] crucial business-shaping decisions. In cases in which OR/MS wasn’t used . . . the company performed poorly.

Corporate strategists have also recognized the strategic value of OR/MS:

. . . a reservation system, with its yield management capacity, is arguably the single most important strategic asset of an airline (Loveman and Beer 1991, p. 4).

Bell (1998, p. 381) suggests that the primary impact of a successful strategy is that it creates a competitive advantage that is sustainable over a period of time, and he defined strategic OR (SOR) as operations research that achieves a sustainable competitive advantage. This definition of SOR parallels early definitions of strategic information systems (SIS) (Huff and Beattie 1985).

We examined the literatures of SIS and OR/MS to find evidence that firms can achieve a sustainable competitive advantage using OR/MS.

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## Strategic OR/MS in the Strategic Information Systems Literature

OR/MS work is often implemented within information systems; thus an IS that meets the definition of SIS might also include SOR. The research literature on SIS should provide evidence of SOR. We therefore looked in the MIS literature to find SIS that contained OR/MS work.

Kettinger et al. (1994) examined the performance over 15 years of 30 corporations that had recognized SIS (Table 1). These systems were implemented between 1971 and 1983. Kettinger et al. compared companies' profitability and market share to industry averages using financial data from the Compustat II

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### OR/MS is often used to address strategic problems.

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database. They then mapped the competitive positions of these 30 organizations based on changes in market share and profitability from prior to implementation of the SIS (stage 1) to two periods after its introduction, five and 10 years out, stages 2 and 3 (Table 2).

Several of these 30 organizations are recognized in the OR/MS literature for their OR/MS competency. For example, both American Airlines and Federal Express have won the ORSA prize for their OR work (Horner 1991). We attempted to assess the degree to which OR/MS played a role within the 30 SIS examined by Kettinger et al. (Table 1). To do this, we examined the literature, including case studies of the systems. We assessed the OR/MS content as medium or high when publications at the time of implementation provided evidence that the IS included an OR/MS model or algorithm. We assessed the OR/MS content as low when contemporary accounts made no mention of a model or algorithm. We also included system improvements made during the five- and 10-year periods when financial results were being computed. For example, because of system improvements American Airlines made by adding overbooking and inventory controls, we ranked its Sabre system as higher in OR/MS content than United's Apollo system (assessed as low OR up to 1986).

We assessed 10 of the 30 SIS as containing high or medium OR/MS content, providing direct evidence

that OR/MS has been a contributor to IS that have been recognized as being strategic. References to the model content of some of the systems assessed as having either medium or high OR/MS content include the following:

For Air Products and Chemicals, Inc., inventory management of industrial gases at customer locations is integrated with vehicle scheduling and dispatching. Their advanced decision-support system includes on-line data entry functions, customer usage forecasting, a time/distance network with a shortest path algorithm to compute inter-customer travel times and distances, a mathematical optimization module. . . . (Bell et al. 1983, p. 4).

American Airlines had begun utilizing reservations data to fine tune their operations and focus their marketing strategies. These accurate passenger inventories afforded the opportunity to control under/overbookings to jointly optimize passenger service levels and load factors (Copeland and McKenney 1988, p. 357).

ASAP (at Baxter International) . . . increases productivity and information while helping to control official/unofficial inventory expense. Provides the solution to the entire materials management chain of events (Konsynski and Vitale 1988, p. 12).

Federal Express Corporation has used operations research (OR) to help make its major business decisions since its overnight package delivery operations began in 1973 (Mason et al. 1996, p. 17).

. . . the (General Electric) factory can make 10 different types of motor frames with no manual adjustments to its machinery (Buday 1986, p. 60).

The system (at McKesson) is fully integrated. At the distribution center, the customers' orders produce. . . a map of the warehouse that shows employees where the products are and how to get them without retracing their steps (Schindler 1986, p. 50).

Xerox has several systems that automate the material-flow and manufacturing processes . . . another supplies master manufacturing schedules (Buday 1986, p. 62).

We then mapped the OR/MS ratings into Table 2 adding (H), (M), or (L) for high, medium, or low assessed OR/MS content to show the relationship with the success of the SIS based on the Kettinger et al. (1994) measures of market share and profitability.

Kettinger et al. (1994) concluded that 15 of the 30 firms were sustainers, including Air Products and Chemicals, American Airlines, Banc One, Baxter, Bergen, CIGNA, Dow Jones, Digital Equipment, Federal

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Company	System	OR/MS content	System launch
Air Products and Chemicals	Vehicle scheduling	High	1981
American Airlines	Reservations and pricing	High	1976
American Express	Preferential travel service	Medium	1980
Banc One	Transaction processing	Low	1977
Baxter International	Order entry	Medium	1980
Bergen Brunswig	Credit card processing	Low	1971
Chase Manhattan Bank	Credit card processing	Low	1971
Chemical Bank of New York	Information systems	Low	1971
Cigna	Risk assessment	Low	1980
Citicorp	ATM networking	Low	1977
Deere and Company	Parts and inventory	Low	1981
Digital Equipment	XCON expert system	High	1980
Dow Jones and Company	Satellite page transmission	Low	1975
Federal Express	Tracking and sorting	High	1980
First National Bank of Chicago	Asset management	Low	1983
Gannett Company	Satellite page transmission	Low	1982
General Electric	CAD/CAM application	Medium	1982
IBM	Marketing management	Medium	1983
Manufacturers Hanover	Global networking	Low	1981
McGraw-Hill	Marketing database	Low	1982
McKesson	Order entry	Medium	1975
Mellon Bank	ATM networking and transaction processing	Low	1972
Merrill Lynch and Company	Cash management	Low	1978
Nucor	Tracking and billing	Low	1982
Owens-Corning Fiberglass	Materials selection	Low	1976
Philadelphia National Bank	ATM networking	Low	1979
Procter and Gamble	Customer response database	Low	1974
United Airlines	Reservation	Low	1976
Toys 'R' Us	POS inventory tracking	Low	1981
Xerox	Materials flow and scheduling	High	1982

**Table 1: Kettinger et al. (1994) identified 30 strategic information systems for which we estimated the OR/MS contributions.**

Express, Gannett, IBM, McKesson, Nucor, Owens, and Toys 'R' Us. Seven of the 10 systems that we assessed as having high or medium OR/MS content are represented in this group. Kettinger et al. included among their 15 sustainers five firms (Banc One, CIGNA, Dow Jones, Gannett, and Nucor) that showed increased market share but decreased profitability from stage 1 to stage 2 and from stage 1 to stage 3. The evidence that these firms achieved a sustainable competitive advantage seems weak. We assessed all five IS in this group as low in OR/MS content.

Seven of the 10 IS that we rated as having high or medium OR/MS content belonged to firms Kettinger et

al. considered to be sustainers, supporting the view that these systems were SIS. We assessed only three of the 20 IS for which Kettinger et al. found little evidence of sustainability as having high or medium OR/MS content.

Our assessment of OR/MS content is subjective but conservative. We assessed OR/MS content as high or medium only when we found clear contemporary evidence to support this conclusion. The contemporary information about firms' IS is seldom complete, and some systems may have contained greater OR/MS content than we recorded.

We hypothesize that OR/MS played a role in sustaining competitive performance in 70 percent of the

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		Change in performance Stage 1 to 3			
		Profitability down		Profitability up	
		Market share down	Market share up	Market share down	Market share up
Change in performance Stage 1 to Stage 2	Market share up Profitability up				Air Products and Chemicals (H) American Airlines (H) Bergen (L) DEC (H) Federal Express (H) Toys 'R' Us (L)
	Market share down Profitability up	General Electric (M) First Chicago (L) McGraw-Hill (L) Philadelphia NB (L) Xerox (H)	Deere and Company (L) Manufacturers Hanover (L)	IBM (M)	McKesson (M)
	Market share up Profitability down		Banc One (L) Cigna (L)		Baxter (M) Owens-Corning (L)
	Market share down Profitability down	Chase (L) Mellon (L) United (L)	Dow Jones (L) Gannett (L) Nucor (L) Citicorp (L) Merrill Lynch (L) Procter and Gamble (L)	American Express (M) Chemical Bank (L)	

**Table 2: The competitive positions for the 30 companies (from Kettinger et al. 1994) show changes (up or down) in market share and profitability between stage 1 (five years prior to implementation) and stage 2 (five years after implementation) and between stage 1 and stage 3 (10 years after implementation). The OR/MS content is indicated by (H), (M), and (L) (high, medium, or low).**

10 SIS for which market share and profitability data support classifying these IS as SIS. While this approach may be simplistic, it does provide support for viewing some OR/MS work as strategic by providing the firm with a sustainable competitive advantage by contributing to the success of an SIS.

### Strategic Operations Research in Published OR/MS Applications

Searching the OR/MS literature for OR/MS work that contributes to sustained competitive advantage is com-

plicated by the difficulty of observing a sustainable competitive advantage directly. Bell (1998) suggested that the existence of SOR could be supported by:

- evidence that the corporate chief executive officer (CEO) was aware of the OR/MS activities and of their importance,
- identification of the particular OR/MS work as a strategic asset,
- evidence that OR/MS people regularly participate in corporate decision making, and
- observable reactions by competitors to the OR/MS work, including attempts to replicate the

work, the spinning-off of new OR/MS businesses from successful OR/MS corporations, and perhaps industrial restructuring.

Using this secondary evidence, Bell (1998) identified some organizations (American Airlines Decision Technologies (now renamed Sabre Decision Technologies),

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## Strategic OR/MS applications must be long-term focused and sustained.

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AT and T, and Federal Express) in which OR/MS appears to play a strategic role and perhaps generates sustainable competitive advantage.

We attempted to identify OR/MS work that meets Bell's definition of SOR as "OR work that creates a sustainable competitive advantage" in papers published between 1990 and 1999 from the Edelman Prize competition.

One basic premise, derived from the resource-based view of the firm (Barney 1991, Wernerfelt 1984), is that financial gains achieved through OR/MS, not currently easily achieved by the firm's competitors, can be a source of a sustained competitive advantage. In publications on OR/MS applications, authors usually discuss the financial consequences of the work and any gains in the firm's competitiveness. They rarely discuss the sustainability of the gains or what would prevent competitors from quickly replicating the OR/MS and eliminating any first-mover advantage.

We analyzed all Edelman finalist articles for the period 1990–1999 and identified 42 private-sector OR/MS applications. We examined these 42 applications from a traditional strategic management perspective and in light of dimensions outlined in the published research on SOR and SIS. We hoped to assess the extent to which the applications might be strategic and to differentiate the application of OR/MS to strategic problems from strategic OR/MS as defined by Bell (1998).

To analyze the OR/MS applications, we relied on concepts from studies of SIS (King and Sabherwal 1992, Neo 1988, and Sabherwal and King 1991) and from strategy and strategic management. We examined the applications using six strategic dimensions: initiation, corporate strategy, form of advantage, competitive forces, organizational change, and level of

managerial support or involvement. We also examined the level of costs and benefits, and grouped the works by OR/MS tools used, form of managerial use, and by the originator of the OR/MS expertise.

## Initiation

Initiation of the work can be through a problem, crisis, or opportunity and refers to the reasons for the activity as discussed by Mintzberg, Raisinghani, and Theoret (1976, p. 251):

Decisions may be categorized by the stimuli that evoked them along a continuum. At one extreme are *opportunity* decisions, those initiated on a purely voluntary basis, to improve an already secure situation. At the other extreme are crisis decisions, where organizations respond to intense pressures. Here a severe situation demands immediate action. . . . opportunity and crisis decisions may be considered to form two ends of a continuum. *Problem* decisions . . . fall in between, evoked by milder pressures than crises.

## Corporate Strategy

An OR/MS application can affect three levels of corporate strategy (Hofer and Schendel 1986):

(1) Corporate strategy concerns what businesses the company should be in and where it does business. It tries to achieve competitive advantages within industries through business synergy.

(2) Business strategy concerns how to compete in industry or product-market terms and focuses on specific competitors and specific functions.

(3) Functional strategy concerns maximizing resource productivity and focuses on specific products or processes.

## Form of Advantage

Firms can achieve a competitive advantage through three basic strategies: cost leadership, differentiation, and focus (Porter 1980). To become the low-cost producer in its industry, a firm may rely on economies of scale, superior technology, or access to raw materials. To differentiate itself from others in its industry, a company would concentrate on qualities that many customers consider important and try to satisfy those needs. To focus its efforts, a firm would choose a segment

within its industry and try to serve that segment more efficiently than its competitors, through either cost or differentiation.

## Competitive Forces

Porter (Porter 1980, Porter and Millar 1985) identified five key competitive forces: (1) entry of new competitors, (2) threat from substitutes based on other technology, (3) bargaining power of buyers or customers, (4) bargaining power of suppliers, and (5) competition from established companies. Firms seeking a competitive advantage must defend against these competitive forces and make plans to influence them.

## Organizational Change

Because much OR/MS work is easy to replicate, creating a sustainable competitive advantage usually requires some firm restructuring (Bell 1998). This restructuring motivated by the OR/MS model results might be the purchase of capital equipment, changes in union contracts, or changes in plant or warehouse locations. While competitors may be able to buy the OR/MS work, the needed organizational change often takes time, providing the first-mover with a sustainable advantage. We therefore looked for evidence of organizational restructuring motivated by the OR/MS models.

## Level of Managerial Support or Involvement

Gerstein and Reisman (1982) noted that the rift between IT specialists and managers is the greatest hindrance to the adoption of computer technology for competitive advantage. Successful SIS usually depend on managerial involvement and knowledge of the work. Bell (1998) argued that if a firm's OR/MS work was strategic, senior managers would know about it and support it.

## OR/MS Tools

We characterized the applications according to the OR/MS tool(s) used: (1) mathematical programming (optimization), (2) queuing, or (3) simulation. We also

identified whether they involved decision-support systems (DSS), and if so, what level of management used the DSS.

## OR/MS Expertise

To identify whether the OR/MS resource was specific to the organization or transferable, we characterized the OR/MS experts as (1) internal, (2) outside consultants, or (3) academics.

## Other Information

We tried to identify the costs and benefits (financial and intangible) for each application. We also identified applications by industry type and by the issue or problem tackled.

## Data Sources

Each January-February issue of *Interfaces* publishes papers by the finalists for the Franz Edelman Award for Achievement in Operations Research and the Management Sciences, now in its 29th year. The Edelman papers describe some of the most effective OR/MS applications, and they are an excellent source for information on strategic OR/MS activities. We analyzed the 42 corporate applications published between 1990 and 1999 to identify SOR applications.

## Analysis of 42 Corporate Edelman Prize Finalists

We analyzed the OR/MS activities along six dimensions (Table 3): initiation, corporate strategy, form of advantage, competitive forces, organizational change, level of managerial support, and for OR/MS tools, and OR/MS expertise.

Problems (50 percent) or opportunities (50 percent) motivated most of these applications. We would expect applications responding to crises or problems to be inward looking and geared towards preserving the structure of the organization. Applications directed towards opportunities are more likely to take the firm in a new direction or to change its structure. The high number of opportunistic projects suggests that firms are applying OR/MS techniques proactively and in ways likely to initiate strategic change, not simply to

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Dimensions		Composite score	
		Raw	as % of identified
Initiation	Problem	21	50%
	Crisis	5	12
Corporate strategy	Opportunity	21	50
	Functional	26	62
	Business unit	16	38
Form of advantage	Corporate	6	14
	Low cost	32	76
	Differentiation	13	31
Competitive forces	Focus	4	10
	Suppliers	8	20
	Competitors	23	56
Organizational change	Customers	26	63
		16	38
Level of managerial support	CEO, president, or directors	10	33
	Vice-president	15	50
OR/MS tools	MP	28	67
	Queuing	3	7
	Simulation	12	29
	DSS	27	64
	Other	11	26
OR/MS expertise	Internal	32	76
	Consultants	7	17
	Academic	17	40

**Table 3: We calculated composite scores for the six strategic dimensions for each level, for OR/MS tools used, and for source of OR/MS expertise for the 42 applications; the maximum value attainable is 42 if all projects exhibited that characteristic. The totals may exceed 42 as levels are not exclusive; for example, a study could use simulation and be a DSS.**

refine current practice. Also, pursuing opportunities should promote OR/MS work that competitors cannot readily duplicate.

Most of the finalist articles (62 percent) are applications at the functional level, indicating that firms focus primarily on doing what they do better. Bell (1998) argued that functional-level OR/MS activities can provide a sustainable competitive advantage and hence be strategic; for example, both Harris Semiconductor and GE Capital report having achieved an advantage sustained over a number of years from functional-level applications.

Many (52 percent) of the applications target business and corporate levels of strategy, indicating that firms use OR/MS to create new business and to change the way they compete. Such applications may be original and nontransferable, enabling firms to sustain an advantage.

We judged over 76 percent of the projects to have created a cost advantage, although the objective may not have been cost savings. In two cases, low cost was the focus (Harris Corporation, Merit Brass), but there is good evidence that firms initiated the work hoping it would save the companies.

A cost advantage indicates a focus on efficient deployment of resources versus creative deployment. We found that 20 of the 42 applications combined functional-level strategy and low-cost advantage, work that was inwardly focused and easily replicated. While such functional cost savings may justify and pay for the OR/MS group, such work may not provide the firms with sustainable positions.

The work we examined concerns competitors, customers, and suppliers. The targeting of competitors (56 percent) is consistent with the high frequency of applications creating a cost advantage, while the focus on

customers (63 percent) shows the use of OR/MS to create advantage through delivering and improving customer service.

Some form of optimization (integer, linear, or mixed-integer programming) played a role in 67 percent of the applications. The use of DSS as the delivery vehicle for the OR/MS work in almost two-thirds of the applications shows that firms are using DSS to support high-level managerial decisions. The high level of DSS use to make OR/MS models accessible to managers shows that firms are involving managers with

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### We should assemble empirical evidence on the rate of return from OR/MS work.

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models, which should increase management's support for investing in OR/MS as part of the corporation's IT strategy.

In most applications (32 of 42), firms relied on some internal OR/MS expertise, and many (16 of 42) depended only on internal knowledge. Keeping OR/MS secrets may sustain any advantage gained, but these Edelman Prize finalists apparently believed that entering their successful OR/MS work in this competition would not reduce the advantage they had gained. Bell (1998) observed that a competitive advantage from OR/MS work can be sustained without secrecy, first, because the first mover has progressed further down the learning curve, developing improved techniques and technology that provide a continuing advantage over any new entrant, and second, because the first mover has restructured the organization to take additional advantage of the OR/MS algorithms: 16 of the articles provided evidence of organizational change

In 24 of the 42 applications, firms relied on external OR/MS expertise, mainly academics (17 of the 24). This result is counterintuitive since the major industrial OR/MS consultants (such as Sabre Technologies and Manugistics) are the leading practitioners of OR. One might therefore expect firms to call on an industrial consultant rather than a professor at the local university. While a likely explanation for the preponderance of academic involvement is that the Edelman Competition requires academic publication, a contrib-

uting factor may be the structure of the OR/MS industry, in which a few firms occupy niche markets.

The dominant supplier is Sabre Technologies, which specializes in revenue management, airline operations, and large-scale logistics applications. Some OR/MS groups in other airlines (such as United) offer outside consultancy, while others work entirely in-house (for example, British Airways).

Other suppliers of OR/MS services are software houses, which usually provide consulting in the area their software supports, specialized consultancies that serve particular problem types, and academics. As examples, AutoSimulations markets simulation software and also offers consulting services in materials handling and plant layout and design, Giro Enterprises provides software for workforce scheduling in transportation systems and consults in this area, and D.H. Wagner and Associates specializes in problems that require physical searches.

Firms seeking OR/MS services may have few suppliers to choose from, and competitive factors may further limit their options. For example, revenue management (RM) is successful in the automobile rental business. In 1990, Hertz engaged DFI to implement RM (Carroll and Grimes 1995), and Sabre implemented RM at Avis. National Car Rental Company, seeking a revenue-based turnaround, faced a situation in which two of the leading suppliers of RM were in alliances with competitors, and it turned to Aeronomics, a fledgling RM company spawned from Delta Airlines. The RM systems Aeronomics developed saved National Car Rental and also made Aeronomics a major RM supplier, leading to a merger with Decision Focus Inc., the formation of Talus, and Talus's recent purchase by Manugistics.

The need for firms that rely on outsourcing OR/MS to prevent competitors from buying their supplier's knowledge has produced a network of formal and informal strategic alliances, which has the effect of removing many suppliers from the marketplace. This has created the opportunity for startups of new independent OR/MS providers and in-house groups.

For 29 of the 42 applications, we were able to assess the organizational level of the manager(s) who supported the work. Twenty-five of the 30 applications were supported at the corporate-vice-president level



or above, with 10 supported by the president, CEO, or directors. This high-level support indicates that senior managers saw the work as strategic. Thirteen of 24 applications that had support at the vice presidential level were functional, as were five of the 10 applications with support at the CEO, presidential, or director level. These results show that functional-level OR/MS applications can provide advantages of interest to senior managers and are candidates to be strategic OR/MS.

### Costs and Benefits

The reported financial benefits of the applications often exceed \$100 million annually. In most cases, authors do not report the OR/MS costs or the return on investment. In some cases (for example, American Airlines) the firms have conducted research and for a long time. In other cases (for example, Merit Brass), the firms relied on external expertise and could estimate investment returns. We estimated internal rates of return (IRR) when we had cost and benefit information (Table 4).

A wide array of industries and issues are represented in the 42 cases, indicating that OR/MS is providing competitive gains across a large variety of industries (ranging from service industries to utilities) and is being applied to a wide variety of issues.

### Evidence of Strategic OR/MS

Most of the 42 Edelman finalist papers contain evidence of significant financial gains but not necessarily of a strategic impact. In looking for strategic OR/MS, we divided the applications into four groups based on whether the OR/MS work created a competitive advantage and, if so, whether the advantage was sustainable.

In the first group are firms for which there is strong evidence that the OR/MS work created a sustainable competitive advantage: AT and T (telemarketing site selection (Spencer et al. 1990) and business operations analysis (Brigandi et al. 1994)); ABB Electric (Gensch et al. 1994); American Airlines (Anbil et al. 1991; Smith, Leimkuhler, and Darrow 1992; Vasquez-Marquez 1991); Delta Airlines (Subramanian et al. 1994); Harris Corporation (Leachman et al. 1996); National Car Rental (Geraghty and Johnson 1997); Sadia (Tauben Netto 1996); Sears (Weigel and Cao 1999); Southern Company (Erwin et al. 1991); and Vilpac Truck Company (Nuno et al. 1993).

Most of these firms continually improved the OR/MS methods, systems, and databases over time, which is crucial to sustaining the advantage they created. American Airlines, Delta Airlines, Harris Corporation, National Car Rental, Sadia, Sears, and Southern Company all used OR/MS to tackle complex

Organization	Costs	Benefits	First Year IRR	Five Year IRR
	In millions	In millions		
Harris Semiconductor	\$3.8	From loss of \$75 to profit of \$42 in 3 years	1,332%	1,500%
Hewlett Packard	\$1.4	\$280 new business		2,900%
Keycorp	\$0.5	\$98 over 5 years		3,920%
L. L. Bean	\$0.04	\$9–10 per year	22,400–24,900%	22,500–25,000%
Merit Brass	\$0.078	\$0.201 per year	158%	257%
National Car Rental	\$9.5	\$96 additional revenue	31%	128%
NYNEX	\$5	\$33.4	2,375%	
Pacific Gas and Electric	\$5	\$15 per year	200%	300%
Reynolds	\$0.618	\$7 per year	1,033%	1,133%
Sainsbury	\$138	\$88 per year	–36%	57%

**Table 4: We summarized reported costs, benefits, and computed IRR. When detailed information on benefits was available in the public domain, we used these values directly to estimate IRR. When only an annual benefit was reported, we computed two IRR: the first based on the first year of benefits only, and the second assuming the same level of benefits continued for five years.**

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		SOR	Low impact	Nonsustainers
Initiation	Problem	5	7	8
	Crisis	4	0	1
	Opportunity	7	9	1
Corporate strategy	Functional	8	9	6
	Business unit	6	6	1
	Corporate	1	0	1
Form of advantage	Low cost	9	12	7
	Differentiation	5	5	1
	Focus	2	0	1
Competitive forces	Suppliers	1	3	2
	Customers	9	9	6
	Competitors	6	7	4
Organizational change		5	2	4
Level of managerial support	CEO, president, or directors	5	0	4
	Vice president	1	7	4
OR/MS expertise	Internal	10	13	4
	Consultancy	4	2	2
	Academic	3	2	6

**Table 5: We tabulated the strategic dimensions of the three main groups of applications described in 42 papers of corporate Edelman Prize finalists.**

problems incrementally with each new development adding to the sustainability of the advantage created. ABB Electric and Vilpac Truck Company used OR/MS to change their organizations in ways that competitors could not replicate quickly. Sadia and Southern Company used OR/MS as the basis of a management philosophy.

In the second group are firms that relied on several factors, including OR/MS work, to create the advantage: Gas Research Institute (Burnett, Monetta, and Silverman 1993) (managers used OR/MS to choose R and D projects, which then yielded benefits); KeyCorp (Kotha, Barnum, and Bowen 1996) (OR/MS supported a strategy based on superior customer service, which provided the advantage); Procter and Gamble (Camm et al. 1997) (OR/MS contributed to a restructuring); Sainsbury (Ormerod 1996) (managers used OR/MS to choose an SIS to implement. The SIS provided an advantage).

In the third group, the financial benefits were small relative to the size of the firm or were unreported: AT and T Capital Corporation (Curnow et al. 1997); Bellcore (SONET (Cosares et al. 1995), PDSS (Katz, Sadrian, and Tendrick 1994), and R and D (Hoadley, Katz, and Sadrian 1993)); Digital Equipment Corpo-

ration (Arntzen et al. 1995); GE Capital (Makuch et al. 1992); GTE (Jack, Kai, and Shulman 1992); IBM (LMS (Sullivan and Fordyce 1990) and Optimizer (Cohen et al. 1990)); Kodak (Farley 1991); Nortel (Brinkley et al. 1998); NYNEX (Barnea et al. 1996); Prudential Securities (Ben-Dov, Hayre, and Pica 1992); PG and E (Johnson et al. 1998); and Reynolds (Moore, Warmke, and Gorban 1991).

In the final group are firms in which the work appears standard and nothing appears to prevent competitors replicating it: Cerestar (Rajaram et al. 1999); Grantham, Mayo, Van Otterloo and Company (Bertsimas, Darnell, and Soucy 1999); Hewlett Packard (Burmant, Gershwin, and Suyematsu 1998); L. L. Bean (Quinn, Andrews, and Parsons 1991); Merit Brass (Flowers 1993); PALCO (Fletcher et al. 1999); Taco Bell (Hueter and Swart 1998); Tata Steel (Sinha et al. 1995); and Yellow Freight Systems (Braklow et al. 1992).

In the remaining application, Columbus-America (Stone 1992) used OR/MS to find a sunken treasure ship. The company obtained a one-time competitive benefit and sustained it through property-rights legislation. The method used to find the wreck is a strategic asset that the developers are marketing. This example falls outside Bell's definition of OR/MS creating

a sustainable advantage but illustrates two other ways that OR/MS might be considered strategic.

We tabulated the applications (Table 5) in the three major groups according to the strategic dimensions listed in Table 3.

Most of these applications are cost saving, functional, and problem initiated with very few corporate level projects. Based on a traditional view of strategy, we would class few of these projects as strategic, but in our assessment, more than a third created sustainable competitive advantages and should therefore be considered strategic OR/MS. Second, firms for which the advantage does not appear to be sustainable tackled problems with outside help and little long-term focus. When an internal OR/MS group was heavily involved, we categorized projects with similar characteristics (cost saving, functional, problem initiated) as either strategic or low impact, depending on whether the work saved enough money to earn senior managers' attention and the resources to maintain and develop the application to sustain the advantage.

Strategic OR/MS applications must be long-term focused and sustained, characteristics not considered in the traditional analysis. The data from these projects shows that they are also functional, low-cost focused, and tackled by internal personnel.

## Conclusions

We conclude with two recommendations. First, since OR/MS work is an investment, we must demonstrate to senior managers that their investment in OR/MS will yield a return commensurate with that obtained from other investment options (such as an advertising campaign, a new plant, or even an interest-bearing security). We should assemble a body of empirical evidence on the rate of return from OR/MS work. A first step in this direction would be to require Edelman finalists and authors of articles on OR/MS applications to compute and report rates of return on OR/MS investments.

Second, many see DSS as a topic that belongs in the MIS literature, but since the majority of these major OR/MS applications are incorporated in DSS, OR/MS researchers should pay much more attention to DSS.

DSS typically use graphic user interfaces as the communication medium between model (or models) and the user. OR/MS researchers should learn to design effective and efficient user interfaces for OR/MS models.

Tom Cook, president of Sabre Decision Technologies, has talked about OR/MS as a competitive weapon:

The things we are doing are designed to create a competitive advantage (Horner 1991, p. 38).

Evidence from the literature of SIS and from the Edelman Prize competition finalists shows that some firms, including Sabre, have achieved a sustainable competitive advantage from their OR/MS work. OR/MS researchers should seize the opportunities that arise when OR/MS work is considered a corporate strategic asset.

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