

STRATEGIC OPERATIONS RESEARCH AND THE EDELMAN PRIZE FINALIST APPLICATIONS 1989–1998

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In an earlier study we examined the available evidence on the Edelman Prize finalist applications 1989–1998. This study concluded that 13 of the 42 private sector applications provide examples of strategic operations research (SOR) when SOR is defined as operations research that creates a sustainable competitive advantage. In a follow-up study we tested our classifications, gathering longitudinal information on the continued success of the Edelman applications. We contacted people who were familiar with all the private sector applications that were Edelman finalists 1989–1996 and had at least five years of history since the competition. We describe the post-Edelman history of these applications and use this data to reassess their strategic role. We found that the longitudinal data provides evidence to support our original classification, but also suggests that several additional applications were more strategic than was originally apparent. We conclude that almost 60% (20 of 34) of these applications created a sustainable competitive advantage for their firms and provide examples of SOR.

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The primary impact of a successful business strategy is that it creates a competitive advantage that is sustainable over a period of time, leading Bell (1998) to define “strategic OR” (SOR) as . . . *operations research that achieves a sustainable competitive advantage.*

While it is generally accepted that OR work can create an advantage, it is not nearly so clear that any advantage created can be sustained over a considerable period of time. We (Bell and Anderson 2002) therefore examined the private sector Edelman finalist applications 1989–1998 (published in *Interfaces*, 1990–1999) to assess whether the *Interfaces* article and presentation describing these major applications provided evidence to support the existence of SOR. We were looking for evidence that organizations used OR in a way that provided a distinct advantage over their competition, sustained over a period of time.

In this article, we first summarize our initial assessment of the strategic importance of the 43 private sector Edelman finalists between 1989 and 1998. The initial study had two shortcomings: First, the documentation from the Edelman competition (articles in *Interfaces*, plus videotapes of the final presentations) often did not provide the necessary detail to make an informed assessment of the strategic importance of the work. Second, the Edelman competition provided data at a point in time, and the importance of an application may only become apparent over a longer period.

We therefore describe a follow-up study in which we collected longitudinal data on all the private sector Edelman finalists published in *Interfaces* between 1990 and 1997.

We summarize the post-Edelman history of these 34 applications and use the data collected in the follow-up study to reevaluate the strategic importance of these applications.

THE INITIAL ASSESSMENT OF THE EDELMAN FINALIST APPLICATIONS 1989–1998

The first group of applications (SOR in Table 1) provided the strongest evidence that the work met a definition of SOR based on the creation of a sustainable competitive advantage. AT&T (Spencer et al. 1990, Brigandi et al. 1994), American (Anbil et al. 1991, Smith et al. 1992, Vasquez-Marquez 1991) and Delta Air Lines (Subramanian et al. 1994), Harris Corporation (Leachman et al. 1996), National Car Rental (Geraghty and Johnson 1997), Sadia (Taube-Netto 1996), Sears (Weigel and Cao 1999), and Southern Company (Erwin et al. 1991) all used OR to tackle very complex operations problems over a period of time, with each new development adding to the sustainability of the advantage created. ABB Electric (Gensch et al. 1990) and Vilpac Truck Company (Nuno et al. 1993) used OR to assist or lead major organizational change that would be costly for competitors to replicate quickly. In two cases (Sadia and Southern Company) OR was being used to provide a basic philosophy for overall management of the entire operation and provide its host organizations with substantial and apparently sustainable results.

The second group of applications (Contributors in Table 1) were judged to have created an advantage sustained over a period of time, but this advantage appeared to be the result of many factors, with the OR work playing a

Table 1. The 42 private sector Edelman finalist applications from 1989–1998 grouped according to our initial assessment.

SOR	Contributors	Insufficient Impact	Nonsustainers
ABB Electric	Gas Research Institute	AT&T Capital	*Cerestar
American Airlines	KeyCorp	Bellcore; SONET,	*Grantham,
yield management	Procter & Gamble	PDSS and R&D	Mayo, Van Otterloo
arrival allocation and	Sainsbury	DEC	and Company
TRIP		GE Capital	*Hewlett-Packard
AT&T—call simulator		GTE	L.L. Bean
AT&T—telemarketing		IBM; LMS and Optimizer	Merit Brass
site selection		Kodak	*PALCO
Delta Air Lines		*Nortel	*Taco Bell
Harris Corporation		NYNEX	Tata Steel
National Car Rental		Prudential Securities	Yellow Freight Systems
Sadia		*PG&E	
*Sears		Reynolds	
Southern Company		Yasuda	
Vilpac Truck			
(13)	(4)	(16)	(9)

Those marked with * were finalists in 1997 or 1998 and were not included in the follow-up study.

relatively minor role. At the Gas Research Institute (Burnett et al. 1993), OR helped managers choose R&D projects, but the principal benefits accrue from the projects themselves. At KeyCorp (Kotha et al. 1996), OR supported a competitive strategy based on superior customer service, but the service strategy itself looks to be the real advantage, while OR was one contributor to a major restructuring at Procter and Gamble (Camm et al. 1997), and Sainsbury (Ormerod 1996) used OR to help management decide which systems to implement, but the major advantage appears to come from the systems chosen for implementation.

The Edelman documentation for the third group of applications (Insufficient Impact in Table 1) does not support a view that these applications created a sustainable advantage because the financial benefits were dwarfed by the scale of the host corporation or were not provided.

Finally, the fourth group of applications (Nonsustainers in Table 1) reported significant benefits, but the nature of the company or the OR work suggested to us that any advantage created was unlikely to be sustainable. For these companies, the OR work appears to be relatively standard and/or the problems appear to be routine. There appears to be nothing to prevent competitors from replicating the work quickly and nullifying any advantage gained from the OR.

The 43rd application, the Columbus-America Discovery Group (Stone 1992), was unclassified. Here OR was used to locate a sunken treasure ship. Ownership of the wreck was a significant one-time competitive benefit to the client that was “sustained” through property rights legislation, while the OR methodology used to define the search became a “strategic asset” that was used by the provider as the basis of a new business. This application illustrates two ways that OR work might be considered to be “strategic,” but since neither involves a sustainable competitive advantage for a client organization, this project was excluded from further study.

THE NEXT STEP: FOLLOWING UP ON THE EDELMAN FINALIST APPLICATIONS

As a follow-up on our earlier study, we set out to investigate whether the history of the Edelman finalist applications following the competition supported our original classification of these OR works and, in particular, whether those applications that we had classified as examples of SOR had lived up to this designation in the years after the work was made public. We selected the private sector Edelman finalist applications published in *Interfaces* between 1990 and 1997. We chose 1997 as the cutoff because these applications were presented in the spring of 1996, providing at least five years of post-Edelman history.

Thirty-four applications from 28 corporations were 1990–1997 Edelman finalists. Semistructured telephone interviews were conducted with representatives familiar with every application. Starting with the authors of the *Interfaces* article, we followed a “trail” to determine those who were working in the company today and were familiar with the application or its fate. We spoke with four or five people familiar with some applications, and in other cases we spoke to several people (who we think should have known) but could find no sign of the application. We asked open-ended questions to document the history and current state of the Edelman application, and asked about managerial interest in OR, competitor response to the Edelman work, and the extent to which OR had evolved at these organizations. The interviews were taped and transcribed, and most were between 30 and 45 minutes in duration.

OPERATIONS RESEARCH AS A SOURCE OF SUSTAINABLE ADVANTAGE

Our major hypothesis is that firms can and do use OR to create a sustainable competitive advantage. We first sought to confirm that the longitudinal evidence, from the 5–10 years after the Edelman prize competition, supported our

earlier classification of 12 applications as examples of SOR.

The second set of research hypotheses relate to the “contributors,” “insufficient impact,” and “nonsustainer” groups. Our assessment of these applications was based on the limited evidence contained in the original publication, but would further data collection, including the passage of time, move some of these applications into the SOR group?

In our data collection, we attempted to assess whether the OR work had had a strategic impact using three interpretations of a strategic impact.

For the first group of firms, it was possible to identify the specific problem or issue where the OR work provided a source of competitive advantage. There was evidence that this “SOR work” produced a significant cost or revenue impact, that senior management of the client organization has recognized this, and that the impact was sustained for some time. “SOR work” generally involves large complex operations-level problems that are tackled using OR over an extended period of time. The strongest evidence of the strategic value of such OR work is clear evidence that the OR methods, systems, and databases have been developed and improved upon over a considerable period of time, the client firm underwent organizational change to support the results of the OR work, and that competitors were aware of and responded to the success of the work (Bell 1998).

A second group of firms had “SOR Groups.” The archetype of the SOR group is the OR group at Federal Express (FedEx).

OR has been thoroughly ingrained in FedEx activities since start-up in 1973. The FedEx multi-hub distribution system was designed by the OR group, and its operation and expansion over the years has been managed with the extensive use of OR. OR at FedEx appears to be involved in almost every major decision the corporation takes—and it has been in this position since the very beginnings in 1973 (Bell 1998, p. 390, citing Mason et al. 1996).

Frederick W. Smith, Chairman, CEO, and founder of FedEx has said:

Employing OR techniques and modeling skills, the OR department has played a role in the development of long-range plans for the past 17 years and was instrumental in determining the specific growth sequence that allowed FedEx to become the world’s largest and most reliable air express carrier. Every major system change . . . (was) modeled by OR several years in advance of the actual system change. This enabled the company to grow smoothly. . . . By modeling various alternatives for future system design, FedEx has, in effect, made its mistakes on paper” (Horner 1991).

We therefore looked for evidence that the OR group had garnered additional resources and additional projects, and perhaps even become a part of the corporate culture.

The third group of firms applied OR tools and techniques to strategic-level problems or the analysis of “policy problems.” While this represents a common understanding of

“strategic OR” (see, for example, Dyson 2000), it is usually very difficult to determine whether these firms achieved a sustainable advantage as a result of the OR work. The decision(s) that was implemented may have resulted in an advantage, even a sustained one, but since it is usually impossible to tell what decision the firm would have implemented if it were not for the OR work, it is problematic to assess the value of the OR work. We therefore categorized these firms as “OR contributors” and suggest that most of any advantage gained for these firms is attributable to the resulting strategic decision, with OR playing a relatively minor contributing role.

THE 12 “SOR” APPLICATIONS

The interview evidence on the 12 applications we originally classified as examples of SOR is summarized in Table 2.

American Airlines (Yield Management, Crew Pairing, and Arrival-Slot Allocation)

American Airlines Decision Technologies was renamed as Sabre Decision Technologies and then was spun out of American Airlines (AA) as a separate company (The Sabre Group), but retains AA as a client that they support on technical and business levels. Sabre’s business has grown substantially in the last few years, and they now work for many airlines: AA now accounts for only about 20% of their business. The next generation yield management system has been implemented, and has been far advanced compared to what was in the Edelman paper and has been implemented by two or three other airlines. The crew-pairing initiative (TRIP) has moved ahead with some advances in terms of efficiency, especially with technical help from researchers at Georgia Tech. The arrival-slot allocation system has not moved ahead very much.

The OR staff working on the yield management and crew-pairing initiatives has increased slightly since the time of the articles. Barry Smith, coauthor of the 1991 Edelman-prize-winning “yield management” article is now chief scientist for Sabre.

Yield management at AA/Sabre continues to provide the strongest evidence that OR can be “strategic.” This application was created out of the competitive necessity for AA to find a competitive response to the rapid rise of discount carriers, such as People Express (PE), following airline deregulation in 1979. AA yield management gained almost instant senior management recognition by addressing this crisis, in part by driving PE out of business in a very short time. Donald Burr, founder and CEO of PE, “believes that major carrier’s use of sophisticated computer programs to immediately match or undercut his prices ultimately killed People Express” (Bryan 1989). Commentaries on the Harvard Business School PE case series conclude: “The major carriers met People Express’ pricing structure . . . and used their reservations systems to achieve optimal pricing and yield management. PE’s performance, in essentially all dimensions, immediately declined. . . . The end was

Table 2. Summarized findings for the “SOR” applications.

Application	Period in Use	Improvements on Initial Work	Evidence of Organizational Change	Competitive Response	Other OR Work As a Result of Implementation	OR Has Become Part of Company Culture	Additional Resources Devoted to OR
AT&T—Telemarketing	1987–	✓			✓		
AT&T—Call simulator	1978–1998	✓	✓	✓	✓		
ABB/Waukesha	1976–	✓	✓	✓	✓		
AA—Yield management	1985–	✓	✓	✓	✓	✓	✓
AA—ASAS	1989–??					✓	✓
AA—TRIP	1971–	✓		✓	✓	✓	✓
Delta	1991–	✓	✓	✓	✓	✓	✓
Harris Corporation	1992–	✓	✓	✓		✓	
National Car Rental	1994–	✓	✓	✓	✓	✓	✓
Sadia	1989–	✓			✓		✓
Southern	1981–	✓	✓	✓	✓	✓	✓
Vilpac Truck	1988–1993		✓			✓	

swift” (Loveman and Beer 1991a, p. 4), and “It is worth emphasizing that a reservations system, with its yield management capacity, is arguably the single most important strategic asset of an airline” (Loveman and Beer 1991b, p. 4).

The financial impact of yield management to AA has grown dramatically as the methods and algorithms were further developed over a six-year period. In 1992, R. L. Crandall, chairman and CEO of AMR (the parent company of American Airlines) estimated that “yield management has generated \$1.4 billion in incremental revenue in the last three years” (Smith et al. 1992, p. 31). By 1998, Tom Cook, president of SABRE Decision Technologies, had increased the estimated impact to “almost \$1 billion in annual incremental revenue” (Cook 1998, p. 29).

Senior management at AA was aware of the strategic importance of yield management and supported its continued development. Crandall stated “I believe that yield management is the single most important technical development in transportation management since we entered the era of airline deregulation in 1979” (Smith et al. 1992, p. 31).

Finally, there has been a clear competitive response. Almost every major airline has adopted yield management, and suppliers such as PROS Revenue Management operate very successfully as providers of yield management software and systems to the airline industry.

Crew pairing has followed a similar, although lower-profile, path. Crew-pairing algorithms have become a competitive necessity in the airline business, and suppliers such as AD OPT Technologies and Sabre now provide crew-pairing systems for those airlines that prefer to outsource rather than develop their own algorithms.

While the recent evidence supports the view that AA yield management and AA crew pairing created a competitive advantage for AA for at least a 10-period, the evidence on the strategic impact of arrival-slot allocation is not as strong. Significantly, Sabre still markets SABRE SlotManager, a slot-managing and tracking system, but arrival-slot allocation does not appear to be as large or as difficult a

problem as yield management or crew pairing, or to have the same level of financial impact.

Delta Air Lines COLDSTART

Delta’s COLDSTART fleet assignment application is still being used on a regular basis and has been upgraded and enhanced with additional features. The airline is spending significantly on other projects as well as its two major projects in fleet assignment and revenue management, which are being developed with the help of external consultants. Delta sees considerable scope for gaining a competitive advantage in these areas, and believes that airline companies cannot remain competitive without using OR tools. Delta plans on “being there” and being competitive in the industry; and this has entailed making significant investments in OR. It was suggested to us that the biggest differentiator between the airlines is who has the better, more complete, more sensible model and therefore Delta is constantly looking for different applications or improvements.

AT&T Telemarketing Site Selection

The site selection model was used extensively between 1987 and 1997 in support of a “value-added” corporate strategy at AT&T, but this strategy has now been discarded. AT&T viewed the model as a vehicle to attract clients as it attempted to differentiate itself in a commodity business. The model was used for a few customers at the request of account teams between 1997 and 1999, with the final U.S. use of the model in 1999 for a major global site selection application for an international telecommunications company. A Canadian version of the model was used by AT&T Canada from 1995 through 2000+ to support a value-added approach to trying to attract market share in Canada.

AT&T Call Process Simulator

The original system was viable and in use up until about 1998, when AT&T went away from their value-added strat-

egy. Basically, the client stopped funding the project, and since the technology (i.e., the capability of the switches, the internal software that is used by call centers) required constant updating, it aged very quickly. The system still exists, but is not being used much.

ABB Electric

Daniel Elwing, former ABB Electric CEO, was a major advocate of OR, and the Edelman article reports a number of projects that appear to have had a major impact. Specifically, customer segmentation work in the electrical transformer market, in conjunction with production planning improvements, enabled ABB to enter a shrinking market and eventually dominate it by becoming both the low cost and highest-quality manufacturer. Larry Ritzman, Director of Market Services and Planning, stated that ABB's Waukesha plant became the most productive in the world, being the most vertically integrated, and the highest-volume producer at the lowest cycle time. This combination drove some of ABB Electric's largest competitors out of the transformer market.

ABB Electric's Waukesha plant was sold to Magna Tech Inc. in 1990 because of U.S. government concerns that the parent would control almost 70% of the industry after they purchased Westinghouse Electric. In 1993, Magna Tech was in financial difficulties and was forced to spin off six companies—one of which was the Waukesha plant. General Signal purchased the plant and subsequently was acquired by SPX Corporation. The former ABB Electric transformer division now operates as Waukesha Electric Systems.

Waukesha is still using the initiatives described in the Edelman article and has started a best practices transfer of the production planning processes to other business units in the transformer market at SPX. Waukesha Electric has no OR department and employs no OR consultants, but has instituted a training program for employees through the American Production and Inventory Control Society (APICS). Ritzman reports that the company's involvement with APICS has been a very effective way of developing new managers and that achieving the certification demonstrates a sound cross-functional knowledge of how the business operates.

Other more generic tools have augmented the original production planning tools with help from APICS educational processes. Waukesha Electric has implemented a continuous improvement process, is launching Six Sigma, and looking to implement CRM. The company has developed some internal tools for the sales process and also uses some packaged software. The move to a multiplant environment has caused some difficulties because of scalability problems with the original software.

Ritzman reports that there is strong management support for their new initiatives, which require the interaction of several disciplines. The outcome is a more focused organization, a much clearer supervisory work force, and a work force that understands the systems and what is necessary. Waukesha Electric is focused towards performance

improvement through the economic value-added (EVA) approach with an emphasis on growth and a compensation structure that rewards sustained initiatives rather than short-term results. Dan Elwing (now retired from Waukesha) argues that EVA works towards consistency of results and steady growth of the company rather than what ABB used to do, which was to use OR to determine where the market was and capture maximum efficiency.

Waukesha Electric has improved quality departments in all of their facilities as well as a strong industrial engineering team. In addition, they have a management-level person in charge of the continuous improvement process.

Harris Corporation—IMPReSS

Harris (now InterSil) has realized substantial savings and competitive advantage over the last 10 years from the IMPReSS production planning system, but it should be noted that this was a major system reengineering and no one tool was responsible for all the savings. InterSil still uses IMPReSS on a daily basis and is totally dependent on it to run the entire planning system. Since implementation, they have added new tools and have modified the system on an ongoing basis. IMPReSS is seen to be nearing the end of its useful life and InterSil is looking to replace it or upgrade it soon.

There was nothing like IMPReSS commercially available at the time, but the Harris implementation triggered a significant competitor response, and many competitors now have similar tools, many of which are now seen as an improvement. InterSil was able to maintain a competitive advantage for a long time, in part because of their success in changing the culture of the company to work with this particular tool: The success of the company in changing the organizational dynamics paid off significantly. InterSil management recognizes that tools (such as IMPReSS) and people who can build and maintain these types of tools are necessary to run the business efficiently, and as InterSil moves to replace IMPReSS, they are looking to hire more technically competent OR people. We were also told that demand has increased for consulting services in the industry, partially because of the Edelman article on Harris Semiconductor.

National Car Rental

Talus Solutions Inc. (then Aeronomics) partnered with National Car Rental to develop the revenue management (RM) application that was the Edelman prize finalist. This application is still in use, has been upgraded and maintained, and remains a critical part of National's (now Automation after mergers with Valu and Alamo) operations.

The dedicated RM group of some 30 business specialists responsible for executing the RM program is still in existence and has expanded over time. National has continued to invest both personnel and monies in this area since 1994. National also has a small OR department that deals with

applications such as inventory management or scheduling, and acts as a support group for RM.

Management recognizes and is very appreciative of RM, and it has become vital to the culture of National. RM activities are critical to the firm's success and people from the RM group are involved in all aspects of the business—financial planning, marketing, advertising, fleet acquisitions, and disposals, and have been promoted. Ernest Johnson, formerly VP of RM, is now president of the National Group. The RM experts have embraced OR and made it a part of their work culture. This is true throughout the industry. All the major airport car rental companies now practice revenue management.

The success of the project at National also resulted in tremendous success for Talus, which was acquired by supply-chain specialist Manugistics in a deal worth \$366 million at signing. (More details of the National application appear in Bell and Anderson 2001.)

Sadia—PIPA Project

Sadia spent more than U.S. \$1 million annually on the PIPA project (an integrated poultry planning system) for more than 10 years and the system is still used regularly. The support and influence of the vice-president of Agriculture was fundamental to the early success of PIPA, and when he left for a new position, PIPA survived because the economic benefits were already perceived at a corporate level.

There has been some expansion of the scope of PIPA, but it is no longer a high priority at Sadia, although management strongly recognizes the importance of the PIPA system. A SAP/ERP project competed for resources with the PIPA system, resulting in less attention being paid to the utilization of PIPA. Although the SAP project now commands greater management attention, the PIPA system of integrated, optimized planning has proven superior to the administrative connectivity of ERP.

There is still no OR group at Sadia. There is a feeling that OR techniques work well but are not critical, and traditional management thinking still dominates. OR has not become part of the culture of the company, although ideas from OR developed by consultants are being applied in logistics and marketing. TQM and ERP are causing a resurgence of interest in OR, although the PIPA system predates the emergence of supply-chain management and advanced planning and scheduling as important issues.

Southern Company

Several runs of the model are still done every day to determine unit commitments, and OR optimization techniques are a critical aspect for remaining competitive in this industry with work similar to Southern's now standard in the industry.

Since 1991 the business of the regulated utilities in the southern United States has changed very dramatically. The changes in the marketplace are increasingly requiring the inclusion of bidding, ancillary services (services that ensure reliability and support the transmission of electricity from

generation sites to customer loads), and financial instruments in the models. Most of the OR being done now has to do with how to integrate the purchase of energy to optimize supply to meet the demand load. OR at Southern is now integrated into functional groups and studies specific problems. Examples include optimizing the purchase of gas for gas-fired units, or optimizing bids for separate and distinct markets (i.e., spinning reserve energy) such that, when combined with existing capacity online, the combination together minimizes the cost of delivering energy. The optimization problems have become more complicated with the inclusion of risk management, and Southern is currently working extensively on the bidding problem with a number of recent hirings.

It is anticipated that deregulation of the industry will produce more opportunities to achieve long-term sustainable competitive advantage through the use of OR.

Vilpac Truck

The initiative reported in the Edelman article was very successful and production of trucks went from 8 per day to 42 per day over a three-year period. The company integrated people across multifunctional teams and there was a cultural shift within the company to an acceptance of OR as an integral part of the process. The company was so successful in streamlining the business that it was purchased by Kenworth Truck Company. It is not clear what happened to the OR work following the acquisition, but it was reported that the new management team wasn't comfortable with the tools employed in the optimization process and went back to their old way of doing business.

THE FOUR "CONTRIBUTORS"

The interview evidence for the four applications originally classified as contributors is summarized in Table 3.

Gas Research Institute

The project appraisal methodology (PAM) continues to be applied on an annual basis in very much the same way that it was when the Edelman article was written, with benefits from the chosen projects for the last five years estimated at U.S. \$9.6 billion. More resources have been devoted to the OR group over the last five years and the majority of the work is now done in-house. The focus of the group's work has shifted towards the business analysis of commercial ventures because of the deregulation of the energy business and the resulting loss of national public funding. GRI plans to use its OR expertise to create an advantage in choosing technologies that have the greatest chance of commercial success, and will profit either through partnerships with the developers or by taking an equity interest in the start-up companies.

KeyCorp

The service excellence management program is still in existence at KeyCorp and has been extended several times. The

Table 3. Summarized findings for the “Contributor” applications.

Application	Period in Use	Improvements on Initial Work	Evidence of Organizational Change	Competitive Response	Other OR Work As a Result of Implementation	OR Has Become Part of Company Culture	Additional Resources Devoted to OR
Gas Research Institute	1978–		✓		✓	✓	✓
KeyCorp	1991–	✓	✓	✓	✓		
Procter & Gamble	1993–	✓	✓	✓	✓	✓	✓
Sainsbury	1989–		✓		✓		

project has been very successful; in five years, approximately 3,000 staff have been eliminated at an average cost savings per branch of around \$23,000. This result was obtained while reducing customer wait times and increasing customer satisfaction. KeyCorp has reached the point where it is almost impossible to go any farther—it requires at least three people to run a branch and KeyCorp now has 950 Key Centers with fewer than 3,000 employees working as tellers. Key centers are now doing less than 15% of the transactions with changes in technology. For example, one-third of transactions are now done by debit cards, one-third through ATMs, and 50% of customer inquiries are now done through 1-800 numbers.

Top management has shown an interest in these initiatives because of the increased revenues and reduced costs, and KeyCorp has experienced numerous inquiries into this program from other banks. Recently, the OR group has been dismantled and moved over to the strategic analysis group, where they now are concentrating on data warehousing and data mining and are working on credit scoring mechanisms.

Procter & Gamble

The success of this project led to a renewed focus on OR at P&G, and resulted in other implementations of this model for different corporate businesses on a worldwide basis. To date P&G has done over 30 types of similar analyses on optimally positioning manufacturing operations. Since the time of the Edelman article there have been significant resources devoted to OR at P&G, with OR consolidated into a single group of 12 to 15 people and continuing to grow. The head of the group remarks that OR’s credibility is high within the organization at this time and that the group’s clients are the vice presidents of the company. OR has been involved in influencing strategic decisions in project portfolio management on a very broad basis and has influenced key initiatives that the company is considering undertaking. The Edelman application did lead to a renaissance of OR at P&G, and OR is currently heavily involved in supply-chain management and evaluating e-commerce opportunities.

Sainsbury

The information systems that were selected for development are still operating and are central to the day-to-day

activities of the company. These systems are considered essential, but Sainsbury is now at the point where they are considering replacing them with more sophisticated systems (which may use more mathematics). While the information systems have lived up to design parameters, they have not accomplished as much as some people anticipated, and this has created a perception that there is room for further improvement. Sainsbury has also lost market share.

Sainsbury has not hired OR specialists since this project and has no internal OR people although it has some statisticians and mathematicians spread through different functional areas. The company is planning to develop a decision support tool to assist with the next round of IS development and will be outsourcing OR expertise to help accomplish its goals in this area.

THE FOURTEEN APPLICATIONS CATEGORIZED AS HAVING “INSUFFICIENT IMPACT” TO BE EXAMPLES OF SOR

The interview evidence for the 14 applications originally classified as having insufficient impact to be examples of SOR is summarized in Table 4.

AT&T Capital Corporation

AT&T Capital vice president Michael DiBernadi used consultants from AT&T Laboratories to develop the 1996 application on credit decision making (Curnow et al. 1997), credit line management, and delinquent account management. AT&T Capital was acquired by Newcourt Credit, and DiBernadi was able to persuade Newcourt management to hire the consultants as full-time employees. CIT Group then acquired Newcourt, and DiBernadi convinced CIT management to actively support the group. With strong support at the vice-chairman level, the Edelman system has been expanded in terms of breadth of deployment, and OR is now penetrating new areas, including factoring, the consumers’ business, and the equipment-financing business. This is an industry where the use of OR is expanding and there are good opportunities for future work and future employment. Tools, such as credit scoring, that were once considered to be a competitive advantage are now a competitive necessity.

Strong upper management support for the OR work has been evident and management believes that with the proper resources, the group will offer a competitive advantage to the company. If there is a downside, it is the fact that the

Table 4. Summarized findings for the applications considered to have had “insufficient impact” to be examples of SOR.

Application	Period in Use	Improvements on Initial Work	Evidence of Organizational Change	Competitive Response	Other OR Work As a Result of Implementation	OR Has Become Part of Company Culture	Additional Resources Devoted to OR
AT&T Capital	1992–	✓	✓	✓	✓		✓
Bellcore—R&D	1991–97						
Bellcore—PDSS	1989–97	✓					
Bellcore—SONET	1992–	✓	✓	✓	✓		
DEC	1989–	✓	✓	✓		✓	
GE Capital	1987–	✓		✓	✓	✓	✓
GTE Corp.	1987–	✓	✓	✓	✓	✓	
IBM—LMS	1986–	✓			✓	✓	✓
IBM—OPTIMIZER	1983–??						
Kodak	1988–93	✓		✓	✓		
NYNEX	1990–	✓	✓	✓	✓		
Prudential Securities	1988–	✓		✓			
Reynolds	1988–	✓	✓	✓			
Yasuda	1991–	✓		✓		✓	

OR group has not managed to expand beyond five people, so the model for the future is to outsource more work and use the internal people to provide internal guidance. There has also been some loss of OR identity, with the group now seen as more of an “analytics” group than an OR group.

Bell Communications Research (Bellcore) (R&D, PDSS, and SONET)

Bellcore was acquired by Science Applications International Corporation (SAIC) and changed its name to Telcordia Technologies Inc. The Bellcore Consortium R&D application (Hoadley et al. 1993) died after the consortium disappeared (and all its consortium-related tools) when Bellcore was acquired by SAIC. The PDSS decision support program (Katz et al. 1994) has either disappeared or its usage is minimal. The SONET Toolkit (Cosares et al. 1995) is still in existence (not currently being marketed) and has been updated as recently as one year ago, and while it is not currently in use, it is still state-of-the-art.

After the acquisition, the environment for OR changed dramatically with the new focus on projects with immediate results. The members of the OR group were transferred to other areas and the structure became much more distributed in terms of the effort and the market that different business units were trying to reach. Recently a Mathematical Research Center was formed in Telcordia and this is beginning to interact with SAIC’s OR group.

Digital Equipment Corporation

Compaq acquired DEC in 1998. The global supply-chain model (GSCM) (Arntzen et al. 1995) developed by DEC and Insight Corporation is now marketed by Insight and currently has about 10 licensees. There have been a number of enhancements made to the program, with a new design released in September 2000. Compaq was initially unaware of the GSCM license that it obtained with the acquisition, but has since used the software extensively. GSCM was very beneficial to DEC, but with the onset of financial

difficulties, the company began downsizing and the group responsible for GSCM left.

It was reported to us that Compaq’s management believe that OR modeling applications are a way to gain a competitive advantage in the industry, and they are very supportive of this type of work.

GE Capital Corporation

The payment initiative (Makuch et al. 1992), which managed delinquent account collection, was viewed and protected by GE Capital as providing a strategic advantage. The program has been modified many times since implementation, and the process is now much more highly automated. The basic philosophy and techniques developed in the original application are still very much alive today. The success of this project resulted in funding to the R&D Center increasing by approximately 25 times at its peak and the development of numerous other applications in areas such as home mortgages, auto loan payments, and leasing debt.

Subsequent to its launch, other large mortgage and collection companies began implementing scoring throughout their collections process. It is now a requirement in the industry that any individuals hired to risk-management positions be familiar with this technology. Although commonly known as analytical research, optimization research, or scoring research, these OR groups are considered critical to the organization and their opinions are actively sought on many issues.

GTE Corporation

The merger of GTE Corporation and Bell Atlantic closed in 2000 to form Verizon Communications. The NETCAP DSS (Jack et al. 1992) is still in use although it has been modified since its initial implementation. GTE Corporation has no OR department but instead uses OR resources from GTE Laboratories, which developed the original DSS and continues to upgrade the algorithms regularly. Since the

time of the Edelman article, GTE has developed other specific initiatives such as IOS Net and AEIS that have used NETCAP as a foundation.

Recently, GTE has been looking into more automated planning and forecasting modules for the entire network, with a strong commitment from management to engage in this type of research. Many OR professionals from GTE Laboratories have been promoted to higher levels of responsibility, and this has led to GTE becoming much more technologically oriented. Post-merger, the influence of OR is being felt in the network and e-commerce areas especially, since the executives placed in charge of these areas are from the former GTE and have strong analytical backgrounds.

IBM (Logistics Management System and OPTIMIZER)

LMS (Sullivan and Fordyce 1990) continues in daily use and is one of IBM's top applications. Some minor extensions were made to the project so that it could run on different platforms, but these were incremental enhancements only. LMS was designed for the semiconductor division at Burlington, Vermont, and is now used at other manufacturing sites as well. We could find no evidence on the status of IBM Optimizer (Cohen et al. 1990) and assume that it is no longer in use. Following LMS, the two authors became involved in a project called Profit, which is a level up from LMS and deals with divisionwide supply-chain management. Lately, they have been working on another project called the LMS2000 that enables web-integrated supply-chain management. This facilitates real-time monitoring of WIP by customers to show the status of order lots; however, the stochastic nature of chip, wafer, and module manufacture makes this information difficult to interpret. OR is being used more often in all processes at IBM and has become an accepted practice. While there is a central OR group in the research organization at Yorktown, generally OR is decentralized at IBM with groups spread throughout the corporation.

IBM won the 1999 Edelman Award for the Asset Management Tool (AMT) that measures, analyzes, and guides the reengineering of IBM's complex supply chains. Barbara Martin, vice president of Integrated Supply Chain at IBM, said that the Edelman award marked an intensive three-year effort by a core team of 30 people at IBM, and that "our senior executive management is keenly interested in and supportive of our work."

A recent article (Dietrich et al. 2000, p. 52) reviewing the state of OR at IBM began:

After many years of hard work in the field, OR has become an integral part of IBM's core. World-class research in OR and the ability to apply the results to solve business problems have increased IBM's competitive edge—IBM's OR team helped save hundreds of millions of dollars, while improving operations and competitive strategies.

Kodak

The Kodak (Australasia) application (Farley 1991) produced all of the expected gains in productivity and savings for about five years. It was also implemented in the Canadian plant, where it was used for about four years until that plant was closed and production moved to Rochester, NY. After about five years the composition of the bulk photographic paper was changed, eliminating the different blends and dramatically reducing the need for the model. Although the application did spawn some initiatives in other product areas, the employees who worked on this were mostly IT people without experience in OR, and management did not distinguish between an IT application and an OR application. Over time, the interfaces became fancier, while the algorithmic content became more heuristic. There appears to have been at least one instance where an OR simulation model was used for strategic purposes, but management has not developed any strong appreciation of OR.

Other initiatives derived from this model in the areas of graphic arts film and x-ray film are currently being implemented in Kodak's operations around the world. Kodak (Australasia) has never had an OR group and has always outsourced this type of work; however, the head office in Rochester does have a group with OR skills called the artificial intelligence group. Author Farley suspects that competitors implemented similar work in pursuit of cost savings.

NYNEX Arachne

NYNEX merged with Bell Atlantic in 1998, and the combined company merged with GTE. The Arachne DSS (Barnea et al. 1996) is still operational in the New England district, but it has been discontinued in New York. Arachne was financially successful in first trials, but after implementation there were no relevant benchmarks to measure against and this made maintaining funding problematic. The advent of the Internet and the dramatic increase in new businesses caused the planners to become reactionary and network planning has been curtailed dramatically. After the merger with Bell Atlantic, Bell decreased the amount of money available for research, and when New York stopped using Arachne, the group was cut from approximately six people to three people. There have been several spin-off projects from that initiative, but the resources devoted to OR did not increase. Randy Pope is the only original author who is still working with Arachne and he has been doing some extensions on ring plates and algorithms for SONET. The new merger with GTE will result in the replacement of Arachne with the IOS planning tool and any updates that incorporate SONET planning will likely become part of IOS.

Prudential Securities

The mortgage valuation models (Ben-Dov et al. 1992) are still in use and have been refined in-house every year or so. Since the time of the Edelman article, many OR people

have left Prudential, and the group is not as big as it used to be. Furthermore, the Financial Strategies group has been split into trading and research groups. Currently, Prudential has a group of three or four people that work on the model and with other business units on various projects. They have not extended the model to things like bond arbitrage because the intense fluctuations in price make it hard to justify entering that particular market. The market downturn in the 1990s had adverse effects on the size of the firm that overshadowed any benefits from the utilization of the models. Prudential is no longer ranked in the top three of issuers of collateralized mortgage obligations, and its competitors are now much larger than they are.

Since Prudential implemented these models, all of their competitors have developed proprietary versions of prepayment models. Competitiveness in this market now requires the use of these techniques.

Reynolds Metals

Reynolds Metals was acquired by Alcoa in 2000. The centralized freight operation is still functional and continues to save cost in the service and freight area. The success of central dispatch (Moore et al. 1991) resulted in opportunities to market it outside the firm, and Reynolds has become a transportation service provider for other organizations. Reynolds maintains control of the model and manages the functionality, only releasing the software that controls the client interface information to its customers. The consulting group that was involved in the initial development did most of the refinements to the original model and has an arrangement whereby it can market the software (but not to other aluminum companies) if it pays Reynolds royalties. Nothing major has been added to the model because it was very robust as originally designed.

At the time of the Edelman article, the OR group was five to seven individuals and increased in size until about 1994, and it has remained static since then. This coincides with the departure of upper-level management sponsorship when the president and the COO left the company. Lately there has been a move away from core OR work towards team facilitation and work in business process reengineering.

Yasuda Fire and Marine Insurance Co. Ltd.

The asset/liability management model (Cariño et al. 1994) was used extensively and the company was very happy with it. The Frank Russell Company, consultants in the development of the model, revised the model over the following three years, but then lost Yasuda as a client. Yasuda had no employees trained in OR; however, they had employees with strong backgrounds in actuarial science, finance, and IT. Yasuda had a number of in-house groups comprising 40–50 people working on different types of models of which the Russell–Yasuda model was one key component in the process. Yasuda increased the funding to these groups

when the initial project was started and remained committed to that level for the entire duration of the project. A group of about 20 people remained working on the Russell–Yasuda model after Russell finished their contract.

The project champion, K. Sasamoto, was very senior in the organization and used this project to achieve greater decision-making authority in the company. Yasuda viewed this model as a strategic asset and planned to use it as a foundation to provide them with a sustained advantage over their competitors. There was a noticeable competitor response once Yasuda began using this model.

THE FOUR “NONSUSTAINERS”

The interview evidence for the four applications originally classified as providing no sustainable advantage is summarized in Table 5.

L.L. Bean

The model for optimizing telemarketing resources (Quinn et al. 1991) could not be traced and all of the players that were involved in implementing this model have long since left the company. The consultant, Bruce Andrews, who worked on this initiative did work on three other projects for Bean. The most systematic quantitatively oriented initiatives that Andrews is aware of happening at L.L. Bean were TQM and CQI under VP Tom Day. We could not find an employee at Bean who was familiar with the Edelman initiative; however, some employees reported subsequent projects of drop-shipping optimization (which is still done daily) and TQM.

We found no evidence of management support for OR. Bean does not have a centralized OR group. When Andrews was there, he brought in some students who functioned as a very small OR group, but this disappeared when Day left. Subsequent groups formed that used different types and levels of analytics in their work—catalogue tracking, customer profiling, call center forecasting, and capacity planning scheduling. It is not known if these groups are still in existence. If L.L. Bean needs any additional support, they hire consultants.

Merit Brass

In the Edelman article (Flowers 1993), savings at Merit Brass were estimated at \$200,000 annually, but this was determined by the timing of publication. After implementation, inventory kept coming down while service levels on Class A items went from 74% to 98%. Eventually \$6 million was eliminated from the \$16 million inventory for a conservative savings of \$1 million annually. Immediately after the implementation, sales started to grow rapidly (from \$32 million annually to \$45–50 million). Management offers many reasons for the rapid growth, but it is eminently plausible that customers noted the service improvements and responded. The cost of the initial OR work was estimated at \$78,000.

Table 5. Summarized findings for the four applications considered to be “nonsustainers.”

Application	Period in Use	Improvements on Initial Work	Evidence of Organizational Change	Competitive Response	Other OR Work As a Result of Implementation	OR Has Become Part of Company Culture	Additional Resources Devoted to OR
L.L. Bean	1989–??		✓		✓		
Merit Brass	1990–	✓	✓		✓	✓	✓
Tata Steel	1986–	✓	✓		✓	✓	✓
Yellow Freight	1988–	✓	✓	✓	✓		

Not surprisingly, Merit called in the consultant to do a variety of additional projects, including a warehouse “quick pick” line to assemble 250–350 smaller orders/day. The original project and others that have followed have changed the culture of this company. Merit Brass employees are now “fact-based decision makers.” They don’t always do everything the numbers say, but first they “pound the numbers” so that they know what they say, and then they formulate action plans from that point. The Edelman project has changed Merit Brass and remains a very strong part of their culture. We found no evidence of competitors responding to this work.

Tata Steel

The very successful Edelman-prize-winning project on optimizing resources at Tata Steel Company (Sinha et al. 1995) has led to OR being used in almost all important aspects of management decision making. This includes business plan formulation and monitoring performance against that plan, constrained resource distribution, make-or-buy decisions, calculating break-even prices, and short or immediate decisions that can be optimized.

The model from the Edelman article is not very relevant anymore because Tata Steel has gone from a power shortage to a power surplus, but the model has been used on occasion to manage the surplus situation.

The OR department at Tata Steel was four individuals at the time of the Edelman article and has now expanded to 25 people in four groups: a planning and optimizing group, a data management group, a cost management research group, and an analytics group. Despite the general trend towards downsizing in the rest of the company, the OR department has been allowed to expand at will, providing they find the appropriate individuals. Gopal Sinha, the leader of the OR group at that particular time, has been promoted to deputy general manager. The culture of the company has changed towards an acceptance of OR techniques. Recently, Tata Steel won a gold medal for the most cost-effective steel plant in India.

Tata’s CEO originally was not convinced that the company needed an OR group, but after the success of the Edelman initiative he became a strong supporter, and senior management are now completely convinced of the importance of OR techniques. This has led to the entrusting of many other initiatives to the OR group.

Tata Steel has not noticed significant competitive reaction to their OR initiatives. Sinha attributes this to the weak economic situation for steel plants in India during the economic recession of the last two years. Tata Steel was in economic surplus despite the recession—they see this as a direct result of their optimized decision making.

Yellow Freight System, Inc.

Yellow Freight’s load-planning model, SYSNET (Braklow et al. 1992) is still in use although it has evolved a generation. The original model has been extended to real-time analysis to control line haul operations, and forecasting tools have been added. It is an integral tool within the organization and is used to plan the network and terminal structures. Any new initiatives must be reviewed within SYSNET, and any structure issues or strategic planning decisions are tested within the model. Yellow has used SYSNET as a foundation to build the existing system and stay ahead of the competition. There has been more recognition of the OR department and more interest in investing in these areas from upper management. This has been a slow evolutionary process and has led to other models that are used in the tactical day-to-day operations being installed in the last couple of years. As well, there has been a gradual increase in the decision-making authority of the OR department. Yellow has employed consultants in the past to handle the construction of systems for complex problem solving; however, they intend to run their operation more in-house in the future and have recently hired more people with OR degrees.

DISCUSSION

The longevity of these applications is impressive: 26 of the 34 applications are still in use. The great majority of the survivors (23 of 26) have been developed and improved since the Edelman competition. An objective of the Edelman competition is to promote the use and development of OR, and these applications appear to have done that within their corporations: 24 of 34 have catalyzed other OR work for their developers, 14 have led to additional resources being devoted to OR, and in 18 cases we found evidence that OR is now a widely accepted part of the corporate culture. Perhaps surprisingly, we found evidence that 20 applications had attracted the attention of competitors and triggered some form of competitive response, usually an attempt to replicate the work.

The evidence from the years following the Edelman competition on the fate of the 12 applications originally classified as examples of “strategic OR” strongly supports the view that these applications created a competitive advantage for their firms for an extended period of time. Three of the applications are no longer in use: Both AT&T applications were in use for at least 10 years before a major change in AT&T’s corporate strategy rendered them obsolete (one of these is still in use in AT&T Canada), and the Vilpac application appears to have been set aside when the ownership of the firm changed. Here, as well as in the case of ABB Electric/Waukesha, which has also gone through changes of ownership, the OR work contributed significantly to creating the rosy financial situation that made an acquisition possible.

AA arrival-slot allocation has not been as visible as the AA yield management and crew-pairing applications, although all three applications are now actively marketed by Sabre Decision Technologies, the successor of the AA OR group. The OR group at AA, known as AA Decision Technologies and then Sabre Decision Technologies, before being spun out as Sabre Technology Solutions, was extensively involved in AA operations and decision making throughout this period, and provides the strongest evidence of being a strategic OR group with a portfolio of applications that included the three Edelman finalists.

The post-Edelman evidence on the Gas Research Institute, KeyCorp, and Sainsbury applications strongly suggests that these were correctly classified as “contributors.” These firms do not identify the very substantial benefits attained with the use of OR, and have not made the level of investment in OR that would be commensurate with these levels of benefits.

The development of OR at P&G since 1996 suggests that this application may have been incorrectly classified and now appears to fit the definition of SOR. In the original Edelman literature, this work appeared to be a one-time reengineering project and hence did not meet the definition of “SOR work” but, in the last five years, P&G has used this same OR-model-based methodology more than 30 times to reengineer other supply chains. The OR work has, therefore, been used over a period of time, has been maintained and updated, has precipitated a variety of organizational change, and has created significant benefits for P&G. It has also led to significant investment in an OR group that now appears to be on its way to becoming a strategic OR group.

The new evidence on the fate of the 14 applications originally classified as having “insufficient impact” to be examples of SOR provides no strong reasons to change the earlier assessment of the majority of these applications: AT&T Capital, Bellcore (R&D, PDSS, and SONET), DEC, GTE, IBM Optimizer, Kodak, NYNEX, and Reynolds. While several of these applications continue to be used frequently, none appears to have attracted the level of both internal and external attention that would be expected for an example of SOR.

The new evidence suggests that four of the “insufficient impact” applications, GE Capital, Prudential, Yasuda Fire and Marine, and IBM LMS were more “strategic” than originally thought. These models appear to have garnered senior management support over a substantial period of time, and triggered a strong competitive response that has led to wide-scale adoption of similar models in their industries. The LMS model at IBM provided the foundation for later supply-chain OR applications that have been impressive (Dietrich et al. 2000) and fit the definition of SOR.

The history of the four “nonsustainers” contained some surprises. The new data on the L.L.Bean application is consistent with its classification as a “nonsustainer.” We found no sign of either this application or OR being nurtured over a period of time at L.L.Bean. However, the new evidence on the Merit Brass, Tata Steel, and Yellow Freight applications suggests that these applications are more correctly classified as examples of SOR. The OR work in these applications does not appear to be particularly complex or proprietary, and we therefore assumed that if this work had a competitive impact it would be easily replicated and the impact nullified. This appears to be the case at Yellow Freight, with the use of OR models similar to the load-planning model now a mainstay of the freight industry. At Merit Brass and Tata Steel, the OR work does appear to have provided a significant competitive benefit; Merit Brass’ sales have grown by 50%, Tata Steel won a gold medal for having the most cost-effective steel plant in India. However, competitors do not appear to have responded by replicating the work.

The longitudinal data adds to our understanding of the competitive response to SOR. Several of these applications have prompted competitors to replicate the successful OR application and have produced a situation where OR has become a competitive necessity rather than a competitive advantage: In strategic terms, the OR work is now a core competence. For example, firms in the airline and rental car industries cannot be competitive without yield management systems. When OR, or a particular application of OR, is a core competence, creation of a sustainable advantage for one firm requires that that firm’s OR be leading edge. This requires that one firm consistently be further down the “learning curve” than the competition; that is, the firm has developed its databases, algorithms, and technologies to be continually ahead of the competition. The best example of this would appear to be Sabre, with yield management from the early days (1985) almost to the present day.

The data show that Merit Brass has sustained a major competitive advantage for more than 10 years from some OR work that originally cost less than \$100,000 to undertake, and which has been widely publicized. A competitor observing slipping market share or profitability that attributes this to a cost disadvantage, such as could be created by SOR work, has several ways to respond. While OR professionals might see replicating the OR work as an obvious response, it is not at all clear that the business world is familiar enough with OR to do this. Few

Table 6. Reclassification of the 34 corporate Edelman applications 1990–1997 after the follow-up study.

SOR	Contributors	Insufficient Impact	Nonsustainers
AA yield management	Gas Research Institute	AT&T Capital Corp.	L.L. Bean
AA ASAS	KeyCorp	Bellcore SONET	
AA TRIP	Sainsbury	Bellcore PDSS	
ABB Electric		Bellcore R&D	
AT&T call simulator		DEC	
AT&T TM site selection		GTE	
Delta COLDSTART		IBM Optimizer	
GE Capital		Kodak	
Harris Corporation		NYNEX	
IBM LMS		Reynolds	
National Car Rental			
Merit Brass			
Procter & Gamble			
Prudential Securities			
Sadia			
Southern Company			
Tata Steel			
Vilpac Truck			
Yasuda			
Yellow Freight			
(20)	(3)	(10)	(1)

"strategic consultants" would propose responding to a cost disadvantage by setting up an OR group and trying to replicate the SOR work that is causing the competitive distress. A more likely strategic response would be some form of niche strategy that avoids competing head-to-head with the cost-advantaged firm.

In Table 6, we summarize our assessment of the 34 applications following analysis of the longitudinal data.

CONCLUSIONS

A comparison of the original classification (Table 1) and the revised classification following analysis of five or more years of post-Edelman competition data leads to some interesting conclusions about the long-term impact of OR

Some firms use OR in an incremental fashion to tackle very large, complex problems yielding improved competitive positions over long periods of time, as has been the case of American Airlines/Sabre with yield management. Other firms tackle a number of smaller operational level problems on an ongoing basis, much like Merit Brass, where these improvements incrementally make the organization more attractive. These two approaches both appear to be successful over the long term.

Central to the continued success of any OR effort is an acceptance by management and/or belief in a rigorous approach to decision making. It is clear from those organizations where OR did not become "strategic" following the success evident at the time of the Edelman competition, that quantitative rigor in decision making was not taken to heart nor accepted or deemed valuable by senior management. The reclassification of such organizations as Procter & Gamble, Merit Brass, and Tata Steel as examples of SOR indicates how a continued management commitment to OR methods can extend what would otherwise appear

as transferable, easily replicated, or low impact OR into a long-term competitive advantage.

Additionally, organizations evolve and innovations are often quickly adopted. Systems that once provided a competitive advantage can quickly become a competitive necessity. Sustaining an advantage from OR efforts may require the continual extension of original solutions to more innovative approaches with increased scope. A particular challenge is maintaining the currency of OR solutions as business models change or as organizations themselves change (perhaps through merger activity).

Our findings provide evidence that OR can contribute to organizational success through creating advantage that can be sustained. This can occur even though the OR work is not complex by the standards of OR people, but rather that the OR work is accepted by management and utilized to implement change (either organizational or process). Incremental gains achieved by continuously improving solutions to large-scale projects or a portfolio of successful smaller projects can both lead to expansion and growth for OR (potentially across other business units).

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