The Value of Decision Analysis at Eastman Kodak Company, 1990–1999

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Because of the one-time nature of typical decision-analysis projects, organizations often have difficulty identifying and documenting their value. Based on Eastman Kodak Company's records for 1990 to 1999, we estimated that decision analysis contributed around a billion dollars to the organization over this time. The data also reflect the many roles decision analysis can play. Aside from its monetary benefits, it promotes careful thinking about strategies and alternatives, improved understanding and appreciation of risk, and use of systematic decision-making principles.

Without doubt, management science and operations research (MS/OR) add value to organizations when used well. Authors describing applications in *Interfaces* routinely document value added. Recently, authors have combined MS/OR with information technology to create strategic advantages with striking results in a variety of industries [Bell 1998a, 1998b].

Despite the documented success of MS/OR in general, the value of decision analysis (DA) is more difficult to demonstrate. In part, this is because many DA projects are one time only. As a result, it is not easy to measure the value of the chosen course of action relative to paths not taken. If a firm uses DA to decide which market to enter, for example, it is difficult to measure the value of the analysis. Eventually the firm will realize earnings from the new market, but it can only estimate earnings that might have come from markets it did not pursue.

While decision analysts have difficulty

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measuring the dollar value of one-time DA projects, they also commonly believe that DA adds value beyond the bottom line. Such contributions include facilitating discussions among stakeholders with different preferences, providing a common language for discussing elements of a decision problem and focusing on specific disagreements, and helping to build consensus, which in turn speeds implementation. Such contributions can improve the overall functioning of the organization, thereby contributing to the bottom line. However, measuring their value is problematic.

One method is to use an expected-value-of-modeling approach. As analysts typically do in DA to calculate the expected value of information, they can consider ex ante the difference in expected value between the DA-recommended alternative and the organization's preferred alternative without analysis. Brown [1994], Kiesler [1992], Nickerson and Boyd [1980], and Watson and Brown [1978] have taken this approach. Although normatively compelling, this approach is difficult to put into practice because of the difficulty of judging in advance what an analysis may recommend.

Many researchers and practitioners avoid the problem of measuring DA outcomes entirely by focusing on the process. That is, instead of trying to show that using DA leads to better organizational performance (for example, profits or shareholder value), they focus on the quality of the decision-making process itself. For example, Matheson and Matheson [1998] took this approach in describing nine principles that they believe characterize the decision-making process in "smart" organizations. A typical reason given for such a focus is that process and outcome in decision making are disconnected; even a good decision process can be followed by an unlucky outcome. Nevertheless, we believe that people and organizations work to improve their decision processes precisely because they hope to improve their chances of getting a preferred outcome or achieving their objectives. Matheson and Matheson [1999] presented preliminary data suggesting a positive correlation between their "organizational IQ" measure and financial performance.

Inability to document the bottom-line value of DA has hampered some analysts as they have tried to gain acceptance for DA within their organizations. Although

Analysts have difficulty measuring the dollar value on one-time decision-analysis projects.

analysts have performed many successful applications and published accounts of them (many in *Interfaces*), the evidence for DA's value remains largely testimonial and unsystematic. To help fill the gap, we describe a data set based on 178 DA projects performed for Eastman Kodak Company from 1990 to 1999. We collected these data in an ad hoc way rather than as part of a scientific study, and so we do not claim anything more than an interesting retrospective view of the contributions DA made during this period. In several cases, the data document specific dollar values associated with the analysis and allow us to estimate the incremental value of the analysis performed. In many other cases, the projects

may not have led to quantitatively measurable outcomes but nevertheless contributed to the firm in some way. Overall, the data reveal much about the role that DA has played in the organization.

Decision Analysis at Eastman Kodak Company

Eastman Kodak Company, headquartered in Rochester, New York, is the largest manufacturer of photographic products in the world. In 1998, Kodak held assets worth $14.7 billion. Kodak's 1998 sales of $13.4 billion came from four major businesses: consumer imaging ($7.2 billion), Kodak professional ($1.8 billion), health imaging ($1.5 billion), and other imaging ($2.9 billion), which includes entertainment imaging, digital and applied imaging, document imaging, Eastman software, and customer service. Kodak is a worldwide company, with business operations on all continents and manufacturing facilities in nine countries.

Over the past few years, the growth of the digital business; competitive actions, such as pricing, private label, and new product offerings; and heightened expectations from shareholders have challenged company management. In addition, environmental regulations and a strong commitment to environmental responsibility have led to high expenditures. Like many US companies, Kodak downsized considerably during the 1990s.

The industrial engineering department, now combined with a statistics group and called the productivity and quality improvement division (PQID), numbers about 100 people (down from some 400 in 1988) and reports to the US and Canada region manager who reports to the president and COO. The strategy and decision-analysis group is a small part of one unit within PQID.

Decision and risk analysis (D and RA), a specific form of DA, was introduced at Kodak in the early 1980s under the direction of Terry Faulkner, assistant to the director of research and development. His staff was contracted from the industrial engineering department, which was then part of the management services division (MSD). In 1988 his staff totaled 11. Kenny Oppenheimer of Decision and Risk Analysis, Incorporated, trained the staff in D and RA methodology. Most members of the group held engineering degrees. One had a degree in applied math and another in statistics. Several held master's degrees, often MBAs. One had a doctorate.

The group's original mission was to analyze Kodak's research and development (R and D) portfolio. The company's business-unit (BU) structure had been formed in the mid-1980s; the group sought to work through the BU's product R and D portfolios one at a time. It directed a similar effort toward process R and D.

With the publication of "Strategic intent" [Hamel and Prahalad 1989] and "The core competence of the corporation" [Prahalad and Hamel 1990], the D and RA group shifted to facilitating cross-functional corporate teams to create strategies and identify competencies on which to focus. Around the same time, with the advent of digital technologies, the company had to decide how to balance its efforts between analog and digital portfolios and between media and equipment portfolios, and among various segments of the imaging chain (capture, store, transmit,

output).

In a 1991 downsizing and reorganization, the company reduced the size of the D and RA group. Terry Faulkner moved on to other responsibilities, eventually becoming the director of strategic initiatives reporting to the CEO. Promotions into managerial positions in the business units, transfers to other functional areas of the company, and retirements decimated the unit. Only two of the original 1988 industrial engineers remained, and they continue to work as decision analysts today. During the 1990s, several other industrial engineers joined the group, but they have since moved to other jobs, retired, or left the company.

Since 1992, the two remaining analysts have worked on an assignment-by-assignment basis, relying on clients' word-of-mouth recommendations and their reputations to generate projects. One of these analysts spent the majority of his time on strategy and scenario planning while the other (Kwit) spent most of his time on D and RA before retiring in 2001. Occasionally, they undertook assignments that were not strictly D and RA, sometimes to serve on teams that would eventually need D and RA or to fill temporary needs for industrial engineers. They served as a corporate resource and, as such, were not attached to a business unit or functional area.

The Data

Robert Kwit undertook and kept records for 178 projects from 1990 to 1999 (Table 1). The projects include many kinds of work, including strategy development, vendor selection, technical-manufacturing-process analysis, new-product brainstorming, product-portfolio selection, and emission-reduction analysis. For reasons of confidentiality, we do not list project titles or details. These 178 projects cover a total of 14,372 hours of analyst time over the 10 years. In addition, not included in the list are another 130 hours for miscellaneous small projects and 1,384 hours spent developing and delivering D and RA courses for Kodak managers and staff.

Over the 10 years, data-collection and record-keeping procedures changed: (1) the managers of the division to which Industrial Engineering reported changed their ideas about what value data to keep, (2) the analyst took the initiative to improve records, and (3) the nature of the work changed. For the first three years, for example, quantitative data about the value of alternatives were lacking because the work was primarily strategic and qualitative. Data about the perceived value of the projects, however, were collected until 1994. From 1994 to 1997, the division collected data but used three different survey forms based on direction from the parent division. Beginning in 1998, the parent division again changed emphasis and no longer requested client-perceived value data.

The Nature of the Projects

The 178 projects varied considerably in duration (Table 2). The shortest projects took less than 20 hours and were completed within a few weeks. The longest projects took the better part of a year, both in days duration and in analyst hours. The median project lengths of 54 days and 46 hours are representative. Fifty percent of the projects fell between 27 and 110 days, or between 21 and 90 hours.

The projects were predominantly D and

Table 1: The 178 decision analysis and related projects undertaken at Kodak from 1990–1999 included analytical troubleshooting (ATS); brainstorming; consulting; decision and risk analysis (D and RA) with probability modeling and decision-making components; facilitation; modeling; portfolio analysis; potential-problem analysis (PPA); project management (PM); quality function deployment (QFD); risk analysis (RA); scenario development; strategy; trade-off analysis, including scoring, multiattribute utility, and priority setting; and workflow analysis (WFA). Days duration is the elapsed time from the beginning to the end of a project, and analyst hours are the total hours spent on the project. For 38 projects where quantitative evaluation data were available, the table shows the total number of alternatives considered and evaluation measures V_1 = ENPV(best) − ENPV(second best); V_2 = ENPV(best) − Average(ENPV); V_3 = ENPV(best) − Average(ENPV except best). If evaluation data were not available or not captured, a description of the project result is given in the "No specific project evaluation" column. The last three columns display data on the perceived value of the project as reported by the client.

				Project results								
				Alternatives evaluated				No monetary evaluation	Perceived value (client reported)			
					Value of project ($M)							
Study	Type	Days duration	Analyst hours	No. alt	V_1	V_2	V_3	Result	Estimated added value ($K)	Value/ cost ratio	Satisfaction level
90-1	Strategy	226	715					developed analog strategy			
90-2	Strategy	357	792					proposed technical investments		V > C	4/5
90-3	Strategy	161	278					proposed product portfolio			
90-4	PM	198	148					defined and developed printer		V > C	5/5
90-5	PM	149	163					defined rigorous process			
90-6	Trade-offs	105	27					scored competitor technology		V > C	5/5
90-7	PM	109	42					analyzed feature tradeoffs		V > C	5/5
90-8	Strategy	139	62					developed strategy		V = C	4/5
90-9	Strategy	16	16					developed technology strategy			
91-1	Strategy	352	700					produced strategy tables			
91-2	PM	352	400					proposed and defined product			
91-3	Strategy	176	270					produced technology portfolio			
91-4	Portfolio	104	180					chose top five technologies			
91-5	Portfolio	188	100					prioritized products			
91-6	Trade-offs	53	30					prioritized product segments			

(Table 1) continued

91-7	Strategy	14	20					developed scenarios and strategies		
91-8	Strategy	7	20					created strategy tables and choices		
91-9	Brainstorm	18	30					prioritized new product ideas		
91-10	Strategy	47	30					delivered scenarios workshop		
92-1	Portfolio	265	358					chose technology portfolio	V > C	4/5
92-2	Strategy	325	286					developed a product technology strategy	V > C	5/5
92-3	Strategy	16	66					delivered strategy workshop	V > C	5/5
92-4	Strategy	50	78					chose market and technology segments	V = C	5/5
92-5	QFD	35	72					conducted product feature trade-off analysis	V > C	5/5
92-6	Trade-offs	71	76					studied trade-offs		
92-7	D&RA	154	101					chose manufacturing site and developed cost goal		
92-8	Portfolio	87	107					chose top three technologies		
92-9	D&RA	41	58					chose best coating method	V > C	5/5
92-10	Portfolio	187	111					matched technologies to markets	V > C	4/5
92-11	Portfolio	69	36					improved features and costs		
92-13	Portfolio	130	21					provided policy for portfolio		
92-14	Facilitation	5	12					defined zone manager roles	V = C	4/5
92-15	PM	341	78					coordinated staff support		
93-1	D&RA	67	102	4	0.4	0.9	1.2			
93-2	Facilitation	72	105					developed electronic products strategy		
93-3	WFA	84	97					documented process flow		
93-4	Strategy	155	97					strategy evaluation model		
93-5	D&RA	269	112					chose laser option		
93-6	Scenarios	9	33					produced scenario tables		
93-7	Strategy	44	48					developed scenarios and strategies		
93-8	Portfolio	63	31					selected and balanced portfolio		
93-9	D&RA	236	360	6	18.4	38.5	46.2			
93-10	Portfolio	69	19					evaluated five products in six markets		

(Table 1 continued)

93-11	D&RA	26	56	5	0.5	18.5	23.1				
93-12	D&RA	40	76					chose best of three systems			
93-13	D&RA	33	23					studied centers for upgrade			10/10
93-14	Strategy	61	45					developed scenario and strategy tables			
93-15	D&RA	29	32					justified process measurement equipment			
93-16	Strategy	45	12					created approach for developing a product strategy			
93-17	Strategy	112	156					developed tables and action framework			
93-18	Portfolio	118	86					defined printer portfolio	6	1.0	7/10
93-19	Trade-offs	116	48					developed project valuation methods	12	4.0	9/10
93-20	D&RA	48	36					chose mill location			
93-21	D&RA	68	45					marketed D&RA to managers			
94-1	D&RA	111	49					extended 1993 work			
94-2	D&RA	57	71					chose better environmental versus cost alternative	13	2.0	10/10
94-3	D&RA	57	39					chose better environmental versus cost alternative	27	10.0	10/10
94-4	D&RA	108	90					chose to improve reliability of energy system			
94-5	D&RA	54	11					updated 1993 study			
94-6	Strategy	38	34					developed oil-gas-coal fuel strategy			
94-7	D&RA	42	83	9	0.1	0.2	0.2		232	40.0	9/10
94-8	D&RA	39	20	3	0.0	0.0	0.0		3	2.0	10/10
94-9	D&RA	28	27					chose better alternative	4	1.0	9/10
94-10	PPA	29	17					performed potential problem analysis	2	1.0	7/10
94-11	RA	35	9					created date probability curve			
94-12	D&RA	93	76					initiated '94–'96 D&RA project			
94-13	Portfolio	181	46					selected and balanced portfolio			
94-14	Strategy	140	64					analyzed technical support sources	5	1.0	7/10

(Table 1 continued)

94-15	Modeling		37					aborted—client transferred			
94-16	Strategy	133	102					developed strategy		V > C	10/10
94-17	D&RA	87	237	3	18.1	15.5	23.2		83	5.0	7/10
94-18	D&RA	76	25					assessed world demand	2	1.0	7/10
94-19	Strategy	14	8					aborted—client focus changed			
94-20	RA	42	30					created date probability curve			
94-21	D&RA	9	22	5	0.5	2.9	3.7		2	1.0	7/10
94-22	D&RA	10	13					aborted—client focus changed			
94-23	D&RA	30	30					aborted—client focus changed			
94-24	Strategy	46	30					planned workshop incomplete—illness		0.5	4/10
94-25	D&RA	113	55					saved capital	7000	1400.0	10/10
95-1	D&RA	210	324	6	0.5	2.0	2.4				
95-2	D&RA	20	34					analyzed need for capacity			
95-3	D&RA	156	76	5	0.1	3.1	3.8				
95-4	D&RA	196	142	2	8.5	4.3	8.5				
95-5	Strategy	108	85					created weighted scoring model	72	10.0	8/10
95-6	D&RA	119	66	8	0.7	11.3	12.9			4.0	
95-7	D&RA	122	79	10	36.5	54.0	60.0				
95-8	D&RA	3	20	3	0.2	0.2	0.4		3		
95-9	WFA	9	20					collected data to choose site			
95-10	Portfolio	16	31					prioritized features and technology			
95-11	D&RA	28	17	3	0.3	0.3	0.4				
95-12	D&RA	22	15					aborted—client focus changed			
95-13	D&RA	8	12					chose vendor in workshop			7/10
95-14	Trade-offs	45	21					chose vendor with weighted scoring model			
95-15	D&RA	58	53					discarded data—no longer in file		4.0	10/10
95-16	Strategy	38	33					aborted—client focus changed			
96-1	D&RA	36	38	2	14.6	7.3	14.6		136	50.0	10/10
96-2	D&RA	146	77	3	0.5	0.4	0.6		384		10/10
96-3	D&RA	72	43					postponed to 1997			
96-4	D&RA	3	11					aborted—client focus changed			
96-5	Modeling	165	109					modeled startup business	7957	1.1	6/10

(Table 1 continued)

96-6	Modeling	91	196					modeled startup business	14308	1.1	6/10
96-7	Modeling	45	55					modeled startup business	4015	1.1	6/10
96-8	Modeling	75	53					modeled startup business	3869	1.1	6/10
96-9	Modeling	36	47					modeled startup business			
96-10	Modeling	236	153					modeled demand	53	5.0	9/10
96-11	Modeling	100	92					built model for client use	6	1.0	8/10
96-12	D&RA	57	94	4				studied capacity relative to demand	5955	1000.0	10/10
96-13	D&RA	128	176	4	3.0	4.5	6.0	discarded data—confidential	18	1.5	8/10
96-14	D&RA	138	75	2	5.6	2.8	5.6		6	1.0	9/10
96-15	D&RA	95	115	3	1.6	1.9	2.8		85	large	8/10
96-16	D&RA	35	25	4	0.1	0.4	0.5		46	25.0	7/10
96-17	D&RA	14	20					discarded data—no longer in file			
96-18	D&RA	99	58					aborted—client focus changed	3	1.0	8/10
96-19	Strategy	56	19					developed strategy, led to later D&RA			
97-1	D&RA	185	341	2	20.0	10.0	20.0	discarded data-confidential	77	3.0	9/10
97-2	D&RA	46	94	5	0.3	0.4	0.5		50	5.3	10/10
97-3	Strategy	78	63					aborted—client focus changed			
97-4	D&RA	29	54	2	3.1	1.6	3.1		10	2.4	10/10
97-5	D&RA	43	80	7	0.4	3.0	3.5		10	1.7	9/10
97-6	D&RA	162	55					recommended optimal level	11	3.0	9/10
97-7	D&RA	8	13					updated prior study			
97-8	Scenarios	3	12					developed scenarios			
97-9	Modeling	59	57					calculated risk capacity			
97-10	Modeling	50	36					aborted—client focus changed			
97-11	Modeling	110	19					modeled demand			
97-12	D&RA	14	35					aborted—client made gut choice			
97-13	D&RA	8	26					discarded data—no longer in file			
97-14	D&RA	21	21					aborted—funds cut back			
97-15	Trade-offs	3	15					chose vendor with weighted scoring model			

(Table 1 continued)

97-16	Facilitation	48	17					facilitated workshop			
97-17	D&RA	45	96	3	0.4	0.3	0.5				
97-18	D&RA	28	15	2	0.9	0.5	0.9		2	1.3	8/10
97-19	D&RA	22	14					postponed to 1998			
97-20	D&RA	66	40					modeled capacity relative to demand	25	10.0	10/10
97-21	D&RA	28	79					modeled capacity relative to demand	123	20.0	10/10
97-22	Strategy	11	28					chose strategy in workshop	11	5.0	8/10
97-23	D&RA	35	22					aborted—client focus changed			
97-24	Modeling	43	34					aborted—client focus changed			
97-25	D&RA	12	52	3	1.5	1.6	2.4		12	2.0	9/10
98-1	D&RA	7	30	2	2.9	1.5	2.9		Perceived value data		
98-2	D&RA	18	54	7	9.1	15.9	18.5		not requested in		
98-3	D&RA	84	228	4	3.6	4.4	5.8		1998–1999		
98-4	D&RA	114	178	2	1.5	0.8	1.5				
98-5	D&RA	53	54					modeled capacity versus gate date			
98-6	PM	149	174					analyzed new sales pay plan			
98-7	Modeling	27	14					automated monthly calculations			
98-8	Modeling	7	17					automated performance calculations			
98-9	Modeling	67	139					specified optimization model			
98-10	Trade-offs	63	76					selected software system			
98-11	PPA	62	71					identified probable cause			
98-12	D&RA	6	29					structured technology decision			
98-13	Trade-offs	27	21					structured vendor selection			
98-14	RA	5	18					date probability curve			
98-15	D&RA	32	17					postponed to 1999			
98-16	Trade-offs	40	14					structured weighted scoring approach			
98-17	Facilitation	8	12					facilitated audit of completed job			
98-18	Modeling	17	11					built simulation model			
98-19	D&RA	14	8					structured D&RA			

(Table 1 continued)

98-20	D&RA	7	8					updated capacity relative to demand
99-1	D&RA	66	64	4	1.0	1.0	1.3	
99-2	Modeling	58	11					specified logic and data for model
99-3	D&RA	111	116	4	1.6	1.8	2.4	
99-4	Modeling	1	4					automated monthly reports
99-5	Modeling	95	93					built R&D cost model
99-6	D&RA	154	34	3	0.1	5.2	7.8	
99-7	Consulting	33	9					updated 1998 study
99-8	D&RA	114	142	2	29.0	14.5	29.0	
99-9	D&RA	35	81	7	8.0	46.6	54.3	
99-10	D&RA	13	22	4	0.1	0.2	0.2	
99-11	ATS	14	14					performed analytical trouble shooting
99-12	D&RA	102	142	6	59.0	208.8	250.6	
99-13	PM	146	141					improved commercialization process
99-14	D&RA	14	18					established space unit cost
99-15	D&RA	56	22					incomplete—client aborted
99-16	RA	76	84					analyzed risk of inadequate supply
99-17	RA	16	23					analyzed risk of schedule compression
99-18	D&RA	27	44					performed assessments and created tornado diagrams
99-19	RA	4	6					defined schedule uncertainty

Project effort			Decision analysis projects	
	Days duration	Analyst hours	Project type	Number
Mean	77.7	80.7	D&RA	83
Standard deviation	74.4	112.9	Strategy	28
			Modeling	19
Minimum	1	4	Portfolio analysis	12
25th percentile	27	21	Trade-offs	9
Median	54	46	Project management	7
75th percentile	110	90	Facilitation	4
Maximum	357	792	Risk analysis	6
			Workflow analysis	2
			Scenario development	2
			Potential problem analysis	2
			Other	4

Table 2: We calculated descriptive statistics for the duration in days and number of analyst hours for our 178 projects. The table also shows the different types of projects and their frequency.

RA and strategy (62 percent). Moreover, the very largest projects are overwhelmingly D and RA and strategy; of the 13 projects that took more than 200 hours; 11 were one of these two types. The top five project types (D and RA, strategy, modeling, portfolio analysis, and trade-offs) made up 85 percent of the projects. They account for 87 percent of the total hours.

Despite the predominance of the top five project types, the variety of types listed and the descriptions of the results show that Kodak's D and RA group performed a wide variety of tasks related to decision making. Although not reported here in detail, these projects represent work done for 30 different units at Kodak. Particularly heavy users were the media-manufacturing functional unit, the utilities functional unit, and the professional business unit. They accounted for almost 50 percent of the projects.

The Value of the Projects

Valuing DA projects can be problematic. We measured the incremental value of each analysis on the basis of expected net present values (ENPV) of the alternatives analyzed. Thus, we evaluated the alternatives as of the time the decisions were made but before any outcomes occurred. This is the final point at which we had parallel value estimates for the alternatives; waiting for real outcome results would have led to an actual value only for the chosen alternative.

One way to estimate the bottom-line contribution of DA would be to calculate the difference between the ENPV of the DA-recommended alternative and the ENPV of the momentum strategy, the alternative that the firm would have followed without analysis. Although this may appear to be the best approach, it has drawbacks. For example, it requires identification and evaluation of the momentum strategy, which may not be apparent, especially if the problem concerns new technology, markets, or products. If a momen-

tum strategy can be identified, subsequent modeling and analysis may reveal previously hidden uncertainties or downstream options, and it may not be obvious how the momentum strategy would react to these. (If DA recommends the momentum strategy, its contribution to the bottom line would be calculated as zero. However, this would ignore any nonquantitative value of the DA project, such as providing better justification or improving communication and corporate commitment.)

Our data set does not include documentation of the momentum strategy, so we considered three other measures that range from conservative to liberal estimates of the value of a project:

V_1 = ENPV (best alternative) − ENPV (second best alternative),

V_2 = ENPV (best alternative) − Average [ENPVs for all alternatives],

V_3 = ENPV (best alternative) − Average [ENPVs for all alternatives except the best].

V_1 is the most conservative estimate, essentially assuming that without the analysis, the firm would have chosen the second-best alternative (as ranked by ENPV). V_2 and V_3 also can be interpreted in suitable ways. In these two cases, the average of ENPVs represents an average of what the decision maker might have achieved without modeling and analysis. V_2 includes the best alternative in the average, whereas V_3 does not; V_3 essentially assumes that the best alternative (after analysis) would not have been chosen without analysis. Thus, V_3 is the most liberal estimate of the value of DA among the three that we considered, while V_2 occupies the middle ground.

For 38 of the 178 projects, our records included the ENPV for each alternative considered. Although not shown here, the 38 projects varied widely in the ENPV of alternatives considered, ranging in magnitude from $100 thousand to over $2 billion. (Table 1 shows the calculated values according to our three measures.)

For the conservative V_1, the average per project is $6.65 million (M), standard deviation $12.26M, and total (for all 38 projects) of $253M (Table 3). This contrasts with the corresponding figures for V_2 (average $12.82M, standard deviation $35.03M, and total $487M) and the more liberal V_3 (average $16.35M, standard deviation $41.81M, and total $621M). All three distributions are somewhat skewed: For example, the minimum for V_2 is 0, 25th percentile $0.6M, median $2.4M, 75th percentile $9.3M, and maximum $209M.

The calculations above include all 38 projects. Project 99-12, however, was an extreme outlier. Its alternatives had the largest ENPVs (all six well above $1.5 billion), giving V_1 = $59M, V_2 = $209M, and V_3 = $251M. Because of the effect that this project had on the average and standard deviation of V_1, V_2, and V_3, we also calculated these summary measures excluding Project 99-12. Excluding 99-12, we obtained average per-project values of $5.24M, $7.52M, and $10.02M for V_1, V_2, and V_3, respectively, and similarly deflated standard deviations.

From any perspective, these data represent substantial added value to the organi-

ENPV measures ($M)

	n	Average	Standard deviation	Estimated total value
V_1	38 (37)	6.65 (5.24)	12.26 (8.73)	253
V_2	38 (37)	12.82 (7.52)	35.03 (12.85)	487
V_3	38 (37)	16.35 (10.02)	41.81 (15.21)	621

Perceived value measures

	n	Average	Standard deviation	Estimated total value
Estimated value added ($M)	39	1.14	2.96	44.64
	n	Ratio $<$ 1	Ratio $=$ 1	Ratio $>$ 1
Value/cost ratio	54	1	12	41
	n	Level $<$ 5	Level 5–7	Level $\geq$ 8
Satisfaction level	56	1	12	43

Table 3: Projects for which alternatives were evaluated using ENPV are included in the top part of the table, where V_1 = ENPV(best) − ENPV(second best); V_2 = ENPV(best) − Average(ENPV); V_3 = ENPV(best) − Average(ENPV except best). Numbers in parentheses for V_1, V_2, and V_3 exclude the outlier project 99-12. Client estimates of value summarized in the lower part of the table include dollar values of DA projects as estimated by the client, estimated value/cost ratio, and satisfaction level (on a 10-point scale, where 1 = very dissatisfied and 10 = very satisfied).

zation. Assuming that the cost of maintaining an analyst over the 10 years was about $1.50 million (or $150K per year), the total value added by these 38 projects was over 300 times the cost, based on measure V_2. Excluding Project 99-12, the remaining 37 projects were still worth (by V_2) more than 185 times the cost.

Nonquantitative Results

The quantitative results discussed above arose from only 21 percent of the 178 projects. What about the others? DA contributed to the organization in many ways (Table 1). Practicing analysts know that projects do not always lead to complete evaluation of fully developed alternatives. For example, in some Kodak projects the analysts developed weighted-scoring systems. In others, they proposed strategies or portfolios. In some projects, analysts facilitated discussion among managers or stakeholders. In a few projects, they only structured a model that managers used for subsequent analysis. Some projects required only scenario development, brainstorming alternatives, or developing strategy tables.

Although the projects in Table 1 are organized by year (and by far the majority of projects were completed within a year), six led directly to later projects (94-8, 94-12, 96-3, 96-19, 97-19, and 98-15). Many more were interrelated. Satisfied clients returned for follow-up projects or analyses of related problems or passed on favorable reports to colleagues, thereby leading to further related studies.

Not all of the projects listed in Table 1 were completed. Beginning in 1994, 16 projects were not completed, typically because client focus changed. Other reasons include client transfer, illness, cut-back of

funds, or the client's making a gut choice before the project was completed.

We extrapolated from our quantitative results to estimate the total value to Kodak of all DA efforts over the 10 years. We used an average of $7.52 million per project (based on V_2 and excluding Project 99-12) to estimate the value of the 140 non-quantified projects. Using this approach, we estimated that the total value to Kodak of all 178 projects was $1.45 billion. Using V_1 or V_3 instead of V_2, we obtained corresponding estimates of $923 million and $1.90 billion, respectively. More conservatively, we could discard the 16 projects that were not completed and assume that the remaining 124 without quantitative results were worth on average (per project) 75 percent of the 37 completed projects (again excluding 99-12) with quantitative results. By doing so, we obtained total values of $740 million with V_1, $976 million with V_2, and $1.30 billion with V_3.

Value to the Client

For 58 of the projects, we had data related to clients' perceived value. The firm collected these data sporadically and in a variety of ways over the years. In all cases, though, analysts tried to help clients think about the various ways in which the projects could add value. The appendix shows the form used in 1995. Analysts asked their clients, in filling out this form, to consider such dimensions as cycle time for decision making, quality of plans, implementation speed and effectiveness, and learning of skills on the part of the client. Other sources of value (included on other versions of the feedback forms used at other times) included effectiveness of framing the problem, provision of necessary analytical skills, improvements in the decision-making process (for example, communication and consensus building), and the effects on inventory, project cost, safety, and other intangibles.

The clients' estimates of value for 39 projects range from $2,000 to over $14 million, with an average of $1.14 million, standard deviation of $2.96 million, and a total of $44.64 million (Table 3). The contrast with the much higher value estimates based on ENPV is striking, even in comparison with the conservative V_1. A partial explanation for this contrast may be that V_1, V_2, and V_3 yield positive values for DA as long as the ENPV of the best alternative is more than the ENPV of the second best. If it were possible to identify the momentum strategy and it turned out to be the best strategy, however, it could be argued that the value of the analysis should be zero. Another explanation for the lower client estimates is that decision makers may, in hindsight, believe that they knew the best alternative all along, even before any analysis.

Over 54 projects, clients judged that 41 had value greater than cost, and only one had a value lower than its cost (Project 94-24, which was not completed because of illness). Of those with quantitative estimates, the ratios range from a minimum of 0.5 to a high of 1,400.

Clients assigned only one project out of 56 a rating less than five (again Project 94-24) on a 10-point satisfaction scale, and and they rated 43 at eight or better.

Conclusion

DA can be extremely valuable. Even with the limited amount of data we have, and even though the data reflect the mess-

iness of collecting field data in an ad hoc way over 10 years, the data clearly show that DA adds value. We have documented at least (by V_1) $253 million in added value for projects that led to quantitative results, and we estimated that all the projects taken together may have added well over $1 billion.

Our data also paint a rich picture of the nature and variety of the contributions of DA beyond the direct dollar contribution. Future researchers might try to identify appropriate organizational dimensions that represent such intangibles, along with scientifically valid questionnaires for measuring value along these dimensions.

The data further show a realistic picture of the nature of real-world DA projects. Some are completed and are models of what can be done, but many others are limited in scope. Some are aborted for a variety of reasons, often because a client's focus changes. The latter suggests two things. First, analysts must be nimble to provide analytical support quickly enough to be useful. Second, organizations must have realistic expectations of DA; not all efforts work out perfectly, especially when it comes to developing and analyzing new strategic possibilities for a firm in a rapidly changing environment.

Finally, we wish to emphasize the difficulty of collecting and maintaining a database over many years. We were fortunate to have substantial records, largely as a result of one analyst's efforts over the 10-year period. Analysts wishing to track the value of DA contributions in their firms should document the value of all DA projects and develop an effective record-keeping process. To show the value added by DA, they must gather appropriate documentation for every project. Data to capture include

—Project title, description, and client;
—Start and end dates;
—Analyst hours and cost per hour;
—If practical, identification (and early documentation) of the momentum strategy;
—ENPV (or similar) for each alternative studied (if the results are so quantified);
—Results or benefits described verbally (drawn from a standard questionnaire); and
—Client feedback after the decision but before implementation or outcome.

It may be tempting to try to improve on the system over time, but analysts should keep in mind that inconsistencies can make the data less useful. Hence, it is worthwhile at the outset to put thought and effort into designing the system.

To implement the system, analysts must establish effective record-keeping procedures and follow them consistently year after year. All analysts must be trained, motivated, and supported in the data-collection process, and clients should be educated in the importance of the data-collection discipline. An effective process further includes management of personnel turnover in the analysis group. As new analysts are hired, they must be trained, and as analysts leave, their records must be secured.

What does the future hold for DA at Kodak? Robert Kwit retired in 2001, and the other analyst is nearing retirement. They have been effective in proliferating DA concepts, and some individuals in the company use these techniques. Neverthe-

less, no successors for these analysts have been identified.

Kodak has no mandate that its employees must use DA techniques for research or capital-program evaluations. Project leaders rather than vice presidents are the typical initiators of DA projects. This makes it unlikely that analysts will apply DA and consistently collect data for evaluating the DA process. Kodak's commitment to a standard organizational decision-making protocol could improve this situation. For example, General Motor's dialogue decision process [Barraba 1994; Matheson and Matheson 1998] is such a protocol. Sharpe and Keelin [1998] describe a similar one for SmithKline Beecham. Adopting such a protocol would facilitate the collection of evaluation data and ensure that the organization follows good decision-making practice.

APPENDIX
IE Contract Closing/Feedback Form

Please help complete this form in order to improve the quality of services we provide.

Engineer, please fill in the following:

Client: Actual Completion Date:
Project: Actual Cost ($):
Engineer:

Client and Engineer, please fill in the following:

A. What did MSD do that added real value to the outcome of your project? (What changed in your organization due to MSD's intervention?)

B. Considering the effect on unit cost, inventory, capital cost, project cost, safety, capability transfer and other intangibles, how would you classify the value received relative to the cost of the job? (check one)

Value< Cost	Value= Cost	Value> Cost

C. If value > cost, what is the approximate value/cost ratio?

D. What could we have done that would have improved our service?

E. What is your overall satisfaction with the services provided by MSD on this contract? (check one box)

1	2	3	4	5	6	7	8	9	10
Very Dis-Satis.		Dis-Satis.		Neither		Satisfied			Extremely Satisfied

Engineer, please fill in the following:

F. Engineer's Satisfaction

1	2	3	4	5	6	7	8	9	10
Very Dis-Satis.		Dis-Satis.		Neither		Satisfied			Extremely Satisfied

G. Learnings from this assignment were

H. Quality design review concluded? YES NO
Was the QDR valuable to you? YES NO

I. Client value being sustained:
quantitative measures:

Estimating the "Value/Cost" Ratio
(included as instructions with the Closing/Feedback form above)

—The Problem: In planning consultation where project value is often in the future, it is difficult to precisely quantify the added value due to MSD's [Management Services Division] involvement in the planning effort. What we are trying to assess is the *incremental* value brought by the MSD consultant.

—Here's how we recommend you go about the assessment of MSD *incremental* value:

—First think about the principal sources of incremental value:
Faster cycle time to arrive at a plan
A better plan as a result of MSD's contribution
Better consensus leading toward more effective/faster implementation
Transfer of process planning skills to the client

—Think about and imagine how the effort would have gone *without* MSD's help. Recall similar efforts *un*supported by MSD.

—Now think about how this *did* progress with MSD's help.

—How much would you be willing to pay for the *incremental* value considering the sources of value noted above? (Iterate within a very low to a very high initial interval, narrowing it until you converge on the point of comfort within the interval.) See example below.

Would you pay $1? *Of course!*
How about $10,000,000? *You've got to be kidding*.
How about $100? *It's certainly more than that*.
What about $1,000,000? *Still too high*.
Was it worth $10,000? *I've got to think about that. No. Still too low*.
How about $500,000? *Too high*
Try $100,000? *Getting close*

—Compute the ratio of assessed value to the MSD cost (Value/MSD cost).

References

Barraba, V. 1994, *Meeting of the Minds*, Harvard Business School Press, Boston, Massachusetts.

Bell, P. C. 1998a, "Strategic operational research," *Journal of the Operational Research Society*, Vol. 49, No. 4, pp. 381–391.

Bell, P. C. 1998b, "Strategic OR/MS," *OR/MS Today*, Vol. 25, No. 6, pp. 24–29.

Brown, R. V. 1994, "The role of statistical decision theory in decision aiding: Measuring decision effectiveness in the light of outcomes," in *Aspects of Uncertainty*, eds. P. R. Freeman and A. F. M. Smith, John Wiley and Sons, Chichester, England.

Hamel, G. and Prahalad, C. K. 1989, "Strategic intent," *Harvard Business Review*, Vol. 67, No. 3, pp. 63–76.

Kiesler, J. M. 1992, "A framework for organizational decision analysis," PhD dissertation, Harvard University, Cambridge, Massachusetts.

Matheson, D. and Matheson, J. 1999, "The link

between organizational intelligence and business results," presentation at INFORMS Philadelphia meeting, November.
Nickerson, R. C. and Boyd, D. W. 1980, "The use and value of models in decision analysis," *Operations Research*, Vol. 28, No. 1, pp. 139–155.
Prahalad, C. K. and Hamel, G. 1990, "The core competence of the corporation," *Harvard Business Review*, Vol. 68, No. 3, pp. 79–91.
Sharpe, P. and Keelin, T. 1998, "How SmithKline Beecham makes better resource-allocation decisions," *Harvard Business Review*, Vol. 76, No. 2, pp. 45–52.
Watson, S. R. and Brown, R. V. 1978, "The valuation of decision analysis," *Journal of the Royal Statistical Society*, *Series A,* Vol. 141, Part 1, pp. 69–78.

Nancy L. S. Sousa, General Manager, New Businesses, VP Health Imaging, Eastman Kodak Company, 1700 Dewey Avenue, Rochester, New York 14650-1828, writes: ". . . Decision and risk analysis has made significant contributions to Eastman Kodak. The application of decision and risk analysis has contributed value in excess of what can be quantified. The contributions are valued several ways:

• Quantitatively—understanding the dollar value difference associated with choices,

• Improved planning—resulting through improved communications among team members,

• Better risk management—through early identification of risk factors, assumptions, and contingency planning.

"As General Manager, New Businesses, VP Health Imaging, Eastman Kodak, I encourage all of the business planners to use the decision and risk principles and processes as part of evaluating new business opportunities. The processes have clearly led to better decisions about entry and exit of businesses."