Automated Decision Making Comes of Age

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For decades futurists have prophesied that computers would relieve managers and professionals of the need to make many decisions.[1] But despite much hype about artificial intelligence and expert systems, widespread automated decision making has been slow to materialize. Too many early applications were just solutions looking for problems and did nothing to contribute to high performance.[2] One expert system promised to automate the diagnosis of diseases, for example, but that is a very difficult problem to address, and one that physicians generally like to solve themselves. When there was a real business issue to address, it was difficult to extract knowledge from decision makers, and the knowledge was too dynamic and difficult to maintain over time.

Instead, some businesses settled for providing managers and analysts with "decision support." The idea of decision support has fascinated academics since the early 1970s.[3] Decision-support systems are typically designed to help managers report, analyze, and interpret data rather than execute business decisions. Someone must manipulate data, review reports, and ultimately make a decision. But the notion of computer-augmented decision making never really caught on to the degree that more transactional software applications did, such as enterprise resource planning (ERP) or customer relationship management (CRM) systems. As with expert systems, it was often difficult to extract algorithms from human experts and put them in the computer. Many executives did not accept the notion that their decisions could be reduced to a set of rules or variables. Rather than advancing fact-based decision making, support tools were often abused by executives to justify their own biases and opinions. While decision-support systems gained widespread acceptance in some quantitatively oriented areas (such as promotion-pricing effectiveness), most executives delegated the use of such systems to subordinates, preferring to rely on their gut or more traditional approaches to decision making. Finally, in today's lean, fast business environment, the greatest obstacle of all to the use of decision-support tools (such as online analytical processing engines [OLAP] or statistical models) may be the time needed to analyze and maintain them. They are also very complex, and typically only a few people in an organization can understand and work with them.

Despite the limitations of earlier technologies, automated decision-making systems have come of age. Decision-support applications provide managers with the information and tools they need to make decisions. Automated decision-making applications, however, are designed to minimize human involvement in an ongoing decision-making process. Their objective is to sense conditions, apply codified knowledge, and respond appropriately with minimal human intervention. As a result, automated decision applications can be much more effective economically.

Accenture's ongoing research into high-performance businesses has identified these applications as an important success factor in several industries, although their direct monetary benefits are generally still unclear. By embracing innovative technologies and carefully managing their implementation, leading companies have been able to simultaneously decrease risk, cut costs, and increase speed and flexibility. Such results add up to improved bottom

lines and enhanced competitive profiles. (Note that legal and ethical concerns may impede the use of these technologies. For example, individuals in the UK have the explicit right to request that a decision affecting them not be made based solely on the automated processing of personal data.)

Current systems have roots in both artificial intelligence and decision-support tools, in that they often involve both business-rule processing and statistical or algorithmic analysis. They are gaining rapid acceptance and penetrating a variety of industries and business processes. These systems often make more consistent decisions than people do and are helping managers move from insight to decisions and effective action more quickly. Automated decision applications are powerful "talent multipliers" that leverage the expertise and judgment of an organization's most valuable employees. They are substantially reducing the number of people necessary to make operational decisions. In many environments, process experts are creating and maintaining the systems, eliminating the need for a specialized class of "knowledge engineers."

These new systems came about not only because technologies have matured, but also in response to business needs. Moving rapidly from insight to action is more important than ever for high-performance businesses, which must deal with increasing amounts of data, consumers' expectations of a rapid response to their needs, and the rising costs of knowledge workers. Competitive and regulatory pressures are prompting executives to apply the same principles that have increased productivity in other areas of the business to information work. The new generation of "industrial strength" decision applications helps reduce labor costs, leverage scarce expertise, accelerate decision-making processes, enforce policies, speed customer responsiveness, offer customers greater flexibility, and improve quality.

To understand how high-performance businesses successfully take advantage of new technology, we studied automated decision-making systems in banking, insurance, and travel and transportation, where they are most common, and in industries where they are emerging, such as health care, utilities, and agriculture. In addition to interviewing people in 19 organizations

Decision Technologies

Decision-support and automated decision systems make use of a variety of tools. The most appropriate ones to employ depend on the type and complexity of the work, together with the degree of interdependence workers have in accomplishing their tasks; there may be considerable overlap in the technologies used for a given task.

Common decision-support tools:

- *Reports* periodically deliver prede fined structured data to subscribers.
- *Alerts* monitor and actively inform users or other applications of exception conditions.
- *Visualization* tools aid in analyzing and interpreting data.
- *Business analytics* are technologies for manipulating and analyzing semi-structured data; they include spread sheets (such as Excel), multidimensional models (also known as online analytic processing, or OLAP), statistical analysis tools, and predictive forecasting/modeling tools.
- *Simulation* tools mathematically model a process, system, or scenario to allow users to see the implications of modifying different variables.
- *Collaboration* tools enable communication and knowledge sharing.
- *Knowledge management* tools aid in creating, disseminating, and using knowledge.

Common automated decision-making technologies:

- *Sensors* are electronic transducers that detect and report on physical phenomena.
- *Actuators* enable systems to act upon sensor data.
- *Data architectures* define how data is collected, stored, aggregated, and shared throughout an organization.
- *Data mining* allows people to use sophisticated algorithms and search engines to find patterns and correlations in large, preexisting databases.
- *Rule engines* process a series of business rules using conditional statements to solve nonalgorithmic problems.
- *Web services* are publicly available modular "micro-applications" that work via the Internet.
- *Workflow applications* are software applications that enable information-intensive business processes.
- *Enterprise systems* are software applications that automate, connect, and manage information flows and transaction processes in complex organizations.

who have implemented such systems, we've also interviewed several software vendors and Accenture consultants who work with these systems.

This report explores the technical and managerial issues associated with automated decision making, both now and in the future. As more and more decisions become automated, it is increasingly important for individuals and organizations to think about which decisions need to be made by people and which can be computerized. The future employment of knowledge workers and the performance of organizations' knowledge-intensive processes are at stake.

Applying Automated Decision Making

Automated decision making involves several approaches that require varying—though generally low—levels of human involvement. The objective of such environments is to have a computer system come up with a decision or a recommendation.

Automated decision applications differ from traditional decision support in two respects. First, in many cases an individual does not need to recognize a problem or initiate an analysis for a system to work. Instead, decision making is embedded in the automated flow of the work process and normally takes place without human intervention. This is not to suggest that people play no role at all. Depending on the application, people may not be involved at all, or someone may always need to review and confirm a decision, or a person may need to make a decision only in exceptional cases. Even the most automated systems, however, rely on experts and managers to maintain rules and monitor results. A system typically draws on a set of rules, but other data and decision technologies may also be involved. Second, unlike decision support, most of these systems (even those that contain rules requiring human confirmation) are linked directly to core business processes that quickly, accurately, and efficiently translate the decision into action.

For the most part, automated systems are being used for decisions that must be made frequently and rapidly using information that is available electronically. Automated decision systems are relatively highly structured, with well-understood decision factors. If the decision rules can be readily codified by experts, and if high-quality data are available, chances are good that the decision can be automated. Some infrequently made decisions may be automated if speed is crucial. For example, in the case of a failure in the electrical energy grid, accurate decisions need to be made instantly in order to avoid systemwide blackouts. Some regions of the United States averted blackouts when the grid failed in the summer of 2003 because their automated decision systems shut off power quickly.

We found that automated decision applications address six types of problems:

Configured Solutions. Configuration of a product or solution was one of the earliest applications of automated decision technologies. Now configuration applications are increasingly being applied to services. The most successful automated applications rarely produce a simple solution; they select the best or most appropriate solution based on many variables (rules, data, and complex relationships) that can be difficult to reconcile manually. For example, a cellular phone provider may have a dozen service plans, none of which would be appropriate to someone who is a poor credit risk. But that individual might still be a candidate for a prepaid phone. An automated configuration system can weigh a variety of customer attributes in real time (including the customer's online credit history) and present an offer to the customer during a call or Web session that optimizes both customer satisfaction and the provider's profit. Similarly, in the mortgage origination business, lenders use automated decision applications to develop highly customized loans that are tailored to each applicant's credit history and requirements. For example, a teacher might prefer a loan with payments due only during the school year.

Yield Optimization. The airlines were pioneers in using automated applications to determine seat pricing based on availability and timing. More recent yield management systems can employ more factors, such as customer loyalty and lifetime value, in their decisions. Manufacturing, logistics, and transportation companies such as UPS employ applications that improve the load-operating efficiency of their trucks. Variable-pricing models have begun to gain acceptance in other industries such as retailing and entertainment. Some apartment owners are even beginning to use yield management systems to optimize rents.

Routing or Segmentation Decisions. Several companies we studied showed productivity improvements by using

filters to route cases or transactions. An insurance firm, for example, established "priority lanes" (much like a grocery store) to process straightforward insurance claims and those in which the customer has a good profile (even when some data are missing). The firm increased its "no touch" rate by 10 percent using this technology. A hospital chain did another form of routing with an automated decision system, using it to perform triage on admitted patients.

Compliance with Regulations or Company Policies. Routine decisions, such as the need to determine someone's eligibility to obtain welfare or insurance benefits, are time consuming and involve many rules but are not inherently difficult. It's important, however, to ensure that the rules are applied consistently. Similarly, U.S. mortgage lenders benefit considerably when they can automatically identify and process loans that conform to the requirements of Fannie Mae or Freddie Mac and will, therefore, be accepted for resale in the secondary market.

Fraud Detection. Credit card companies, government agencies such as the IRS, and SEC security examiners all employ some level of automated fraud detection. New regulatory requirements for financial controls may motivate companies to install more sophisticated controls to detect financial improprieties.

Dynamic Forecasting. The growing popularity of vendor-managed inventory, in which the manufacturer maintains a customer's inventory levels, is prompting manufacturers to consider ways to further automate demand forecasting and automatically align the forecasts with manufacturing and sales plans.

Operational Control. Some automated decision systems sense various aspects of the environment and respond rapidly on the basis of rules or algorithms. For example, electrical sensing systems designed to avoid blackouts fall into this category, as do systems that monitor agricultural growing conditions and take appropriate action based on a network of remote sensors.

We observed a variety of automated decision applications in several industries. The financial services industry has made the most progress implementing industrial-strength, real-time decision making into its core business processes. Investment houses were an early pioneer with program trading and arbitrage applications. These internally oriented applications still exist, but the highest growth seems to be in customer-facing applications. The widespread availability of online credit information and financial history, the need for differentiation through rapid customer service, and the rapid growth of online financial-services providers have all led to increases in automated decisions. In banking, real-time mortgage and secured lending decisions are becoming common. For example, LendingTree.com uses automated decision making for two purposes: to decide which of its participating banks are most likely to issue a mortgage to a customer, and then to offer the customer four mortgage deals within a few minutes, using the banks' technology or its own.[4]

DeepGreen Bank was designed from the ground up to use automated decision technology for home equity loans. An application can be completed by a customer within five minutes, and an automated process then begins. A credit report is pulled, a scoring process is invoked, an online valuation of the property is accessed, fraud and flood insurance checks are made, and a loan decision is made by DeepGreen's systems. About 80 percent of the time the customer receives a final decision within two minutes. (The other 20 percent of the time a conditional commitment is made because some information—usually the appraisal—is not available online.) A notary public who works near the home is automatically selected, and the customer chooses a closing date. All loan documents are automatically created, printed, and express mailed to the notary.[5]

One of the earliest industries to adopt automated decision making approaches was insurance, where automated underwriting applications have been explored for more than a decade. (See "Automated Insurance Underwriting.") The use of rule-based technology in underwriting has become pervasive in large insurers' "personal lines" businesses (such as homeowners' and auto insurance) and is also penetrating the more complex processes of small business underwriting. There have also been some efforts to automate decision making in other insurance processes, including claims, but adoption in those areas has been much slower.

Travel and transportation was perhaps the first industry to use automated decision making.[6] American Airlines initially developed an application that determined airline seat pricing based on availability and timing. This application led to the creation of SABRE Airline

Solutions—a long-term provider of yield management applications to airlines—whose automated pricing applications are routinely used by more than 100 airlines. The technology has now been extended to a variety of operations, including flight scheduling and crew and airport staff scheduling.

Automated decision making is expanding into related areas in the travel industry as well. Yield management is being combined with loyalty management applications to determine real-time pricing for hotel rooms. Harrah's casinos, for example, make several million dollars a month in incremental revenue by optimizing room rates for their hotels and offering different rates to members of the company's loyalty program based on projected demand. The use of yield management systems for hotel room pricing is common, but combining it with loyalty management programs is unusual.

Automated decisions can be found in agriculture, too. For example, Accenture Technology Labs helped a winery in California put remote sensors for temperature, moisture, rain levels, and other weather and soil conditions throughout its vineyards. Using the sensor data, it was able to completely automate some important decisions, including watering protocols. But even this sophisticated system couldn't make every decision affecting the grapes—someone still had to decide the old-fashioned way when to take protective measures as the temperature dropped in cooler months.[7] (See "Sensor Telemetry at Pickberry Vineyard.")

Even when a decision process can be fully automated, fiduciary, legal, or ethical issues may still require human involvement. For example, in the health care industry, many companies and institutions are exploring automated care protocols or intelligent order-entry systems that recommend a particular drug or course of treatment for a patient. In every case we know of, however, these systems augment rather than replace the judgment and decisions of physicians and nurses. A physician either initiates an order (and the system checks it) or is able to override the recommendation of an automated protocol. Patients are safer when an automated system is combined

Automated Insurance Underwriting[12]

Organizations that aspire to high performance have much to learn from the insurance industry, an early adopter of automated decision making. Although the industry's initial attempts to develop artificial intelligence and expert systems a decade earlier did not pay off, it has now largely succeeded in using rule-based technology. Many firms have already used the technology to streamline their individual or "personal lines" businesses and have made headway in automating the more complex processes of small business underwriting. We found that companies implement automated underwriting applications for three reasons:

- to improve underwriting results by controlling costs and reducing insurance risks;
- to increase speed and flexibility;
- to conduct business effectively over the Internet by introducing more efficient online processes.

Underwriting is both risky and expensive. Making a few bad bets, an insurance company can go bankrupt. By implementing an automated system, insurance companies can increase consistency and get more value out of the abilities of their best underwriters. After the initial investment, automation also can save money, either by reducing the number of lower-level underwriters or by underwriting more business without adding employees.

Insurance companies also want to increase the speed and flexibility of their underwriting processes. Customers who receive a quick yes to their policy applications are unlikely to seek insurance elsewhere. And when they can quickly change underwriting policies, insurance companies can chase the most profitable policies and customers. Flexibility in underwriting rules is crucial, for introducing a new insurance product or changing an existing product inevitably results in new business rules. Rules that cannot be easily adapted may result in systems that might have speed but no flexibility. Whether they are brokers or customers, Internet users want not only convenience but also nearly instantaneous replies, which only automated decision-making systems can deliver.

More sophisticated implementations also make decision-support applications augmented by human judgment more effective. For example, when underwriting rule definitions are combined with policy, loss, and premium data in a data warehouse, actuaries can assess profitability at various levels. In an environment in which all types of data are integrated, reports could be generated to provide loss history by line of business, market segment, or individual rule.

with physician knowledge. For example, prescribing errors were reduced at Partners HealthCare in Boston by 55 percent as a result of an order-entry system that combined the two.[8]

In addition to the variety of examples outlined here, other industries are likely to rapidly develop financial, pricing, call-center, and supply chain applications in the near future.

Technology and Applications Environment

Although automated decision making is becoming a more mainstream business activity, the technologies and vendors that support it are still relatively small scale. Some companies have created their own systems, and analytical applications have always had a smaller market than that for transaction-oriented systems. While a variety of technologies are available, most of the organizations we interviewed use business-rules technologies that are available from a few small vendors, such as Ilog, FairIsaac, and PegaSystems. These systems not only make automated decisions using a "rule engine," but also move a "case" or work product through a business process using workflow technology.[9]

Some vendors now provide industry-specific application packages for tasks like underwriting, which typically shorten the time to implementation. Most firms, however, develop their own custom systems using rule engine software; some even use traditional programming languages for this purpose. Others are finding success by having their products built in to major application suites. For example, companies employing the forecasting and decision-making capabilities of i2, Manugistics, JD Edwards, SAP, or Oracle are using Ilog's rules engine. The business rules can work with transaction system data but are still in an easy-to-update rules base. Today there is much less concern about the arcane technical issues of the artificial intelligence era.

One major difference between current technology and the initial generations of artificial intelligence is that end users maintain the rule base, rather than technologists. This is a considerable advance because the difficulty in maintaining expert systems as the knowledge domain changed was a major barrier to their successful use. In

Sensor Telemetry at Pickberry Vineyard

Data for most automated decision applications typically come from end users (often via a Web interface), external data sources such as credit-reporting applications, or from the company's own systems. Accenture Technology Labs field-tested the Accenture Remote Sensor Network prototype to demonstrate the far-reaching potential of sensor telemetry with Pickberry Vineyard, a premium grape grower in Northern California. (The Accenture Remote Sensor Network is a wireless mesh network of sensor nodes that can be spread across any area—from a factory to a forest floor—enabling organizations to gain unprecedented visibility and insight into product conditions and operations.)

The test involved embedding a network of wireless sensors in a 30-acre area to continuously sense humidity, wind, water, soil conditions, and air temperature. Data gathered from the vineyard is relayed via a self-organizing wireless network application to a base station and transmitted back to the labs via cellular uplink. Because the network is self-organizing, it can be easily expanded by adding new nodes, with no configuration work necessary.

Accenture also developed a Web portal and customized reports in Excel that are updated automatically through Web services. These intuitive tools turn real-time data into actionable insight for Pickberry's decision makers. The Remote Sensor Network provides the vineyard with the ability to automate and implement many decisions at a much greater level of detail. The application also enables Pickberry to manage operations and resources, such as water usage, more scientifically. Finally, the system can detect potentially devastating events such as frost and disease, enabling Pickberry to take quick action. These capabilities lead to more effective crop management, lowering costs while raising product quality.

insurance, for example, technologists and consultants generally work with underwriting experts to create an initial rule base, but ongoing management and creation of new rules is typically done by the underwriters themselves. "Enabling underwriters to manage the rules directly affords companies far more flexibility and control, maximizing the speed in which new business rules can be implemented," notes Michael Krans, a senior manager in Accenture's Financial Services group. If an organization is going to adopt automated decision making in a widespread fashion, it needs to ensure that rules are appropriate and well maintained over time. The mortgage company Freddie Mac, for example, created an "enterprise rules architect" position to ensure that rules were current and consistent throughout the company.

In many cases, the goal is not just to establish a rule base but to optimize it. If a system has been operating for some time and there is sufficient data, it's possible to understand the contribution of each individual rule to profitability or some operational measure. To perform this sort of optimization requires substantial IT and statistical skills, as well as an understanding of the knowledge domain being optimized.

Some organizations have embedded their rules directly—not using a separate rules base—in a variety of existing transaction systems. This is problematic because rules must be monitored and periodically modified as business conditions and processes change.[10] Embedded rules are particularly difficult to analyze and maintain. If a company is serious about using these applications over time, it will benefit by extracting the rules into a common rule base. At one health care system, for example, an analysis uncovered 23,000 rules in various systems around the organization, most of which were not being actively managed. The institution is planning a project to extract and isolate them for easier maintenance.

Management Issues

Although automated decision technologies can help companies perform routine tasks efficiently, they can also create a variety of managerial headaches. For example, managers told us that difficulty finding enough experts was one of their greatest challenges. Experts are necessary not just to create a system (a project that requires several full-time experts for several months, typically), but also to optimize it. One manager of a project for small business insurance, for example, had to cease using a system for certain policy lines because he didn't have the underwriting experts or actuaries on staff to tune the system and optimize the rules.

New systems also have an impact on front-line employees. While we heard of only one firm that had made major layoffs resulting from these systems, it is a fact that there is little need for low-skilled or entry-level performers after an automated decision system has been implemented. From a change management standpoint, managers need to communicate as early as possible what will happen to jobs, how decision making will be automated and centralized, and what kind of decisions people will continue to make.

Automated systems can reduce large staffs of information workers to just a handful of the most experienced experts. A key management issue is ensuring that those remaining have the highest possible skills. The remaining staff needs a highly refined understanding of the process being automated and its relationship to the dynamics of the business. The truly talented will thrive in this new environment, but to do so they must have finely honed judgment, usually developed over years of experience working on similar problems, to handle the remaining exceptions. They must closely monitor changing business conditions and act decisively to optimize rules for the benefit of the business.

And where will the experts come from in the future? In the absence of lower-level jobs to build their expertise, experts may be in short supply in the next generation. None of our respondents had used their systems long enough to face this problem, but several admitted it would inevitably arise when their experts retire or leave for other companies.[11]

Another key management issue is how to deal with exceptions. What happens, for example, when the computer has too little data to make a decision (a frequent reason for exceptions)? Several organizations in our study strove to eliminate exceptions altogether (some achieved automated levels of more than 95 percent), but the average level of automated processing was probably closer to 80 percent. Another question is how to treat employees who override the system. Should managers assume that an individual who ignored the system did so for good reason—thus providing an opportunity to learn from the problem and improve the system? Should someone who frequently overrides it be punished? In health care, for example, both attitudes can be found in different hospitals.

A final issue in some organizations is getting consensus on rules. While this is not much of a problem in routine operational environments such as insurance underwriting, it is sometimes a topic of passionate debate in health care settings. At one hospital, for example, some senior physicians had their own sets of rules. Their prestige was such that no one even tried to persuade them to adopt a common set.

Looking Toward the Future

We believe that automated decision-making applications will continue to proliferate and will have substantial implications for organizations and the people who work in them. Individuals, for example, should factor these systems into their career strategies. They will need to look for jobs where face-to-face contact is necessary to make a decision or where the information needed is complex and ambiguous. If, for example, you can gather data and make decisions from home in your job, there's a good chance the decisions you make can be automated. Data analysts and information workers who spend the majority of their time producing reports will find that these functions will be automated out of existence. There will be plenty of opportunities for experts who can work with computers, but there may be limited opportunities to become an expert. Where decisions have been automated, companies will have to explicitly train experts or transfer knowledge from others before they leave; experts won't be developed in the course of daily work.

Organizations with knowledge-intensive business processes need to integrate automated decision-making capabilities into their goals for those processes. Many have implemented knowledge management or decision-support systems, but faster, more consistent processes can be achieved by integrating automated decision-making capabilities into workflow and transactional applications (while maintaining a separate rules base). The greater the amount of data, the greater the potential benefit from automation. For example, the radio-frequency identification (RFID) systems now emerging will create massive amounts of data, and critical supply chain decisions (when to reorder, when to reconfigure a supply chain) will probably have to be made using automated approaches.

Organizations also need to think about how many and what kinds of human decision makers they will need in the future and begin to develop them now. It is likely that automated decision making will move further and further up the organizational hierarchy; if decision support is being used now, decision automation will probably be used in the future. The information analyst may soon be obsolete.

Widespread availability of data and knowledge bases in many industries will hasten the move toward automated decisions. Consumer credit firms quickly found that standardized credit information accelerated the competitive pressure to automate loan originations. Automated mortgage decision making is being spurred on by the availability of online home valuations. As more industries develop online databases, decision systems that analyze and decide on the basis of the data will surely proliferate.

In the future many industries will also find that third-party industry applications (incorporating prepackaged rule bases) will be available to all competitors. Companies will no longer need to develop their own proprietary decision systems. Software vendors already offer decision applications packaged with a rule base in insurance, and health care institutions are beginning to organize to provide it as well. As other companies develop these capabilities, how will organizations differentiate themselves when everyone is using the same knowledge? Strategists should be thinking now about the role of unique, proprietary knowledge in their business models.

Automated decision making will also inevitably have legal implications. On the day we interviewed a hospital manager for this study, for example, she was subpoenaed to appear in court to discuss her organization's computer system. We know of no cases of a rule base itself being subpoenaed, but it will surely happen. Of course, regulatory changes may also increase pressure on companies to industrialize their decision processes as a way to ensure compliance.

This brave new world has been a long time in coming, but it is clearly upon us now. High-performance businesses need to incorporate automated decision making into their strategies and processes or they won't be high performers for long. There is simply too much data and too many decisions to be made for organizations to pass on acquiring and using this technology.

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Notes

1 For example, scientist and fiction writer Isaac Asimov's *I, Robot* (1950) identified the Three Laws of Robotics, an early set of rules to guide automated decision making. Ray Kurzweil's *Age of Intelligent Machines* (MIT Press, 1990) contains an overview of the history of artificial intelligence.

2 T. Grandon Gill, "Early Expert Systems: Where Are They Now?" *MIS Quarterly,* March 1995.

3 Decision support systems were defined in Anthony Gorry and Michael Scott Morton, "A Framework for Management Information Systems," *Sloan Management Review,* 1971.

4 For more on automated decision making in the consumer credit industry, see Tom Davenport and Jeanne Harris, "Automated Decision Making in Consumer Lending," Accenture Institute for High Performance Business, June 30, 2004.

5 For more on automated decision making at DeepGreen Bank, see Jeanne G. Harris and Jeffrey D. Brooks, "In the Mortgage Industry, IT Matters," *Mortgage Banker Magazine,* December 4, 2004.

6 For an overview of yield management applications in the transportation industry, see Anthony Ingold, Una McMahon-Beattie, and Ian Yeoman, *Yield Management* (Continuum Publishing, 2001).

7 "Pickberry Vineyard: Accenture Prototype Helps Improve Crop Management," Accenture Web site, 2004. See *http://www.accenture.com/xd/xd.asp?it=enweb&xd=services%5Ctechnology%5Ccase%5Cpickberry.xml*

8 Thomas H. Davenport and John Glaser, "Just-in-Time Delivery Comes to Knowledge Management," *Harvard Business Review,* July 2002. See also David W. Bates, et al., "Effect of Computerized Physician Order Entry and a Team Intervention on Prevention of Serious Medication Errors," *Journal of the American Medical Association,* October 21, 1998.

9 For a description of business rules technology, see Barbara von Halle, *Business Rules Applied: Building Better Systems Using the Business Rule Approach* (Wiley, 2001).

10 The relationship between business rules and business processes is described in Roger Burlton, *Business Process Management: Profiting from Process* (Sams Publishing, 2001).

11 For more on how losing human expertise in a technologically intensive business can undermine organizational performance, see David W. DeLong, *Lost Knowledge: Confronting the Threat of an Aging Workforce* (Oxford University Press, 2004).

12 For more on automated decision making in the insurance industry, see Thomas H. Davenport and Jeanne G. Harris, "Automated Underwriting in Insurance," Accenture Institute for High Performance Business, September 14, 2004.

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