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Efficient and Viable Organizational Forms\*

Jacob Marschak

January 23, 1959

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## EFFICIENT AND VIABLE ORGANIZATIONAL FORMS

Jacob Marschak  
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If several persons agree to follow a certain set of rules we shall say - just for the purpose of this paper and without quarreling with other existing definitions - that they are members of an organization. We shall call this set of rules, the organizational form or constitution.

The rules that the members are supposed to obey deal with their actions, mutual communications, and observations. Typically such a rule (also called "role" by sociologists, I believe) states what a given member should do when he receives information.

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\* A draft version of the paper, prepared under a contract of the Office of Naval Research with the Cowles Foundation for Research in Economics at Yale University, was presented at a Symposium of the Research Committee on organization planning of the American Institute of Industrial Engineers, March 1958. The paper was expanded and completed when the author was visiting research professor at the Carnegie Institute of Technology, 1958/9, and presented at the Symposium on Organization Modern/Theory sponsored by the Foundation for Research on Human Behavior in Ann Arbor, Michigan, in February 1959. The Symposium Proceedings will be published by John Wiley and Son.

Doing means here either

- (1) impinging on the world outside of the group of people forming the organization: we call this action; or
- (2) sending to or receiving a message from another member; we call this internal communication (and for brevity often omit the word "internal"); or
- (3) receiving messages from the outside world; we call this observation.

For example, an action may consist in adding fuel to a heater, in driving a truck, or in writing to a client. A communication may consist in giving an order to a subordinate, a report to the boss, a speech at the board meeting. An observation may consist in reading a newspaper, a client's letter, the report of a market research agency.

It is convenient to extend the term "communication with another number" to the case of "communication with one's own memory." Committing a received message to one's memory ("Filing"), or digging out past information. A cross-section of what is being done within an organization during a given period of time is schematically represented by a matrix (Fig. 1) which may clarify the logic of our concepts.

	RECEIVER			
	0	1	2	...
0	(0,0)	(0,1)	(0,2)	
1	(1,0)	(1,1)	(1,2)	
2	(2,0)	(2,1)	(2,2)	
⋮				
⋮				
⋮				

Figure 1: A matrix of actions, observations and internal communications.

The cell (1,2) would be filled with the description of messages sent by member 1 to member 2; the cell (2,1) would contain messages in the opposite direction. The row and the column marked "zero" represent the outside world; hence the observations being made by member 1 would be entered in the cell (0,1); and the actions of member 1 (interpreted as "messages to the outside world") would be entered in (1,0). The diagonal cells - (1,1), (2,2) .... - are filled with communications between a member and his memory; with the exception of the cell (0,0) which naturally summarizes all those external events that do not impinge upon, nor are influenced by, the organization's doings.

In general, an organization member acts, communicates, or observes in a given period of time in response to some "message" that he has received from the outside world or from a member (possibly himself), in the preceding period(s). As we have indicated at the beginning, the organizational form consists of rules that describe "who should do what in response to what information?" Schematically, the rules state that if the cells of the matrix in Fig. 1 had certain contents during a given week(s) they should be filled in a certain fashion in the next week.

It would help to understand the workings of an organization if, instead of the usual "organization chart" one could have the description - if only a very rough one - of "who does what in response to what information?"

A description of the rules of action and communication that are in actual use in a given organization (though possibly are not the officially proclaimed ones) would also help to improve them. The set

of rules can be good, less good, bad. One set of rules is better - or more efficient - than another if, on the average, it is more conducive to achieving the organization's goals.

Let us discuss this evaluation of rules - and hence of organizational forms - according to their efficiency, - in some more detail. As so often, it helps to begin with a simple, limiting case: the one-man organization, the rules for a single decision-maker. They prescribe what he shall do in response to a given information. Again, his doing means action (impinging upon outside world), observation (of the outside world) or internal communication (in this case, with his memory only). One rule is more efficient than another if, on the average, it is more likely to further the decision-maker's goals.

I have just said "on the average", because the outcome of a person's doings depends, of course, on the chance events of the outside world, and not only on his manner of acting. No soldier, no farmer claims the gift of prophecy. Every businessman knows that business involves gambling. He acts on the basis of more or less founded ideas of how likely is the demand for his product to rise or to fall; or how likely is an invention to succeed or to fail; and so on. In short, he acts on the basis of some approximate knowledge of, or some hunches about, the probabilities of possible events. More or less consciously he estimates, in effect, the probability with which a given decision of his will lead to one result rather than to another result.

The decision maker cannot control the external events, such as the public's demand in a widely competitive market, or the government policies that lead to inflation or deflation; he can only estimate the probabilities

of such events. But he can control his own decisions. He chooses, from among several decisions open to him, that decision which, measured on his goals, leads on the average, to better (or, at least, not worse) results than other possible decisions. One calls such decisions, good, or more technicall, optimal decisions; (avoiding the term "best decisions", as two decisions may be equally good); or efficient decisions.

The description just given presupposes the simple but rather exceptional case of "one-shot decisions": the case when no consideration is given to the fact that today's decision may affect the outcome of tomorrow's decision. Yet little thought suffices to extend the concept of efficient decisions also to the more interesting, more usual, and more general case when the phrase "sufficient unto the day is the evil thereof" is not valid. In this more general case one makes "decisions about future decisions", one choses "maxims of behavior", also called "sequential decisions", strategies, or, in our terminology, decisions rules. Faced with an unknown sequence of future events, the decision-maker chooses, not only what to do today, but also (more or less roughly) how to respond to each of the various possible events of tomorrow and of the day after, and of a still later day. In this choice he is guided by some (more or less vague, more or less conscious) estimates of probabilities: so that, again, an efficient decision rule is one that, on the average, produces good results, in terms of the decision-maker's goals.

Clearly this is an idealized picture, a norm, a piece of logic not of psychology. To prefer efficiency to inefficiency is itself a norm. Is it therefore a useless exercise? I don't think so. Psychologists tell us how often, and by what kind of people, certain logical - or, for that matter, arithmetical - errors are made; this does not make arithmetic and logic useless.

In fact, we do try to teach children arithmetic. We are concerned when our students lack logic. And, I suppose, teachers of Business and of Military Art are rather anxious to inculcate the ability of efficient decision.

Our picture of efficient decision-making is un-psychological also in another important way; it is not true that a man has consistent goals, or values (on which to measure efficiency). It is an idealization to say that a businessman (as such) tries to make, on the average, a large profit, and that the military man tries to act so as to make victory as probable as possible. Again, I believe this idealization is not useless (measured on the goals of those who try to improve the workings of businessmen or of generals).

We now return to the general case, the several-men organization. The extension to this case of the concept of decision rules just defined for the special case, the one-man organization, is obvious: the "rule" is replaced by a "set of rules" (one for each member); and the concept of internal communication is widened to the scope given it at the very beginning of the paper. It is the concept of the goals (or values) that seems to present difficulties. If, psychologically, even a single man may lack consistency of values, what to say of a group of several?

Nonetheless, it is possible to evaluate the efficiency of an organizational form, for a given goal. A business concern may be inefficient in profit-making but efficient in making its executives love each other. Once the goal is stated, the same logical tools apply.



One empirically useful approach is to estimate the efficiency of an organizational form by taking as the goal a high chance of survival. A census of existing organizational forms in some centuries-old field (e.g., that of religious organizations, or of small handicraft or of family farming), may confirm that certain rules of action and communication, in this particular field, are more viable than others; they have, in the anthropologists' language, a higher "survival value." Such empirical confirmation on evolutionary grounds is, however, true only if one has the right to assume that the environment (that is, the probability distribution of the relevant external conditions) has not changed significantly in the course of time.

Whether the investigator chooses viability or some other goal as the criterion to compare the efficiency of organizational forms in a given field of activity, this goal need not coincide with the goals of any of the members of the organization. Such coincidence is improbable, if only because the individual goals are, in general, not identical among themselves.

This independence of the organizational goal (as chosen by the investigator) from the individual goals does not make, by any means, the efficiency judgments meaningless. It is certainly possible to judge the efficiency of a business corporation in terms, say, of its aggregate profits over the next two generations, without postulating this to be the goal of any of the executives or stockholders. Nor does the frequent praise of the efficiency of the Roman Catholic Church necessarily imply that it has served well the individual aims of all its popes, bishops and laity.

This raises the problem of incentives. Organization rules can be devised in such a way that, if every member pursues his own goal, the goal of the organization is served. This is exemplified in practice by bonuses to executives and the promise of loot to besieging soldiers; and in theory, by the (idealized) model of the laissez-faire economy. and there exist, of course, also negative incentives (punishments).

I shall have to leave the problem of incentives aside. In what follows, we shall not be concerned with individual goals. If they still lurk in your mind, inhibiting our understanding each other, you can make the assumption (actually unnecessary for what follows) that the members of the business organization I am going to discuss are partners sharing the profits equally; or that some perfect system of incentives is operating. In short, you may think of a team. My main purpose is to illustrate how various organizational forms can be compared, and an optimal one chosen, given the organization's goal.

Suppose a shipbuilding firm has two docks: an old one and a new, mechanized one. The former has higher operational costs (mainly labor) and the difference depends on the dockworkers' wage rates (same in both docks). Suppose further the firm has two sales representatives, each in a different market. We shall call the two markets East and West. Each representative receives price offers (orders for ships) in his market: this is his piece of information. The production manager, on the other hand, knows the current wage rate and hence the production costs. Suppose the operational costs per ship are

in the new dock: 20

in the old dock: 35

(we neglect capital charges and other non-operational, fixed costs as they must be paid in any case and therefore cannot affect the choice of a decision). Suppose the prices offered by a client to a salesman are

in the East

29

in the West

21

Clearly if the production manager and the two sales representatives sit in conference they will take the following decision as the best one: use the new dock for the Eastern client (making a profit of  $29 - 20 = 9$ ), reject the Western offer, leave the old dock idle. Instead of having a conference, they might also reach this same decision by each salesman's first reporting the local price to the production manager and then receiving from him the instruction to accept or reject the offer.

But conferences and other forms of extensive communications take time and money, especially in the form of salaries to busy executives. We ask therefore: Is it always best to "centralize" all decisions, i.e., base them on all available information collected at some conference or headquarters? Under what circumstances is such centralization justified? When is it, on the contrary, more economical to let the local, or the specialized, persons go ahead on the basis of their own limited information even if this may involve occasional risks? And what should this limited information be? Should, in our example, a sales representative be constantly informed of the fluctuations in production cost, though not of the fluctuations in markets other than his own? Or could one leave him even without the cost information? Furthermore, each type of information can be used in a variety of ways, applying different rules of action. For example, if each salesman knows the production costs in both docks and has the power to accept or reject offers in ignorance of prices in markets other than his own, at what prices should he accept offers, so as to minimize the risk of forcing the firm into the use of the old dock at too small a profit or even at a loss?

In spite of its artificial simplicity our example may throw light on a fairly large class of practical problems. These arise whenever several decision makers share the same limited facilities, and the unit cost to the firm increases with output. Instead of two docks, one might think of several plants; or one can replace the "new dock" by "operations during the normal working day of the wage earners," and the "old dock" by "overtime work at extra pay." Also, instead of "local prices" one might think, for products like bread, of "expected local demand" (as is the case with the sales organization of bakeries, a problem that has been studied by C. B. McGuire at the Cowles Foundation, Yale University, and that has in part suggested the example I use here). Thus, many aspects of our "shipyard" example carry over into other fields. \*

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\* In collaboration with Roy Radner, now at the University of California, the author has attempted to classify various models of teams on the basis of their mathematical properties. Such models are relevant to many aspects of business such as production, promotion of sales, speculation, etc. A book on the economic theory of teams is being prepared. See also the author's "Elements for a Theory of Teams" in Management Science, January 1955; and "Towards an Economic Theory of Organization and Information" in Decision Processes (Thrall, Coombs and Davis, editors), John Wiley and Sons, New York, 1954.

To return to our problem: We want to find, for each system of communications, optimal rule of action for each sales representative, i.e., that rule of action which results in the highest average profit attainable with this communication system. We may call this the maximum gross average profit. Deducting the communication cost (i.e., mainly the executives' salaries chargeable to communications) necessary to maintain the particular communication system one obtains the (maximum) net average profit of the organizational form that is characterized by the communication system and by the best rules of action appropriate to it.

If, for example, the average profit of a "centralized" decision system is only slightly higher than that of some "decentralized" system (assuming that the appropriate optimal rules of action are used in each case) then the centralized system will have to be rejected, unless the added communication costs that it requires are also slight.

To illustrate, assume that the operational costs in the two docks (20 and 35 respectively) are constant; it is only the prices offered that vary. To figure out in advance the best rules of action, one needs to have an idea of the likely price situations. For simplicity, assume that the prices in the two markets obey the law of chance given in Figure 2. That is, with probability .4 both prices are high; with probability .4 they are both low; with probability .1 the Eastern price is high and the Western low; finally, with probability .1 the price is high in the West and low in the East. (Thus markets are supposed to be more likely to move in the same than in opposite directions). We have further supposed that while the average price is the same ( $= 30$ ) in both markets, the Eastern price jumps more violently: from the "low" of 21 to the "high" of 39; whereas the Western "low" is 29 and its "high" is 31 (no intermediate prices in any market; this simplifies the arithmetic).

EAST

	High (=39)	Low (=21)	Total probability
High (=31)	.4	.1	.5
<u>WEST</u> Low (=29)	.1	.4	.5
Total probability	.5	.5	1.0

	Average price	Price spread
East	30	18
West	30	2

Correlation coefficient = .6

Figure 2. Probability distribution of prices  
offered in two markets

Under the centralized system the head office will clearly choose the following rule as optimal: a ship will be built in the new dock, for the Eastern client if his price is high, for the Western client if the Eastern price is low; the old dock will lay idle (at least as long as the assumed costs remain unchanged). This rule and the resulting profits are shown thus:

Prices:		Offer		
East	West	accepted	Profit	Probability
39	31	East	39 - 20 = 19	.4
39	29	East	39 - 20 = 19	.1
21	31	West	31 - 20 = 11	.1
21	29	West	29 - 20 = 9	.4

Average Profit: 14.2

Figure 3. Optimal decision rule in a centralized firm.

The average profit =  $(19) (.4) + (19) (.1) + (11) (.1) + (9) (.4) = 14.2$

It is easy to see that any other rule, under a centralized system, will yield a lower average profit.

Now, assuming the same cost and price conditions, consider the following form of a "decentralized" system: each sales representative accepts or rejects local offers in ignorance of the price in the other market. Clearly there are four possible rules for each sales representative: (1) accept only if the price offered to you is high; (2) accept only if that price is low (a paradoxical yet reasonable rule, as we shall see!); (3) accept at either price; (4) never accept - i.e., go fishing. Hence there are  $4 \times 4 = 16$  possible pairs of rules for the pair of salesmen. For each pair of rules one can compute, as before, the average profit.

It may seem a paradox, but the following pair of rules turns out to be optimal: the Eastern salesman should accept offers at the high price only; but the Westerner should accept offers at the low price only. With these rules, the average profit is  $(19) (.4) + (13) (.1) + (0) (.1) + (9) (.4) = 12.5$ , computed as follows:

Prices:		Offer accepted	Profit	Probability
East	West			
39	31	East	$39 - 20 = 19$	.4
39	29	East and West	$39 + 29 - 35 - 20 = 13$	.1
21	31	None	0	.1
21	29	West	$29 - 20 = 9$	.4
			Average profit:	12.5

Figure 4. Optimal decision rule in a decentralized firm.

Similar computations show that the next best pair of rules is for the Easterner to accept at high price only and for the Westerner to accept in any case (average profit = 12). The rule that ranks third (with average profit = 10) is: either the East or the West agency should close shop, the other should accept offer at any price. The ranking of such rules would turn out to be a different one if I had not purposely chosen numbers that lead to a "paradox" - i.e., to a correct solution that may not seem right at the first sight. It serves to illustrate the need for some formal thinking and reckoning. The solution becomes plausible if you remember that under our assumption a low Western price of 29 is likely (with odds as high as 4 : 1) to be accompanied by a still lower Eastern price of 21; while a high Western price of 31 is likely (with high odds again) to be accompanied by a still higher Eastern price of 39. This justifies, on the average, the Westerner's acceptance of a low-price offer, and his rejection of a high-price offer, to diminish the risk of forcing the firm into using the second, inefficient dock at a loss.



We thus find that the "decentralized" system (as defined) yields, under the best rules, an average profit that is 1.7 ( = 14.2 - 12.5) below the highest average profit attainable under the "centralized" system. Therefore, if the additional communication cost implied in the centralized system exceeds 1.7, we shall reject it; if it is less than 1.7, we accept centralization.

The answer to every problem depends on the "givens" of the problem. In every team problem, the "givens" are: (1) the "payoff function" i.e., the formula that shows how profit depends on the decision (in our case the decision to accept or reject an offer) and on the external states (in our case the two prices): as shown, for example, in the "profit" column of my two tables; (2) the probabilities function which states the probabilities with which the various possible external states are likely to occur; and (3) the organization cost function which attaches a cost to each of the organizational forms under consideration.

With regard to the payoff function, one can say, in general, that more communication is justified when the payoff function involves "complementarity" between the members' actions, in the following sense: the effect of one member's actions, depends on what his colleague is doing. This was certainly so in our example, because of the high production cost in the old dock. If the two docks were equally efficient the need for communication and, hence, the advantage of centralization would be smaller. There is a high complementarity, and therefore strong need for communication, among the station-masters of a railroad; but, I presume, little complementarity between the branch managers of Sears Roebuck.

Another property of the payoff function which, if present, calls for communication is the existence of "multiple optima." It is equally good for all to ride on the right side, or for all to ride on the left side of the road (as they do in England); but someone has to play the role of a coordinator. Time-schedules for group work are often of the same nature; we needed an organizer to have all participants of this symposium to come to this place at this time, although some other place and time might be equally good.

In our case, I had mentioned a pair of rules of action under which one of the two salesmen - regardless which - should always accept offers (at least as long as production costs remained as they were) while the other should not accept any. This pair of rules ranked third but it would become an optimal one under different numerical assumptions. But then there would be actually two pairs of rules to choose among: either the Westerner or the Easterner should be the one always to accept offers. Thus a coordinator is needed because there are two equally good solutions.

We have also seen how the probability distribution of non-controlled events (prices, in our case) affects the solution. Our "paradoxical" solution was due to a high correlation between the two prices and to the fact that one of them had a higher range of variation than the other. Common sense can add a few more guesses about the way in which the nature of the probability distribution affects the choice between various forms of communication. I am willing to pay a lot for information on future prices of stocks, not of bonds; for the higher the variability of a thing the more useful it is to learn about its state. Further, I am not willing to pay much for special information about the price of a stock if it is strongly correlated with some other price, which I know anyhow.

To obtain other useful theorems about the way in which the payoff function and the probability distribution may affect the ranking of various organizational forms, one has to dig deeper, gathering factual knowledge about live organizations (see my earlier remarks on the deficiency of mere "organization charts") and interpreting it logically and mathematically.

One important gap has to be closed: our ignorance of the communication costs. We need measurements of the executives' efficiency in using their time - a subject on which, I think, psychologists are working. What we need is something corresponding to, but more appropriate than the I.Q., we need a special "E.Q." (executive quotient). The I.Q. scale is essentially nothing but the statistical distribution of a large sample of American children with respect to their performance of certain tasks. For example, "I.Q. = 100" is a set of tasks that 50 per cent of all children can perform (the "median" performance). We need, similarly, a statistical distribution of American executive abilities, as measured by performance truly relevant to efficient communication and decision making.

On Figure 5, the three given functions - the probability function, the payoff function, and the organizational cost function are represented by boxes: they are "operators"; transforming "inputs" into "outputs" as indicated by arrows. Those three functions, or operators, are given; that is, they are not controlled by the organizer. But two other operators (boxes) - the information rule and the action rule - are chosen by him, rather than given to him; and the investigator can compare them with other rules for greater or smaller efficiency. Each input or output is an element of some set, represented by a circle. For example, a particular "external state" is operated upon in three places: together with a particular "action,"

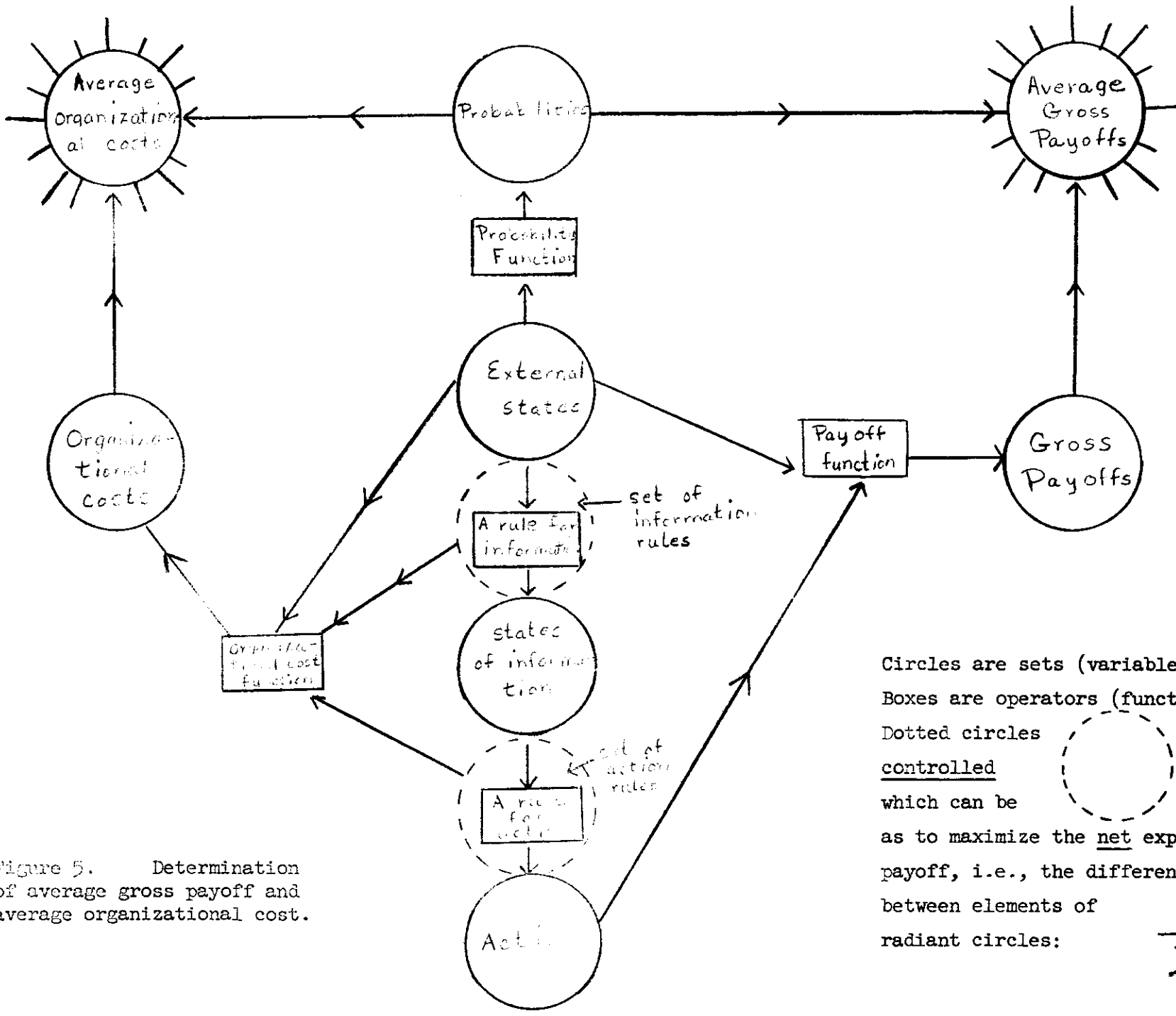


Figure 5. Determination of average gross payoff and average organizational cost.

it determines the particular gross payoff, depending on the payoff function; second the external state has its probability, depending on the given probability function; third, depending on the chosen information rule, the external state will result in a given state of information. The information rule and the action rule can be chosen each out of a set of such rules - represented by dotted circles (thus the two boxes drawn are only typical of other elements of the sets of possible rules of action and information). The two rules are chosen so as to make the net average payoff as high as possible; it is the difference between average gross payoff and average organizational cost; the circles representing these two variables (sets) are distinguished by an aura to emphasize that they are "goal" variables, in light of which the efficiency of rules is judged.

There is no need, in a group like yours, to expand on the differences between a "model" and the "reality," and on the usefulness of models for both understanding and improving practical solutions. My "shipyard" model is easily made more realistic and more complicated. Its solutions would then transgress simple arithmetic, needed for a presentation like this one, and call for more powerful mathematics and machines. (In fact, the "bakery" problem mentioned above turns out to be one in linear programming). Even then, the main service one can expect from organization models is to clarify the general logical lines of a practical problem. This clears the ground for the more subtle aspects of the practical problem that escape formalization and call for so-called intuition judgment. Even the best biochemist will not replace a good restaurant chef. Yet biochemical analysis, has, in fact, improved our food.