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ABSTRACT

In an era of downsizing and financial cutbacks, the operational efficiency of trucking firms dictates their competitiveness and survival. In an effort to help trucking firms develop a winning formula in the fiercely competitive logistics industry, this research aims to develop a meaningful set of benchmarks that will set the tone for best practices. In particular, a data envelopment analysis (DEA) is described. DEA has proven to be useful for measuring the operational efficiency of various profit or non-profit organizations. Using the examples of major trucking businesses in the United States, the usefulness of data envelopment analysis for the continuous improvement of trucking services is illustrated.

INTRODUCTION

The trucking industry in the United States has historically operated on profit margins as low as 3 to 4 cents on every dollar of sales after taxes, compared to the 7 to 9% average profit margin experienced by the heavy manufacturing industry (Dun and Bradstreet, 1999; Lambert and Min, 2000). Recently, the profit margin of the industry declined further, from 3.08% in 1994 to 2.60% in 1999 (American Trucking Associations Economics and Statistic Group, 2001). With tight profit margins and increasing competition, a key to a trucking firm's survival is its ability to keep trucking operations "lean." Sustaining lean operations, however, is not easy given mounting cost pressures from rising fuel costs, taxes, insurance, and labor. For example, the national average price of diesel fuel spiked to $1.491 per gallon in 2000 from $1.044 per

gallon in 1998. In addition, for-hire carriers paid 8.4% more in federal highway-user taxes in 1999 than in 1998 (American Trucking Associations Economics and Statistics Group, 2001). Those trucking firms that could not handle steep cost increases outpacing revenue growth failed to survive in the end. In 2000 alone, 3,670 trucking firms went out of business. This alarming statistic represents an increase of 205.8% in trucking business failures from the previous year (American Trucking Associations Economics and Statistics Group, 2001).

One way of improving the operational efficiency of trucking firms is to learn from best practice firms that can be identified by setting a reliable financial performance standard. Examples of such a standard are a financial audit, an industry norm, and a benchmark. Since a trucking firm needs to measure its financial performance relative to its competitors to constantly strengthen its market position, benchmarking seems to be the most effective way of setting a reliable financial standard and then measuring the operational efficiency of the trucking firm.

In general, benchmarking is a continuous quality improvement process by which an organization can assess its internal strengths and weaknesses, evaluate comparative advantages of leading competitors, identify the best practices of industry leaders, and incorporate these findings into a strategic action plan geared to gain a position of superiority (Min and Galle, 1996). The main goals of benchmarking are to:

- Identify key performance measures for each function of a business operation;
- Measure one's own internal performance levels as well as those of the leading competitors;
- Compare performance levels and identify areas of comparative advantages and disadvantages;
- Implement programs to close a performance gap between internal operations and the leading competitors (Furey 1987, p.30).

In setting the benchmark, this paper will measure the operational efficiency of trucking firms relative to prior periods and their competitors. The operational efficiency measured by input/output ratios can reflect the true overall productivity of trucking firms better than traditional financial ratios that tend to focus on myopic aspects of financial performance. As a way of comparatively assessing the productivity of trucking firms with multiple inputs and outputs, this research uses data envelopment analysis (DEA), which was successfully explored in measuring the operational efficiency of banks (e.g., Thanassoulis, 1999), hospitals (Valdmanis, 1992), nursing homes (Kleinsorge and Karney, 1992), purchasing departments (Murphy et al., 1996), cellular manufacturing (Talluri et al., 1997), travel demand (Nozick et al., 1998), information technology investments (Shafer and Byrd, 2000), customer service performances of less-than-truckload (LTL) motor carriers (Poli and Scheraga, 2000) and international ports (Tongzon, 2001). For further details on other DEA applications, interested readers should refer to Seiford (1990).

In general, DEA is referred to as a linear programming (non-parametric) technique

that converts multiple incommensurable inputs and outputs of each decision-making unit (DMU) into a scalar measure of operational efficiency, relative to its competing DMU's. Herein, DMU's refer to the collection of private firms, non-profit organizations, departments, administrative units, and groups with the same (or similar) goals, functions, standards and market segments. DEA is designed to identify the best practice DMU without *a priori* knowledge of which inputs and outputs are most important in determining an efficiency measure (i.e., score), and assess the extent of inefficiency for all other DMU's that are not regarded as the best practice DMU's (e.g., Charnes et al., 1978). Since DEA provides a relative measure, it will only differentiate the least efficient DMU from the set of all DMU's. Thus, the best practice (most efficient) DMU is rated as an efficiency score of one, whereas all other less efficient DMU's are scored somewhere between zero and one. To summarize, DEA determines the following (Sherman and Ladino, 1995):

- The best practice DMU tha t uses the least resources to provide its products or services at or above the quality standard of other DMU's;
- The less efficient DMU's compared to the best practice DMU;
- The amount of excess resources used by each of the less efficient DMU's;
- The amount of excess capacity or ability to increase outputs for less efficient DMU's without requiring added resources.

In measuring the operational efficiency of trucking firms, DEA was chosen over other alternative techniques (such as Cobb Douglas functions and analytic hierarchy process (AHP)) because DEA reflects the multiple aspects of organizational performances, does not require *a priori* weights of performance measures, and provides valuable insights as to how operational efficiency can be improved.

SPECIFICATION OF INPUT AND OUTPUT MEASURES

The assessment of operational efficiency using DEA begins with the selection of appropriate input and output measures that can be aggregated into a composite index of overall performance standards. Although any resources used by the DMU should be included as input, six different metrics were selected as inputs. These are: account receivables, revenue equipment (e.g., trucks, trailers, containers), buildings (e.g., truck terminals), land, salaries and wages (including fringe benefits) of employees, and operating expenses other than salaries and wages. Since trucking firms often sell their services on credit rather than cash, account receivables can be a key resource for increasing sales and the subsequent revenue. Thus, account receivables reflect an efficiency of short-term asset management and should be chosen as one of the inputs. The revenue equipment is viewed as a resource, because the utilization of a truck's loading capacity can increase the efficiency of trucking firms in filling the needs of their customers. Other fixed assets such as buildings and lands (estimated in book values) are considered to be resources given that they can add value to trucking services by increasing the opportunity to consolidate freight, provide preventive vehicle maintenance, and provide critical part storage.

Due to the labor-intensive nature of the business, trucking firms hire a large number of personnel, consisting of managers, dis-

patchers, drivers, and cargo handlers, among others, on either a part-time or full-time basis. Their payroll represents one of the major costs of doing business. Indeed, as of 1999, salaries, wages and fringe benefits accounted for more than half (52.1%) of general operating expenses and, subsequently, were separated from general operating expenses (American Trucking Associations Economics and Statistics Group, 2001). Thus, salaries and wages (including fringe benefits) reflect the efficiency of direct investment in human resources. Operating expenses (excluding personnel cost) include many elements of variable costs, such as fuel, oil, lubricants, vehicle parts, tires, tubes, license fees, utilities, taxes and insurance premiums that comprise another key resource for maintaining equipment and keeping a fleet operational. Thus, operating expenses were included as input.

On the output side, the overall performance of trucking firms can be measured by operating income that best reflects operational efficiency. Other well-known financial ratios such as profit margin and return-on investment were not considered relevant, because a less profitable firm may be more efficient in utilizing its personnel and equipment than the more profitable firm. For example, a favorable change in fuel price and tax rate can increase profitability, but not necessarily the operational efficiency (e.g., equipment utilization or labor productivity) of trucking firms. In fact, Sherman (1984) observed that profit measure was not a good indicator of how efficiently resources were used to provide customer services.

The input and output data were obtained from the annual scoreboard report of *Business Week* magazine (2001) and a series of annual 10-K reports required by the Securities Exchange Act of 1934 (Edgar Online, 2003). These reports listed six years of data for major trucking firms including Arkansas Best, Consolidated Freightways, JB Hunt Transport Services, Swift Transportation, Werner Enterprises, and Yellow Corporation. To keep the homogeneity of these firms for equitable comparisons, we excluded other major carriers, such as United Parcel Service and FedEx, that offer more comprehensive and diverse services (e.g., air express delivery services, customs brokerage, equipment leasing) and are considerably larger in scale (annual revenue of approximately 20 to 30 billion dollars) from the current DEA analysis.

DATA ENVLEOPMENT ANALYSIS MODEL DESIGN AND TESTING

The DEA model, with the inputs and output summarized in Tables 1 and 2, was adopted for this study. The DEA model is mathematically expressed as

Maximize efficiency score (jp) =

$$\frac{\sum_{r=1}^{t} u_r y_{rjp}}{\sum_{i=1}^{m} v_i x_{ijp}} \qquad (1)$$

Subject to

$$\frac{\sum_{r=1}^{t} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1, \quad j = 1, \ldots, n, \qquad (2)$$

$$u_r, v_i \ge \varepsilon, \quad \forall \text{and } i, \qquad (3)$$

where

y_{rj} = amount of output r produced by DMU j,

x_{ij} = amount of input i used by DMU j,

TABLE 1
DESCRIPTIVE STATISTICS FOR INPUT AND OUTPUT MEASURES

	Number of annual reports	Minimum (in thousand dollars)	Maximum (in thousand dollars)	Mean (in thousand dollars)	Standard Deviation (in thousand dollars)	Type
Operating income	36	-91,087.00	152,529.00	64,373.83	51,926.90	Output
Accounts receivables	36	67,928.00	349,999.00	199,344.36	81,403.75	Input
Revenue equipment	36	207,471.00	1,401,646.00	718,509.86	329,110.32	Input
Building and other properties	36	30,127.00	607,104.00	252,355.97	207,425.80	Input
Land	36	7,351.00	228,051.00	77,812.94	73,867.17	Input
Salaries, wages and employee benefits	36	192,572.00	2,210,505.00	997,870.47	635,700.66	Input
Operating expenses	36	316,108.00	1,327,643.00	786,760.03	298,096.66	Input

TABLE 2
EFFICIENCY SCORES FOR OPERATING INCOME

Company	Year					
	1996	1997	1998	1999	2000	2001
ABFS	N/A	77.06%	73.21%	92.97%	100.00%	77.47%
CFWY	N/A	33.06%	37.87%	5.81%	N/A	N/A
JBHT	41.70%	27.68%	61.35%	38.36%	32.37%	37.40%
SWFT	89.93%	99.39%	100.00%	98.72%	73.56%	38.23%
WERN	100.00%	100.00%	100.00%	100.00%	68.88%	65.34%
YELL	N/A	41.77%	38.86%	48.37%	74.31%	29.34%

N/A represents negative operating income, which is not suitable for the DEA output measure.

u_r = the weight given to output r,

v_i = the weight given to input i,

n = the number of DMU's,

t = the number of outputs,

m = the number of inputs,

ε = a small positive number.

By solving these equations, the efficiency of DMU (*jp*) is maximized subject to the efficiencies of all DMU's in the set with an upper bound of 1. The model is solved n times to evaluate the relative efficiency of each DMU. Notice that the weights u_r and v_i are treated as unknown variables whose values will be optimally determined by maximizing the efficiency of the targeted DMU (*jp*). An efficiency score of 1 indicates that the DMU under consideration is efficient relative to other DMU's, while an efficiency score of less than 1 indicates the DMU under consideration is inefficient. In a broader sense, an efficiency score represents a trucking firm's ability to transform a set of inputs (given resources) into a set of outputs. The above model also identifies a peer group (efficient DMU with the same weights) for the inefficient DMU (Boussofiane et al., 1991).

A complete DEA analysis was conducted by applying a non-linear fractional program formulated in equations (1)-(3) to actual data containing a sample of six major trucking firms with six consecutive years of performance measures. The results obtained from the use of Frontier Analyst software (1998) indicate that Werner Enterprises consistently recorded an efficiency score of 1 (100%) in 1996 through 1999. However, Werner Enterprises experienced a decline in efficiency in both 2000 and 2001 (see Table 2). Swift Transportation and Arkansas Best achieved an efficiency score of 1 (100%) in 1998 and 2000, respectively. On a year-to-year basis, at least one of the trucking firms is considered efficient, with the exception of 2001. In 2001, the relative efficiency scores ranged from 29.34% to 77.47%, suggesting that there is room for substantial improvement in operating income (see Tables 2 and 3). Surprisingly, Consolidated Freightways, J.B. Hunt Transport Services and Yellow Corporation, which ranked in the top 15 revenue generators among U.S. trucking firms in 2000-2001, never rated as efficient throughout the sample period (Bearth, 2001). For example, Consolidated Freightways recorded an efficiency score of only 5.81% in 1999, leaving ample room for improvement. In 1999, it could have improved its efficiency in operating income by as much as 16 times (see Table 3). This may explain why Consolidated Freightways eventually filed for bankruptcy protection. In particular, its buildings and other properties (e.g., office equipment and furniture) were poorly utilized, compared to other competing trucking firms throughout the period (see Table 4). In fact, after liquidating equipment and terminals, Consolidated Freightways still had 21 surplus properties for sale as of December 31, 2001 (Edgar Online, 2003). Also, CF salaries and wages were above the industry average, reflecting its underutilization of labor. CF was also involved in several unsettled labor disputes with various labor unions, which represented 81% of domestic employees as of December 31, 2001. Yellow Corporation shows similar patterns, causing concern for its declining efficiency. Its utilization rate of buildings and other properties has declined significantly over the last five years (1997-2001).

Overall, 2001 was the worst year for every trucking firm studied. Figure 1 displays the decline in efficiency scores for all but J.B. Hunt Transport Services in 2001. In fact, every investigated trucking firm shows a relatively low efficiency score that may have resulted from ever-rising operating expenses and a nationwide economic downturn. For example, the total operating expenses of a benchmark firm such as Werner Enterprises rose from 101 cents per mile in 1996 to 111.53 cents per mile in 1999, while those of the top 20 general freight carriers increased

TABLE 3
POTENTIAL IMPROVEMENTS IN OPERATING INCOME

Company	Year					
	1996	1997	1998	1999	2000	2001
ABFS	N/A	29.77%	36.59%	7.56%	0.00%	29.08%
CFWY	N/A	202.46%	164.06%	1,621.84%	N/A	N/A
JBHT	139.83%	261.68%	63.00%	160.68%	208.92%	167.40%
SWFT	11.20%	0.61%	0.00%	1.30%	35.94%	161.56%
WERN	0.00%	0.00%	0.00%	0.00%	45.17%	53.06%
YELL	N/A	139.42%	157.35%	106.74%	34.57%	240.84%

* N/A represents negative operating income, which is not suitable for the DEA output measure.

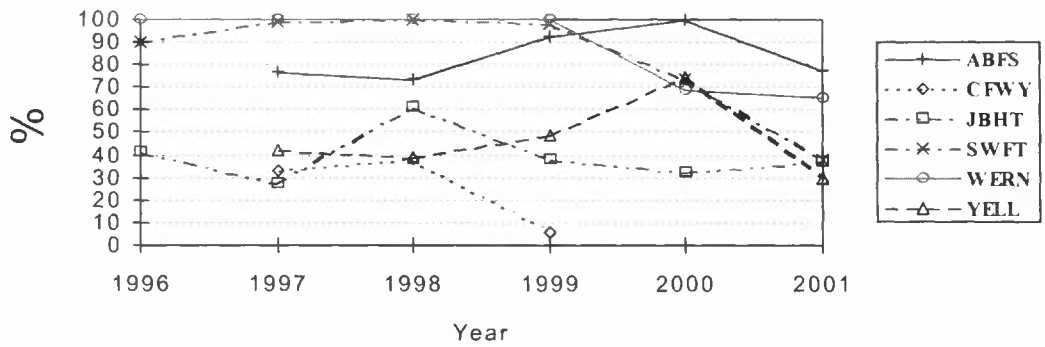
TABLE 4
RESOURCE (INPUT) UTILIZATION RATES IN PERCENTAGE

Resources	Company	Year					
		1996	1997	1998	1999	2000	2001
Accounts Receivable	*ABFS*	N/A	-41.03	-28.95	-22.24	0.00	0.00
	CFWY	N/A	-48.21	-44.68	-52.89	N/A	N/A
	JBHT	0.00	0.00	0.00	-5.33	0.00	-3.90
	SWFT	-8.57	-3.32	0.00	-7.65	-6.68	0.00
	WERN	0.00	0.00	0.00	0.00	-0.87	0.00
	YELL	N/A	-18.12	-4.55	0.00	0.00	0.00
Revenue Equipment	*ABFS*	N/A	0.00	-7.63	0.00	0.00	0.00
	CFWY	N/A	0.00	0.00	0.00	N/A	N/A
	JBHT	-12.22	-9.69	-18.15	0.00	-4.49	0.00
	SWFT	-1.07	0.00	0.00	-4.16	-6.42	0.00
	WERN	0.00	0.00	0.00	0.00	0.00	0.00
	YELL	N/A	0.00	-4.11	0.00	0.00	0.00
Buildings and Other Properties	*ABFS*	N/A	-42.70	-41.13	-32.65	0.00	-34.99
	CFWY	N/A	-73.53	-73.86	-75.93	N/A	N/A
	JBHT	-28.38	-20.62	-17.10	0.00	-8.35	0.00
	SWFT	-6.25	-.059	0.00	-8.75	-8.40	-33.77
	WERN	0.00	0.00	0.00	0.00	0.00	0.00
	YELL	N/A	-62.91	-63.85	-69.71	-78.12	-81.21

Table 4
(continued)

Resources	Company	Year					
		1996	1997	1998	1999	2000	2001
Land	*ABFS*	N/A	-41.58	-34.94	-21.18	0.00	-44.26
	CFWY	N/A	0.00	0.00	0.00	N/A	N/A
	JBHT	-0.41	0.00	0.00	0.00	0.00	0.00
	SWFT	-30.94	0.00	0.00	-21.97	-48.86	-19.87
	WERN	0.00	0.00	0.00	0.00	0.00	0.00
	YELL	N/A	0.00	0.00	0.00	0.00	-2.55
Salaries, Wages, and Employee Benefits	*ABFS*	N/A	-29.33	-17.04	-12.37	0.00	-28.88
	CFWY	N/A	-54.96	-52.86	-54.38	N/A	N/A
	JBHT	0.00	-3.66	-13.37	-11.42	-16.71	-19.56
	SWFT	0.00	-0.52	0.00	0.00	0.00	0.00
	WERN	0.00	0.00	0.00	0.00	-5.37	-9.46
	YELL	N/A	-48.03	-45.99	-48.85	-54.92	-53.65
Operating Expenses	*ABFS*	N/A	-41.32	0.00	-5.93	0.00	-20.72
	CFWY	N/A	-17.40	-16.62	-28.88	N/A	N/A
	JBHT	-28.94	-26.67	-29.16	-27.74	-31.84	-27.23
	SWFT	-12.96	-12.63	0.00	-3.35	-13.13	-14.86
	WERN	0.00	0.00	0.00	0.00	-19.58	-23.50
	YELL	N/A	-2.23	0.00	-6.89	-24.44	-23.05

Figure 1
The Efficiency Trend of Operating Income



from 130.82 cents per mile in 1996 to 145.15 cents per mile in 1999 (American Trucking Associations, 2001).

It is also noted that large LTL carriers such as Yellow Corporation and Consolidated Freightways struggled throughout the sample period, whereas more niche-oriented (e.g., dry van and flatbed) TL carriers such as Werner Enterprises and Swift Transportation fared better. Since today's shippers often require more specialized

services (including online freight exchange services) rather than generic one-way loads, carriers that find niche-markets most profitable for them are likely to perform better and survive in this fiercely competitive environment.

CONCLUSIONS AND MANAGERIAL IMPLICATIONS

At the end of 2000, there were more than half a million trucking firms operating in the U.S., which reflects the highly fragmented nature of the trucking industry (American Trucking Associations Economics and Statistics Group, 2001). Over the last two decades, this fragmentation resulted in intense competition and low profit margins for commercial trucking firms that struggled to develop survival strategies. In an effort to help these firms formulate survival strategies, this research proposed a data envelopment analysis designed to analyze the operational efficiency of trucking firms, identify potential sources of inefficiency, and provide useful information (hindsight) for the continuous improvement of operational efficiency. Several major findings of this benchmarking study are presented and practical guidelines for improving the operational efficiency of trucking firms are delineated.

First, while trucking services continued to dominate the U.S. freight transportation market, all investigated trucking firms but one (J.B. Hunt Transport Services) showed a declining operational efficiency in 2001 (see Figure 1). This declining efficiency within trucking firms coincides with a decline (3.4% decrease from the previous year) in the average annual growth of the manufacturing industry, which is commonly regarded as one of the key drivers for freight transportation (American Trucking Associations, 2002). In particular, Swift Transportation, which was considered relatively efficient during most of the investigation period (1996-2000), registered a steep decline in efficiency score in 2001. Part of the reason for such a decline in efficiency may be an underutilization of fixed assets during 2000 and 2001 (see Table 4). This can be explained by the fact that Swift Transportation engaged in a stock-financing merger with M.S. Carriers in 2001, while joining forces with other carriers, such as J.B. Hunt Transport Services and Werner Enterprises, to form an Internet-based transportation service called Transplace.com in 2000. As a result, Swift Transportation acquired many assets and did not have enough time to translate such an investment into substantial growth in operating income in 2001.

Similarly, Werner Enterprises, which was considered to be the benchmark firm in this study, has experienced declining efficiency for the last two years of the investigation period due to rising salaries, wages, and other operating expenses. Although most elements (e.g., taxes, insurances, maintenance, utilities, depreciation and amortization) of operating expenses seemed to be stable, Werner Enterprises suffered from substantial rises in salaries, wages, operating supplies, and equipment rents for the investigation period (American Trucking Associations, 2001). That is to say, the trucking firm's utilization of personnel and indirect resources needed for equipment maintenance and service operations seems to be correlated to its operational efficiency.

A second finding is that the operating ratio (a measure of profitability based on operating expenses as a percentage of gross revenue) is somewhat (but not directly) correlated to the operational efficiency of trucking firms. For example, Arkansas Best

had the best operating ratio (90.1%) and the most efficient score (100%) among the six trucking firms evaluated in 2000. On the other hand, Swift Transportation had the best operating ratio (89%), but did not have the best score (98.72%) in operational efficiency in 1999 (see Table 2 and Bearth, 2001). In other words, the operating ratio may be a good indicator of a trucking firm's profitability, but does not necessarily reflect the utilization of fixed assets that the trucking firm owned for its operation. Thus, although the American Trucking Association (2001) often uses the operating ratio to benchmark the performances of trucking firms, it should not be the sole performance metric for measuring the true operational efficiency of trucking firms.

Finally, two of the under-achievers (Consolidated Freightways and Yellow Corporation) are large less-than-truckload (LTL) carriers, whereas the two best performers (Werner Enterprises and Swift Transportation) are large truckload (TL) carriers. This can be partially explained by the fact that the TL sector accounted for 44.9% of truck revenue, while the LTL sector represented only 10.3% of truck revenue in 2001 (American Trucking Associations, 2002). TL carriers may have a greater chance to sell their equipment and services, and, therefore, better utilize their resources than LTL carriers. However, such a finding cannot be generalized because Arkansas Best performed relatively well, despite being in the LTL sector. Also, given that the LTL sector is projected to grow faster than the TL sector for the next ten years (up to 2013), the revenue growth opportunity cannot be directly tied to the operational efficiency of trucking firms. More interestingly, during the investigated period, a poor performing peer group (Consolidated Freightways, Yellow Corporation, and J.B. Hunt Transport Services) outperformed its corresponding good performing counterpart (Arkansas Best, Swift Transportation, and Werner Enter-prises) by generating significantly larger revenue and expanding its service offerings (e.g., air freight forwarding, customs broker-age, warehousing, global intermodal services). This finding implies that the size of the trucking firm and the lack of focus on its core competency could hurt its operational efficiency.

Thus, the authors suggest the following survival strategies:

- Focus on the fast-growing or niche-oriented segments of the trucking market. Examples of this include small to intermediate package delivery and the delivery of high tech equipment (e.g., computers and communications equipment);

- Consider leasing fixed assets such as equipment, buildings, and land to increase cash flow and the fixed asset turnover ratio that can, in turn, improve operational efficiency in the long run;

- Control salaries and wages by better managing human resources (e.g., drivers);

- Eliminate unnecessary waste (e.g., indirect costs) in service activities by implementing activity based costing principles that enable management to focus on the activities driving the income.

To conclude, this research differentiates between surviving and struggling groups of trucking firms on the basis of DEA efficiency scores. The DEA efficiency score gives management a warning signal that the lower the DEA score, the greater the likelihood that the trucking firm will fail. Thus, DEA is very useful for identifying less efficient trucking

firms which require the closest attention. However, the proposed DEA model can be extended to include multiple outputs (including non-financial measures) and a greater number of trucking firms in homogeneous business sectors and organizational settings.

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