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Decision Tables

James I. Morgan

DECISION TABLES

These devices for representing a procedure or system are useful in analyzing decision alternatives and in communicating decision rules to operating personnel. This article tells how to construct and use them.

by James I. Morgan
The Dow Chemical Company

In their attempts to make business decisions more scientific management analysts have developed a variety of new descriptive and prescriptive tools and approaches. Terms such as decision maker, decision theory, decision rule, decision function, decision diagram, decision matrix, decision tree, and decision table are becoming increasingly common.

The rapid development of this "decisionitis" has left many businessmen skeptical as to whether these terms refer to something practical or just to some more fancy gimmicks. Some are skeptical because of their feeling that the decision process is so complex that it cannot be explained by simple terms or analytical procedures. A few managers have opposed these new approaches because of a feeling that automating the decision making process will obviate the need for management.

Experience to date indicates that these new tools and approaches are finding practical application, that they are not passing fancies, and that they will remain on the business scene. Potentially one of the most useful, and least publicized, of these new aids is the decision table. This article discusses the concept, structure, and synthesis of decision tables and describes some of the ways in which they can be used in management.

Definition

A decision table may be either an *action* or a *result* table. Basically, an action table is a compact

Decision tables are not limited to computer uses. . . .

representation of a procedure or system in which alternative courses of action are specified for various combinations of conditions. The table states what action (decision) should be taken for a given combination of conditions. This action (which actually may be several actions) is a decision rule which basically states that if such and such happens then this and this should be done. This type of decision table may be viewed as an organized set of decision rules designed to tell what to do for given circumstances. The doing might be done by a person as part of some system or procedure or by a computer as part of a routine. The table can even specify which person is supposed to execute the action.

The result type of table is similar except that numerical results are specified for given combinations of conditions and/or actions. The result might be a cost, mileage, or physical property. This type of table is often helpful in evaluating which decision or action is better in which circumstances.

In its simpler forms the decision table is not new. One of the best known, and least popular, examples is the table from which we compute our income tax. This table gives the tax, or a rule for calculating it, for certain conditions of income and exemptions. A price schedule which relates unit price to quantity ordered is another frequently used decision table. Many other common examples might be cited of tables in which a result or action is given for certain conditions.

A more general form of decision table has come into use within the last few years. The impetus for its development has been the need for designing, communicating, and understanding complex control systems that have been programed for electronic computers. Although especially advantageous for explaining decision procedures for computer systems, decision tables are by no means limited to computer uses.

Inventory control

As an example of this new form of decision table, let us look at an inventory control situation. We have a case where inventory replenishment is made on the basis of the relationship of available inventory to a specified reorder point. We use the decision procedure:

> If inventory is less than or equal to the reorder point, then order a replenishment. Otherwise, don't order.

The procedure can be expressed more succinctly:

> If inventory $\leqq$ reorder point, then order. Otherwise, don't order.

Basically, we have a decision situation based upon one condition (the inventory level). Two alternative courses of action (order or don't order) and two decision rules (based on a "yes" or "no" answer to the condition relationship) are available. The action taken depends upon the condition. The condition states a relationship. The action states a command.

An alternative way of expressing our decision procedure is given by Exhibit 1 on page 16. This is a simple decision table. It is not necessarily more desirable than the narrative description given above. Its desirability would increase, however, if we were to add more conditions and actions.

The table has four principal parts as shown:

CONDITION STUB	CONDITION ENTRIES
ACTION STUB	ACTION ENTRIES

We separated the four parts by double lines in our illustration. The table defines and separates the conditions and the actions. In practice, it would not be necessary to use the headings for each stub. Each row is a condition or action. Each column is a decision rule or course of action. In decision table terminology, a decision rule is a vertical combination of conditions and actions. The condition entries are yes or no. (In more complicated tables, there may not be a condition entry in each square. If so, the condition is not significant and is therefore ignored.) An action entry is a check whenever the action is to be executed. If all the condition entries in a column are satisfied, then the actions checked are effected.

Let's complicate our situation slightly. Suppose that we will order only under two combinations of conditions: (1) if the inventory is less than or equal to the reorder point and the production plant is currently making the item, (2) if the inventory is less than a special critical point which is less than the reorder point. We now have three conditions: inventory in relation to the reorder point, inventory in relation to the critical point, and the existence of current production. As before, we have two actions, order and don't order.

Our decision table might look

JAMES I. MORGAN is a staff member of the pricing and evaluation department of The Dow Chemical Company in Midland, Michigan. He has held engineering positions with Dow, Eastman Kodak Company, and Du Pont and most recently served as operations research analyst for St. Regis Paper Co. He is a member of the American Institute of Chemical Engineers, The Institute of Management Sciences, and the Operations Research Society of America.

like Exhibit 2 on page 16. Some simplifications have been made to avoid unnecessary writing. We now have four decision rules. There is no required reason for putting the rules in the order given. The given Rule 4 could have been Rule 1, and so forth. In practice, it is preferable to put the most common situation first. For instance, if the inventory were more likely to be above the reorder point, then the given Rule 4 would be made Rule 1. Thus, in checking which rule to execute we would come to this rule, and if it were applicable we would not need to try the other rules.

In this particular case, the order of the conditions or the actions is not of major importance as far as simplifying the table is concerned. In general, it is preferable to put the most sensitive condition first.

Testing all circumstances

Of prime importance is whether or not we have evaluated all the possible rules. To check, we need to know how many conceivable rules there are.

We have three conditions which can have either a yes or a no state. The conceivable number of rules is thus 2^3 or 8. (A general formula is 2^c where c is the number of conditions.) If we were to evaluate all eight eventualities we would get Exhibit 3 on page 16.

We note that whenever we have a no answer to the first condition, we have the same action. Hence, the first condition is the significant one. If the inventory is greater than the reorder point, it doesn't make any difference whether there is a current production run or how the inventory compares to the critical point. Thus, we really need only one rule. Hence Rules 5 to 8 in Exhibit 3 can be replaced by Rule 4 of the previous table. Similarly, if the inventory is less than or equal to the reorder point and there is a production run, then the critical point comparison is immaterial, and Rules 1 and 2 can be combined. Thus the eight conceivable rules have been reduced to four.

If we apply some logic, we note also that Rules 5 and 7 cover impossible circumstances. Since the critical level is less than the reorder point, the inventory cannot be above the reorder point and less than the critical point.

This evaluating of all conceivable circumstances is important in many cases. It is a check to see that a possible situation is not overlooked and that there is a course of action for each situation. (The action might be to call the boss or to go out of business, but it still must be specified in the table.) One of the key advantages of constructing decision tables is that omissions, inconsistencies, and unforeseen circumstances can be discovered.

If the number of conditions were large, it might be difficult to evaluate all possible circumstances. For instance, if there were ten conditions, there could be 1,024 possibilities. Generally, however, it is possible to find situations where a given answer to one condition will specify a course of action that is not influenced by the answers to the other conditions. Also, as in our example, there may be combinations of conditions which may be illogical because of physical, mathematical, or other impossibilities.

Identifying all conceivable conditions is a major job in constructing a table—and also in designing a system. Generally, it is not practical to include all possible conditions. There are almost always cases with infinitesimally small probabilities of occurrence. However, while it is desirable to keep the number of conditions to a minimum, care must be taken to include all conditions that will significantly affect the decision made.

Other forms

The decision table of the example might also have been written in the form of Exhibit 4 on page 17. This table tells us that if one of the two combinations of conditions holds, we order. Otherwise, we don't.

The example could also be written as Exhibit 5 on page 17. Here we have included relationships in our condition entries and commands in our action entries. If all the entries were relationships or commands, then we would have an extended entry table as contrasted to the limited entry table given previously. A limited entry table has only yes, no, and execute entries. We have a mixed entry table here because there are relationships and commands and also yes or no and execution statements for entries.

The particular form used depends upon the preference of the table developer. Ease of understanding should be a major consideration. Except for a few fundamentals, the rules for constructing decision tables are not too explicit. The skill of the developer, the situation which the table describes, and the use to which the table is put are factors that influence the table's structure. The important thing is that the table be easily read.

A more complicated example

So far we have discussed only relatively simple situations. If there were other conditions that influenced our course of action, then they should be included. Some additional conditions might be these:

1. Were there sales in the last month?

2. Does the sales department feel

EXHIBIT 1

INVENTORY DECISION TABLE

	CONDITION	Rule 1	Rule 2
1	Inventory less than or equal reorder point	YES	NO
	ACTION		
1	Order	X	
2	Don't Order		X

EXHIBIT 2

ADDITIONAL CONDITIONS

		1	2	3	4
1	Inventory ≤ Reorder Point	Y	Y	Y	N
2	Current Production Run	Y	N	N	
3	Inventory ≤ Critical Point		Y	N	
1	Order	X	X		
2	Don't Order			X	X

EXHIBIT 3

ALL POSSIBLE RULES

		1	2	3	4	5	6	7	8
1	Inventory ≤ Reorder Point	Y	Y	Y	Y	N	N	N	N
2	Current Production Run	Y	Y	N	N	Y	Y	N	N
3	Inventory ≤ Critical Point	Y	N	Y	N	Y	N	Y	N
1	Order	X	X	X					
2	Don't Order				X	X	X	X	X

the product will continue selling?

3. Is the item highly profitable? Inclusion of these conditions might give the decision procedure illustrated by Exhibit 6 on page 17.

Relational symbolism

The conditional statements are relationships. As a result, a decision table can be simplified by using symbols representing relationships. An example is the symbol $\leqq$ to stand for *less than* or *equal.* Other commonly used symbols are:

- $=$ equal
- $\neq$ is not equal
- $\geqq$ greater than or equal
- $>$ strictly greater than
- $<$ strictly less than

Further simplification can be achieved by use of the set-theoretic symbols $\bigcup$ and $\bigcap$, which stand for *intersection* and *union,* respectively. The former indicates that both events must happen. The latter indicates that one or the other must happen. For example, with current production run $\bigcap$ profitable item, a yes answer indicates that there is a current production run and the item is profitable. With current production run $\bigcup$ profitable item, a yes indicates that either there is a current production run or the item is profitable. Both events may be true, but at least one of them must be true before the yes answer is valid. Using these symbols, we can shorten the table of Exhibit 6 to get Exhibit 7 on page 17.

Further applications

This inventory control example is just one of many uses to which decision tables have been and could be put. Exhibit 8 on page 17 is an example of a table used in the handling of customer orders. Here we have combined the order handling with our previous inventory replenishment example. Such a combination would be used with a transaction inventory control system.

In the area of economic analysis, decision trees and decision matrices have been used by many to help define decision alternatives and consequences.[1] Just as there is some interchangeability in the use of decision trees and decision matrices, there is some interchangeability of tables, trees, and matrices.

Of particular interest to accountants is the expression of a tax schedule by a decision table such as Exhibit 9 on page 17. This example is hypothetical, but more realistic situations can be expressed by decision tables. Other examples include take-home pay determination, handling of airline reservations, listing insurance rate schedules, listing product specifications for given customer requirements, listing of quantities to buy of different materials at various prices,

[1]For example, see John F. Magee, "Decision Trees for Decision Making," *Harvard Business Review,* July-Aug., 1964, pp. 126-138. Also, James I. Morgan, "Questions for Solving the Inventory Problem," *Harvard Business Review,* July-Aug., 1963, pp. 95-110.

EXHIBIT 4

SIMPLIFIED FORM

		1	2	3
1	Inventory ≤ Reorder Point	Y	Y	ELSE
2	Current Production Run	Y	N	
3	Inventory ≤ Critical Point		Y	
1	Order	X	X	
2	Don't Order			X

EXHIBIT 5

MIXED ENTRY TABLE

		1	2	3
1	Inventory	≤ Reorder Point	≤ Reorder Point	ELSE
2	Production Run	Yes	No	
3	Inventory		≤ Critical Point	
1	Action	Order	Order	Don't Order

EXHIBIT 6

ADDITIONAL CONDITIONS

		1	2	3	4	5	6	7
1	Inventory ≤ Reorder Point	N	Y	Y	Y	Y	Y	Y
2	Sales in last month		N	Y	Y	Y	Y	Y
3	Inventory ≤ Critical Point			N	N	N	N	Y
4	Current production run			N	N	N	Y	
5	Sales future optimistic			N	Y	Y		
6	Profitable item				N	Y		
1	Order					X	X	X
2	Don't Order	X	X	X	X			

EXHIBIT 7

USE OF SYMBOLISM

		1	2	3	4
1	(Inventory > Reorder Point) ∪ No sales in last month	Y	N	N	N
2	Inventory ≤ Critical Point		Y	N	N
3	Current production ∪ (Sales future optimistic ∩ Profitable item)			Y	N
1	Order		X	X	
2	Don't Order	X			X

EXHIBIT 8

PROCEDURE FOR HANDLING CUSTOMER ORDERS

Order size less than truck load	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N
Inventory at nearest warehouse	Y	N	N	N	N									
Inventory in transit		Y	Y	N	N									
Inventory at nearest plant						Y	N	N	N	N	N	N	N	N
Production run scheduled							Y	Y	Y	Y	N	N	N	N
Can be made by requested date											Y	N	N	N
Customer will wait		Y	N				Y	N	N	N				
Inventory at another plant								Y	Y	N		Y	Y	N
Customer will order truck load				N	Y									
Can be shipped by requested date								Y	N			Y	N	
Ship from warehouse	X													
Ship from w.h. when available		X												
Ship from plant						X								
Schedule production											X			
Ship from plant when available							X				X			
Ship from other plant								X				X		
Refuse order			X	X					X	X			X	X
Investigate stocking item				X	X						X	X	X	X
Continue with rest of table					X									
Go to Exhibit 6	X	X				X	X	X				X		

EXHIBIT 9

TAX SCHEDULE FOR CASE WHEN THERE CAN BE INDEFINITE CARRYOVER OF OPERATING LOSSES

		1	2	3
1	Income > Expenses	Y	Y	N
2	Carryover > Income-Expenses	Y	N	
1	Tax = 0	X		X
2	Tax = (Rate) (Income-Carryover-Expenses)		X	
3	Earnings = Income-Expenses-Tax	X	X	
4	Loss = Expenses-Income			X
5	Carryover=Old Carryover-(Income-Expenses)	X		X
6	Carryover = 0		X	

determining transportation cost schedules, credit rating determinations, maintenance procedures, medical diagnoses, and so on.

Strategies for games of chance can be set up as decision tables. As an exercise, the bridge player might set up his own strategy, or Goren's, as a decision table. He would soon be impressed with the need for defining the significant conditions and also would be able to discover the situations about which the experts are "silent." Such an exercise would undoubtedly improve his bridge game just as the development of decision tables in business situations often helps to improve business operations.

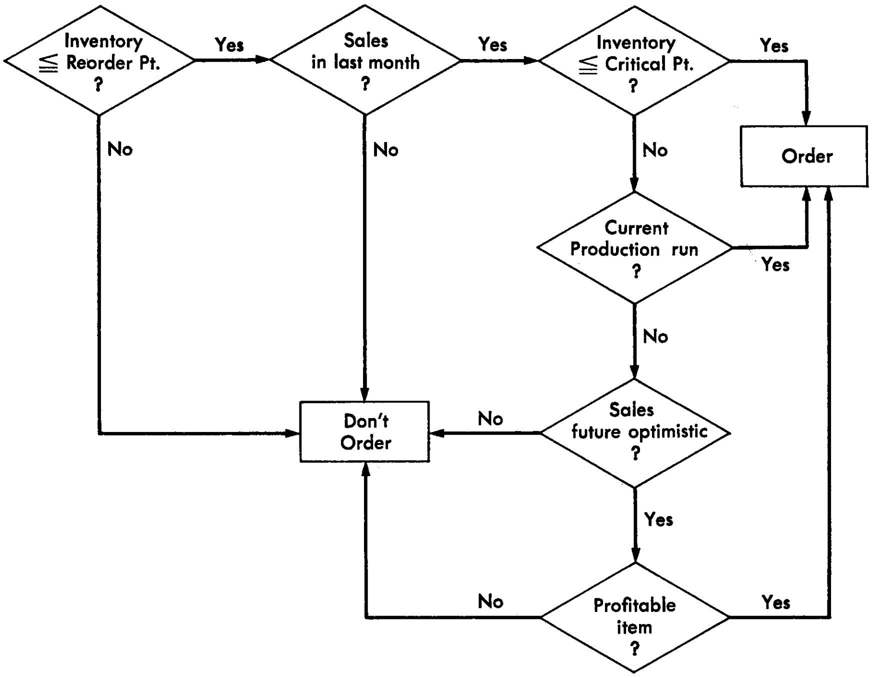
Fundamental requirement

The use of decision tables depends upon some kind of logical procedure for arriving at the actions or results. In many cases, the actions or results may be based on definitions, laws, mathematical formulas, or experiences. In other cases, they may be based on policies or subjective reasoning. For some situations, they may be based upon some "best" procedure determined by an objective analysis. Unless such a procedure can be determined, a decision table cannot be developed.

Decision tables are but one way of expressing a system or procedure. We could take the table of Exhibit 6 or Exhibit 7 and ex-

EXHIBIT 10

FLOW DIAGRAM



press it in words. It might, however, take a page of writing to express it adequately. Even then some ambiguity might be present. A decision table has the advantage over the narrative in its conciseness and its precision. The table allows easier visualization of relationships and alternatives. Furthermore, with the table, it is easier to see that we have covered all eventualities.

Other means of expression are flow and block diagrams. These have been used extensively by computer programers. Exhibit 10 on this page is an example. Depending upon the use and the person's familiarity with them, these diagrams may or may not be easier to read and use than decision tables. They are harder to draw neatly and are not as compact. They are generally harder to modify than decision tables. With a decision table, it is easier to trace results for a given set of conditions.

For a complicated system, it is generally helpful to have both flow diagrams and decision tables. One can often be a valuable check on the other. With more complicated systems, more than one decision table may be required. The tables are connected by use of "Go to . . ." executions. With complex systems, flow diagrams can help to show the interconnections among decision tables. The flow diagrams can give the generalizations, leaving the details to the decision tables.

Advantages

A main value of decision tables is their use as a communication tool. An analyst or engineer can design a system, express it as a table (or tables), and then use the same table to explain the system to a computer programer, an inventory scheduler, a manager, or another analyst. A decision table gives them all a common language that is precise and less likely to be misinterpreted.

To the analyst, decision tables are extremely valuable in helping to think through a problem. They aid in defining relationships and actions. They are an easy and concise way to present a solution to a problem and to document and implement a system.

For the programer, tables are an aid in coding computer programs with a minimum of misunderstanding and further analytical work. Some high-level computer languages are under development which will have special instructions for handling decision tables.

To managers and users, tables are effective means of understanding, checking, and modifying a proposed system. For the users, tables are an explicit, easy-to-use tool.

To date, the use of decision tables has been in areas where there are a relatively small number of well-defined possible combinations of conditions and where logical decision procedures can be determined. Within these areas, decision tables have been an important tool in making more effective decisions. In some cases they have been a factor in "automating" decision procedures. Further use will depend upon man's ability to interrelate logic with the need for choosing alternative courses of action. For the manager who is concerned about being put out of a job by a computer system based on decision tables, it should come as some solace to learn that business appears to be growing more complex at a faster rate than man's ability to comprehend it by decision tables or other means.