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Early Warning System for Business Managers

Gerald Winston

Discriminant analysis can indicate which are good risks, which bad; which financial institutions are healthy, which unhealthy—and it can do this well before the facts are clear. It is, in short, an—

EARLY WARNING SYSTEM FOR BUSINESS MANAGERS

by Gerald Winston
Price, Waterhouse & Co.

MANY important business operations have a common object and a common problem. The object is the judicious allocation of resources, which may consist of money spent in hiring and training potential managers; advertising funds aimed at the most responsive segment of the market; shopping facilities designed to attract a particular large group of shoppers; or time spent in detecting actual or potential weakness in debtors holding business loans or in financial institutions. The problem is to separate people or institutions accurately into two mutually contrasted groups—stable or unstable, reliable or unreliable, customers or noncustomers, winners or losers—on the basis of the critical individual characteristics or profiles of the two opposing groups.

The methodology recommended for approaching the problem is known as statistical discriminant analysis.* Because this technique can be used to anticipate the be-

*For a general discussion of the technique of discriminant analysis see "Discriminant Analysis" by Sidney I. Neuwirth and Michael Shegda, M/S March-April '64, p. 28. The technique was applied to credit rating in two other *Management Services* articles, "Credit Analysis: An OR Approach" by Robert A. Morris, March-April '66, p. 52, and "Measuring the Value of Information in Consumer Credit Screening" by Carl C. Greer, May-June '67, p. 44.

EXHIBIT I

Comparison of Effectiveness in Classification of Discriminant Analysis and Most Sensitive Single Ratio

MOST SENSITIVE SINGLE RATIO			DISCRIMINANT ANALYSIS		
SCORE	ASSOCIATION TYPE		SCORE	ASSOCIATION TYPE	
	Nonproblem	Problem		Nonproblem	Problem
Less .25	xxx	x	20 or Higher	xxxxx	
.25—1.74	xxxxxxxxxxx xxxxxx	x	10—19.9	xxxxxxxxxx xxxxx	
1.75—3.24	xxxxxxxxx	xxxxx	0—9.9	xxxxxxxxxx xx	
3.25—4.74	xxxx	xxxxxxxx	—9.9 to 0		xxx
4.75—6.24		x	—19.9 to —10		xxxxxxxx
6.25—8.24		xxxx	—29.9 to —20		xxxxxxxx xx
over 8.24		xxx	—30 and lower		xx

WIDE OVERLAP IN SCORES

Even using most sensitive single ratio, there is a very low degree of segregation between the problem and nonproblem associations, with 11 associations being misclassified.

NO OVERLAP IN SCORES

Problem associations of 1965 were *completely* segregated by the discriminant analysis of their financial information available in 1962, although the weakness of these associations did not become apparent until approximately three years later.

havior of people or institutions and to warn of impending danger or coming advantages so that one can act appropriately, it is the basis of what may be called an early warning system for business enterprises.

Experience proves value

Early warning systems have been shown by Price Waterhouse & Co. to predict accurately healthy and unhealthy financial trends in, for example, California savings and loan associations. Other studies have used them productively to anticipate financial difficulties in many different kinds of corporations.

This technique is thus equally applicable to any area of business or administration in which effective allocation of resources is important and strongly affected by the proper classification of individuals into two opposite groups. Marketers in designing promotional campaigns and apportioning their advertising budgets can determine to whom their product appeals and what media will best reach their potential patrons. There is a great need to predict customer behavior as well as to determine the relative importance of various customer characteristics as they contribute to prediction. A chain can choose to locate new facilities in proximity to the shoppers disposed by income and environment to that type of store. Businesses seeking to maximize profits can select the applicants to whom credit should be granted and loans extended. From the columns of eager college graduates filing through their offices every spring, personnel interviewers can cull the candidates most likely to develop into potential managers.

Use in personnel hiring

In hiring, it is important to minimize the risk of taking on and expensively training men who will stagnate or fail entirely at low levels. Statistical discriminant analysis offers a solution to the problem of picking the winners right at the starting gate.

In 1948 the AICPA expended a considerable amount of effort and money in developing a testing program to discover what unique abilities were needed for outstanding performance in accounting. The objective was to identify in advance the potential CPAs who would succeed in practice. Four tests were given, consisting of a general intelligence test, two achievement tests in accounting, and an interest test designed to develop the applicant's profile for comparison with a norm profile of 1,000 practicing CPAs.

Once the tests were given, however, and a measure of the applicant's interest determined, significant problems arose:

1. How are all the test scores in one package interpreted? How does one take account of the variability or spread of the individual test scores?

A series of test scores supplies the investigator neither with a profile nor with a basis for determining in which group an individual should be classified, especially when there is pronounced variability among the scores. This fact is brought out by examining the results of tests given to 535 students at the Harvard Business School. Dr. Lewis P. Ward, director of admissions of the Gradu-

EXHIBIT 2

Relative Importance of Critical Ratios in Year 1962
(In discriminating between nonproblem and problem associations)

CRITICAL RATIOS	AVERAGE VALUE			COEFFICIENT	RELATIVE WEIGHT	
	Nonproblem	Problem	Difference		Value	%
1. Scheduled Items/Specified Assets	.0154	.0495	+.0341	−2.4805	.0846	20.3
2. Single Family Dwelling Loan Percentage	.697	.478	−.219	− .3312	.0725	17.4
3. Total Construction Loan Percentage	.367	.532	+.165	− .3377	.0557	13.4
4. Out-of-State Savings Percentage	.084	.217	+.133	− .3208	.0427	10.3
5. Slow Loans/Total Loans	.0090	.0237	+.0147	+2.2323	.0328	7.9
6. Promotional Costs/Savings Dividends	.039	.089	+.050	− .6501	.0325	7.8
7. Operating Costs/Average Total Assets	.0097	.0131	+.0034	−6.1379	.0209	5.0
8. Adjusted Total Capital/Specified Assets	.0846	.0733	−.0113	+1.8376	.0208	5.0
9. Total Savings/Total Assets	.839	.766	−.073	+ .2011	.0147	3.6
10. Increase in Assets/Prior Year Assets	.235	.504	+.269	− .0515	.0139	3.3
11. Savings Withdrawals/Prior Year Savings	.401	.558	+.157	+ .0753	.0118	2.8
12. (Interest Income + Fees)/Total Loans	.0709	.0762	+.0053	−1.3528	.0072	1.7
13. REO/Scheduled Items	.100	.206	+.106	+ .0580	.0061	1.5
			TOTAL		.4162	100.0

The ratios which discriminated best between the nonproblem and problem associations (as assessed in 1965) and their relative weights are detailed in this exhibit. The most important of these ratios was scheduled items/specified assets, which had a relative weight of 20.3%, computed by multiplying the difference, +.0341, by the coefficient, −2.4805, to arrive at a value of .0846, which was divided by the total value of .4162.

ate School of Business at Harvard University, stated that an examination of the test score profiles of these students did not reveal a single one which seemed to him to resemble the standard profile.

2. The AICPA test battery was given to 1,000 practitioners, unclassified as to success or failure. Consequently, characteristics distinguishing between the two could not be developed.

Discriminant analysis techniques might very well have been able to resolve these difficulties. A practicing group of accountants could have been selected and classified as successful or unsuccessful. Test scores and personnel assessments received by these accountants in college, at graduation, or at the beginning of their careers might then have been obtained and quantitatively related to their classification groups. Thus, the unique abilities or characteristics needed for outstanding performance in accounting could be determined. In this way, by working backwards from a known group of successful and less successful accountants, the basis for classifying an individual could be established. The results could be validated empirically by taking a second group of successful and unsuccessful accountants, obtaining their original assessments, and determining how well this group could be classified.

The entire problem of personnel hiring thus seems to be amenable to solution by the use of discriminant analysis methodology. Once and for all, we should be able to determine the profile of a successful accountant and quantitatively assess those aptitudes and characteristics that distinguish him from the unsuccessful accountant. Once we have this conceptual structure and quantitative basis for prediction, we can most effectively learn from experience. We can study our personnel evalations, sharpen up our subjective assessments, and continually improve our personnel hiring procedures with concomitant benefits to the firm. We can profit by our mistakes instead of perpetuating them. In addition, we can use this approach to determine promotions and associated salary raises.

Obviously this approach can be applied to positions in fields other than accounting.

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Financial stability

A study has shown that it is possible to classify corporations as those that will run into serious financial difficulties or those that will not as early as two years before the occurrence. This appraisal was accomplished by studying four out of an original list of twenty-two financial ratios. These four measured corporate liquidity, profitability, solvency, and capital turnover.

This ability to identify firms with serious potential financial problems meant that much more profitable investments could be made,

portfolios and banks could have a sounder basis for granting commercial loans and for knowing when to discontinue the loans.

Financial planning could be implemented to determine which firms might merge as an alternative to financial distress. Sound financial firms looking for possible acquisitions of firms in distress could have a much sounder basis for selecting possible merger candidates. Less cost and greater simplicity would be entailed by detecting those firms which might be in distress in the next year or two.

Illustration

To illustrate the methodology of this early warning system for business managers, let us take an actual example of such a study developed for savings and loan associations in the state of California.

It is important to get an early reading on associations which will have difficulties and can thus be classified as problem associations. The state savings and loan commissioner must have some way of differentiating clearly between problem and nonproblem financial positions among savings and loan associations. However, since about forty financial ratios can be used for this discrimination, confusion arises when an association scores as a nonproblem association on one ratio and a problem association on another. Furthermore, for any one ratio, the scores of problem and nonproblem associations usually overlap widely.

This dilemma was presented to Price Waterhouse, and a program was developed to determine how ciation" could be detected. The method developed may illustrate use of this technique in other areas. The financial conditions of savings and loan associations in the state of California were examined for a specific year, 1965, and their financial ratios were evaluated. About thirty associations were found to be problem associations and thirty others to be relatively nonproblem associations by sound criteria. Three years before, all sixty associations had been considered sound. Certain financial ratios which in 1965 indicated the weakness of the thirty were not sufficiently prominent in 1962.

The objective was to determine whether the associations found to be problem and those found nonproblem in 1965 could have been correctly identified three years earlier using the information then available. This objective was attained.

In attacking this problem use was made of statistical discriminant analysis to express the relative strength or weakness of each association in terms of a single number, or score, which in effect was a composite of all the important individual measures of financial well-being. Thus this method bypassed the confusion arising when an association scored as being a nonproblem one as measured by one ratio but a problem as measured by another.

A second benefit obtained by discriminant functions was that they segregated nonproblem and problem associations more completely than could any single financial ratio. Third, the method determined the proper degree of

It is possible to classify corporations as those that will run into serious financial difficulties or those that will not as early as two years before the occurrence.

EXHIBIT 3

Classification Index

Classification Index (I)	1.0	2.0	3.0	4.0
Probability of Misclassifying (%)	31%	16%	7%	3%

EXHIBIT 4

Two Individual Financial Ratios of a Representative Sample of Nonproblem and Problem Financial Associations

PERCENT OF LOANS ON SINGLE FAMILY DWELLINGS		PERCENT OF SCHEDULED ITEMS TO SPECIFIED ASSETS	
ASSOCIATIONS		ASSOCIATIONS	
(34)	(23)	(34)	(23)
Nonproblem	Problem	Nonproblem	Problem
%	%	%	%
64.2	21.8	2.12	5.21
55.6	45.8	3.14	6.74
36.5	41.8	.32	10.49
...	..	...	...
...	..	...	...
...	..	...	...
...	..	...	...
...	..	...	...
...	..	...	...
...	56.1	...	1.94
..		...	
...		...	
79.5		1.34	
Average 69.7	47.8	1.54	4.95

Cut-off Score $= \frac{69.7 + 47.8}{2} = 58.7\%$

Cut-off Score $= \frac{1.54 + 4.95}{2} = 3.25\%$

importance (or weight) that should be assigned to each component ratio to attain the maximum separation between the scores made by problem and nonproblem associations. The proper assignment of weighting factors for maximum separation was assured by the statistical procedures used in discriminant analysis. Fourth, the percentage of misclassifications could be measured, and success in distinguishing between the two groups could be judged.

Here is the approach employed:

Approximately forty financial ratios can be used to describe nonproblem and problem associations. For practical purposes, this number was reduced to the ten to fifteen critical ratios which differentiate most reliably between the two groups of associations. However, even the most sensitive single ratio was found to permit a wide overlap among the individual ratios of the nonproblem and problem associations. This overlap befor any discriminant analysis was performed is illustrated for the most sensitive single ratio on the lefthand side of Exhibit 1 on page 29. Even though the average values of this ratio may differ significantly for the nonproblem and problem associations, many problem associations have ratios as good as the nonproblem associations, and vice versa.

One ratio not enough

Thus, any one ratio by itself provides poor discrimination. However, an overall score combining these various ratios may be arrived at by using statistical discriminant analysis to obtain the coefficients to weight the ratios. The respective distribution of the scores for the two groups would then overlap very little. This distribution of the overall scores resulting from the statistical discriminant analysis for each of the two groups of nonproblem and problem associations is also shown in Exhibit 1. There is no overlap of the composite scores. An overall cut-off score was then established, and it was statistically estimated that the probability of misclassifying a nonproblem association as problem, and vice versa, was approximately 3 per cent.

As shown in Exhibit 1, the problem associations of 1965 were completely segregated by the discriminant analysis of financial information available in 1962, although the weakness of these associations did not become apparent until approximately three years later.

The ratios which discriminated best between the nonproblem and problem associations (as assessed in 1965) and their relative weights were determined to be those shown in Exhibit 2 on page 30. It will be noted in the exhibit that the most important of these ratios was scheduled items/specified assets, which had a relative weight of 20.3 per cent, the computation of which is illustrated in Exhibit 2.

Once we have determined these ratios, it is essential then to de-

EXHIBIT 5

Illustration of a Profile of Nonproblem and Problem Financial Associations (2 ratios)

CHARACTERISTIC	ASSOCIATION NONPROBLEM	PROBLEM	DIFFERENCE
Percent of loans on single family dwelling	69.7%	47.8%	+21.9%
Percent of scheduled items to specified assets	1.54%	4.95%	—3.41%

termine the discriminant function's classification ability. For example, how often will a mistake be made in classifying an association as a problem when it is nonproblem, and conversely? The degree of success in correctly classifying an association will depend upon the amount of overlap of the individual composite scores obtained for the initially classified problem and nonproblem associations. For example, the greater the degree of overlap, the greater the likelihood of misclassifying an association.

An index of the degree of accuracy in classification has been developed. This index is based upon (a) the difference between the average "composite" score for each of the two groups (the greater the difference the smaller the overlap) and (b) the spread of variability of the individual composite scores of the associations within each group. This is measured by the standard deviation of the variability of scores within the two groups: The greater the variability, the greater the overlap.

The classification index is equal to the average difference divided by the measure of variability. By normal probability theory we may associate the probability of misclassifying an association with its classification index. (Exhibit 3, page 31.)

In this particular discriminant evaluation, the difference between the average composite scores for the two groups was 31.4. This was divided by the spread of variability of the individual composite scores of the association, which was 7.6, to arrive at a classification index of 4.1. A classification index greater than 4 is interpreted as a less than 3 per cent probability of misclassification.

In summary, the discriminant analysis completely segregated the problem from the nonproblem associations with a low probability of overall misclassification, indicated which ratios were important, and produced their associated relative weights.

Basis for classification

In using the early warning system, the problem must be resolved of classifying an item or individual into one of the two contrasted groups that exist in any situation.

The first step is to select a representative sample from each group and to measure the characteristics of each member of each group. To determine the group to which a newly appearing individual belongs, its characteristics are also measured so that they can be compared to the existing data.

For purposes of simplicity, let us first consider the case in which only one characteristic is available. Suppose that, in the sample of savings and loan associations, all we know about each association in each group is its percentage of single family dwelling loans. Exhibit 4 on page 32 tabulates these percentages and the average percentage for each of the two groups. We also would know the percentage of single family dwelling loans for an unclassified association. To which group would we assign it? It seems reasonable to assign this association to that group which it more nearly resembles, as indicated by its percentage. Quantitatively, we could do it very easily by observing whether the individual percentage is closer to the group average of the nonproblem or problem group.

Specifically, the average percentage of single family dwelling loans

EXHIBIT 6

Overall Combined Score of the Two Financial Ratios (single family dwelling percentage and scheduled item ratio)

Score	Nonproblem	Problem
150 and over	xxxxx	
100 to 149	xxxxxxxxxxxx	x
68 to 99	xxxxxxxxxx	x
20 to 67	xxxx	xxxxxxxxx
—20 to +20		xxxxxxx
Less than —20		xxxxx

Using only one criterion, we would misclassify approximately 20 per cent of the time

for the 23 problem associations is 47.8 per cent, while that for the 34 nonproblem associations is 69.7 per cent. The halfway point, or cut-off score, between the two averages is 58.7 per cent. Then, depending upon which side of the cut-off score the individual association value lies, we can decide to which group it belongs. For example, if it exceeds the cut-off score, we can classify it as a nonproblem association. However, we would find that seven nonproblem associations out of the thirty-four sampled fell below the cut-off and four of the twenty-three problem associations exceeded it. Thus, approximately 20 per cent of the time we would misclassify a nonproblem association as problem and vice versa.

Weighting the values

Let us suppose that instead of using just one characteristic, the percentage of single family dwellings, we undertook to improve our classification ability by determining an additional characteristic, the percentage of specified assets that were scheduled items. These values are also tabulated in Exhibit 4. The overall approach is now to replace the values of the two ratios for each association with a single value. There are many alternative ways of weighting these two values and combining them to arrive at one overall value for each association.

The appropriateness of our selection of the values for weighting the two ratios can be measured against our success in classifying correctly. Our object, therefore, is to determine the weights for combining the financial ratios to obtain the maximum separation between the two groups. The less overlap we get, the easier it will be to assign an association more accurately to a group.

Statistical discriminant analysis is used to find the optimal weights (coefficients of a linear equation) which are then used to multiply each ratio. The coefficients which were obtained by this process were 199 for single family dwellings and −1529 for scheduled items/specified assets. The product is a composite score of the two ratios. For example, for the first association listed in Exhibit 4, its percentage of loans on single family dwellings was 64.2 per cent and its percentage of scheduled items/specified assets, was 2.12 per cent. The optimal combined score for this association would thus be:

$$199 \times .642 - 1529 \times .0212 = +95$$

As shown in Exhibit 5 on page 33, a profile of an association should be stronger as the percentage of single family dwelling loans increases and weaker as the percentage of its assets that were scheduled items increases.

The combined optimal scores for each of the individual associations belonging to the two groups are tabulated in a frequency distribution in Exhibit 6 on page 33, and an assessment is made of the classification in Exhibit 7 below.

The concept governing group assignment is the same for combined scores as for single ratios. As shown in Exhibit 7, the average weighted composite score for the nonproblem group is 115 and for the problem group is 19. The cut-off score is equal to the average of these two scores, or 67. If the individual score exceeds 67, it would be called a nonproblem; if not, a problem.

As shown in Exhibit 7, there is a much better classification using the optimally combined scores of the two financial ratios than utilizing the two individual ratios. This results from the reduction in overlap of the composite scores of the two groups of associations contrasted with the distribution of the individual ratio scores of the two groups.

The value and power of the linear discriminant analysis function for two ratios can also be shown graphically. Exhibit 8 on page 35 illustrates the scatter of the nonproblem and problem group of associations according to the two

EXHIBIT 7

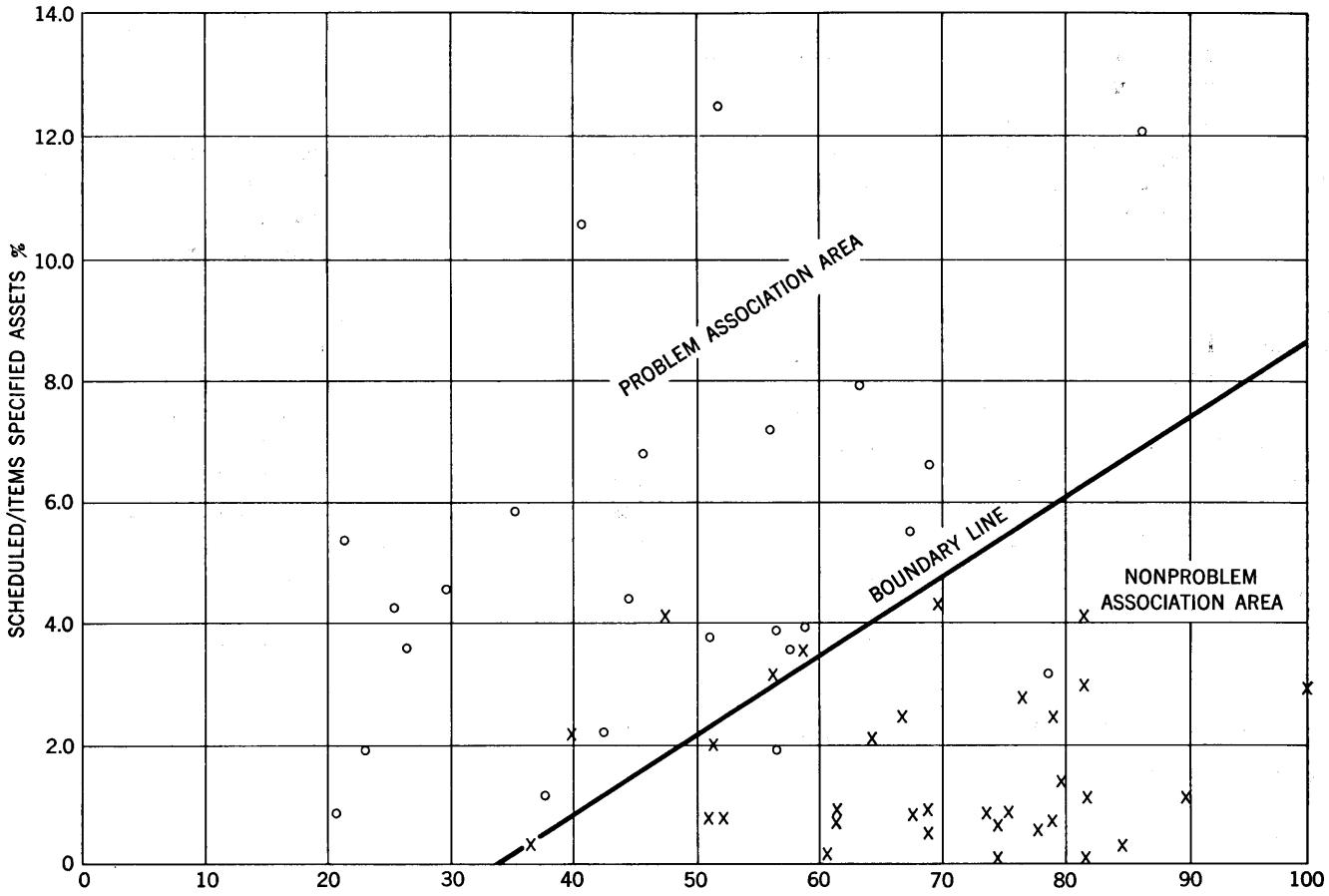
Improvement in Classification Ability by Optimal Combination of Two Financial Ratios Versus Individual Ratio

Characteristics	AVERAGE VALUE Nonproblem Associations	Problem Associations	Cut-off Point	Misclassification No.	%
Scheduled Item Ratio	1.54%	4.95%	3.25%	11	19
SFD Percentage	68.7%	47.8%	58.7%	12	21
Combined Score*	115	19	67	6	11

*Combined Score (199 x SFD%) — (1529 x SI Ratio)

EXHIBIT 8

Percent of Single Family Dwellings to Total Loans



ratios of single family dwellings and scheduled items. There is no pronounced clustering of the nonproblem and problem associations. It would be quite difficult to discriminate accurately between them. If we consider single family dwellings or scheduled items separately, and select individual cut-off scores, we would misclassify approximately 20 per cent of each group. However, by using the linear discriminant function and optimally combining the scores, we obtain, as shown on the graph, the boundary line (which can be expressed by a linear equation) which provides the maximum separation of the samples and discriminates most effectively. We would misclassify only two (about 9 per cent) of the problem, and four (about 12 per cent) of the nonproblem associations.

As the number of characteristic ratios in use increases, the percentage of misclassifications decreases. The introduction of new variables increases the efficiency of discriminant analysis and promotes optimum discrimination between two groups. This feature was demonstrated earlier in this article in Exhibit 1, which illustrated the complete segregation of the two groups by using the thirteen ratios tabulated in Exhibit 2. In addition, the methodology enables us to assess the accuracy of the classification that can be achieved, by extending the results obtained on the basis of the sample.

The continued accuracy of these categories, of course, assumes a stable environment. What happens if the housing market declines? How well does discriminant analysis stand up to time? If we were to apply them to the savings and loan problem, the question would be answered as follows:

It is evident from the results given in preceding sections that as early as 1962 there existed real and determinable differences in operating characteristics between associations which subsequently found themselves in financial trouble and associations which did not. The table of critical 1962 ratios (Exhibit 2) specifies, in fact, the particular operating characteristics most closely associated with "future" troubles. Do these same ratios and weights apply today? That is, can the 1962 ratios and weights be used to determine which associations are in trouble or are getting into trouble in 1969? Some of the same ratios still discriminate in 1969. However, certain other ratios no longer discriminate be-

tween nonproblem and problem associations, and weighting factors which were applicable in 1962 are no longer applicable in 1969.

The primary reason for this change is that the significant decline in the housing market resulted in sharp drops in the number of loans that were made and to a certain extent increased the riskiness of the loans. This situation has resulted in changes in the operating methods of the associations. As an example of changing operations, loan fees formed a substantial percentage of operating income for some associations in 1962, particularly those associations which were subsequently classified as problem. Thus the ratio of loan fees to operating income was a good discriminator in 1962 but is so no longer in 1969. With few exceptions, loan fees today are relatively unimportant.

Because of these changes in the economic environment and in the resulting operating characteristics of the associations, the ratios and weights which were determined to provide the best discrimination in 1962 must be updated to reflect today's conditions. Furthermore, because of the considerable time span involved between 1962 and 1969, the entire procedure used for the 1962 data should be repeated for 1969, to arrive at a completely independent set of ratios and weights which can then be implemented in today's environment. After this new set of measures has been determined, it can be updated periodically without the necessity for a complete re-evaluation.

Updating the model

To ensure continual improvement of the discriminant function to detect future problem associations, it is important to identify shifts in the relative importance of the critical ratios and relate them to shifts in the changing external environment, including economic conditions, the housing market, the money market, etc. The changes in these external factors may affect the relative importance of the weights of the critical ratios differentiating between problem and nonproblem associations; i.e., new ratios may become important and old ones unimportant.

Consequently, in this example, a discriminant analysis should be performed for the individual years between 1962 and 1969 to determine the changes both in the weights of the ratios and in economic conditions. For classification and analysis the results of these studies could be summarized in the two tables, Exhibits 9 and 10, on this page.

By relating the changes in the critical ratios to different economic conditions, the impact of the economic environment on the mathematical model may be identified. Then as economic conditions change in the future and as these conditions are noted, the need to change the mathematical model may become apparent.

External environmental conditions would also affect the degree of control that one would wish to exercise in establishing a cut-off score to classify an association as being potentially a problem. In prosperous economic times one can run a greater risk of not identifying a potentially problem association. During periods of recession it would be most essential to detect potential problem associations.

Conclusion

As our example shows, an early warning system uses internal and external economic and environmental information. It predicts change and gives the business a basis for intelligent and effective planning. It records and explains possible dangers and difficulties and transforms its criteria as significance drifts from one factor to another. This methodology provides another potent weapon to the business manager in meeting the challenge of change.

EXHIBIT 9

Relative Weights of Ratios						
Critical Ratios	1962	1963	1964	1965	1966	1969
etc.						

EXHIBIT 10

	Economic Conditions					
Factor	1962	1963	1964	1965	1966	1969
Housing starts						
Money supply						
Interest rates						
Index of production						
Net increase in savings						