ITERATIVE COMPUTER SIMULATION AS AN AID TO SYSTEMS DESIGN AND COST EFFECTIVENESS ANALYSIS

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COST EFFECTIVENESS RANKING OF ALTERNATIVES

Traditionally, in the design of a major system, product, or procedure, various cost effectiveness analysis techniques have been employed in order to choose the best from a set of alternative configurations. In choosing the best design, it is first necessary to divide the set of alternatives into acceptable and unacceptable members. Figure 1 presents those alternatives making up the set of acceptable alternatives which forms a boundary below and to the right of which no unacceptable alternative may be found. Consideration of a great number of alternatives finds more points included in this acceptable set and thereby the boundary smooths into a curve, possibly of the type shown in Figure 2.

The acceptable set of alternatives comprised of those points which lie on or near the boundary is further reduced in the face of additional known constraints. For example, if a bidder proposes alternatives to a customer whose maximum expenditure may not exceed the value $\$_{max}$, the bidder presents the customer with a choice of alternatives A, B, and C as shown by Figure 3. Likewise, if a minimum level of effectiveness E_{min} is required and known by the bidder, he submits only alternatives F and G for consideration. This is depicted in Figure 4. A third type of known constraint reducing the set of acceptable alternatives arises from the customer's desire to minimize the cost per unit of effectiveness of the purchased product or system. Figure 5 shows this minimum as θ_{min} and indicates alternative D as the most acceptable alternative under this condition.

SIMULATION METHOD OF ANALYSIS

Methods of accurately determining the likely cost of an alternative, as well as its probable effectiveness level, are required in order to perform the analysis discussed in the previous section of this paper. In some cases, a strict accounting approach may give an accurate enough description of the likely cost of a given alternative, while a mathematical model or optimization process of some nature may closely describe its level of effectiveness. In most cases, however, such approaches fall short in their attempts to accurately describe these aspects of given alternatives which are of any degree of sophistication. In such cases, computer simulation has proven to be extremely valuable.

A variety of computer simulation languages have been utilized by many types of firms. One of the most successful of these languages is the General Purpose Simulation System (GPSS) initially developed by International Business Machines Corporation. It has generally been the case, as is borne out by those who have written of their use of GPSS, that the application of this language facilitates the understanding of major systems to be simulated and the quickness with which the simulation's user can construct, validate, operate, and gain the required results from his model. Proceeding on this basis, that the user of a simulation technique should be acutely critical of its contribution to understandability and response as well as its accuracy, the extended use of simulation as discussed in the following pages will be presented in relation to the GPSS language.

EXTENDING THE USE OF SIMULATION

This section of the paper advocates an extension of the simulation procedures, previously discussed, which today are primarily concerned with predicting the cost or level of effectiveness required for a classification of alternatives. The simulation approach to be presented here not only evaluates given alternatives in terms of their cost effectiveness characteristics, but allows the iterative evolution of superior alternatives as well.

Two working simulation models, both written in the General Purpose Simulation System (GPSS) language, support this "design and analysis for choice" effort. The approach followed in developing both models requires three essential elements. These elements are:

- An initial system configuration.
- Units of measure for cost effectiveness.
- A learning rule supporting the iterative evolution of alternatives.

AIRCRAFT MAINTAINABILITY MODEL

The first model, depicted in Figure 6, is concerned with maintaining and operating a complement of military aircraft. As mission requirements occur, these aircraft experience preflight inspection, launch, various mission-peculiar activities, postflight inspection, and return to state of readiness. Failures may occur during any of these stages, depending on mission type, and may be critical or noncritical in terms of rendering the aircraft incapable of carrying out its mission. These failures create maintenance demands upon several resources whose levels are determined by the system configuration.

The learning rule used in the aircraft maintainability model reallocates resource levels and hence "maintenance dollars expended" in such a way that the level of effectiveness increases for the new system. Resources which have low utilization or little queuing are decreased, while corresponding increases are made to those resources which are highly utilized and experience much queuing. This increases the efficiency of resource utilization, results in increased aircraft readiness, and improves the effectiveness of the system at approximately the same cost.

Figure 7 shows the results of running the aircraft maintainability model with several initial system configurations: A, B, C, D, and E. The final system designs represented by points P, Q, R, S, and T form the acceptable set as discussed earlier.

ASSEMBLY LINE MODEL

The second model, shown in Figure 8, represents the equipment in a production assembly line together with the policies regarding its operation. Parts flow through the line and are transformed into a final product while various equipment within the line experiences random failures. Preventive maintenance action serves to increase the average time between failures and thus the productivity of the line.

The learning rule used in the assembly line model allocates preventive maintenance action to those machines whose failures contribute most to reduced productivity in the line. Those machines which have large processing queues, thus not meeting their productivity requirements, are singled out for additional preventive maintenance action.

Figure 9 shows the results of running the assembly line model beginning with initial system configuration A with no preventive maintenance as discussed. The use of the learning rule is slightly different in this case, in that the objective is to minimize the per unit variable costs of production. This corresponds to finding the minimal angle or slope θ_{min} as discussed earlier. The final system designed in this manner is represented by point B in Figure 9.

CONCLUSION

In both of the models presented, the approach is to extend the use of simulation to more than a mere analysis of a given complex system operating according to no purely mathematical rules. Rather, the approach is to incorporate within the simulation procedure a heuristic capability facilitating the evolution of a better alternative system. This capability allows an iterative process to analyze alternative configurations developed without analyst intervention and to present a system or group of systems comprising the acceptable set of alternatives.

The advantages of such an incorporation are quite obvious. They are essentially the same as those realized by using other iterative techniques of a more mathematical or optimizing nature. That is, such approaches save considerable time and effort and lead to a better solution. And this is, after all, precisely what is desired when systems design is undertaken with a cost effectiveness constraint.

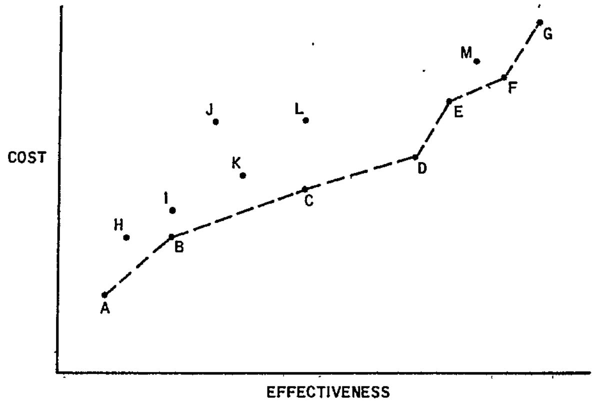

FIG 1 ACCEPTABLE AND UNACCEPTABLE ALTERNATIVES

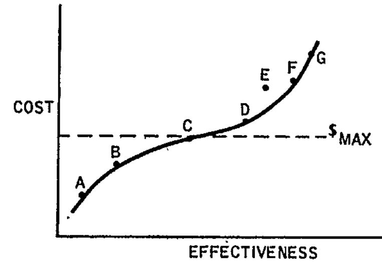

FIG 3

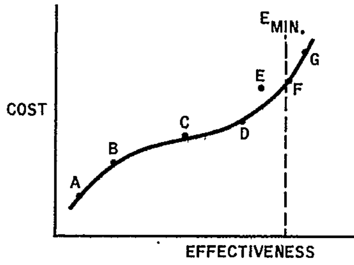

FIG 4

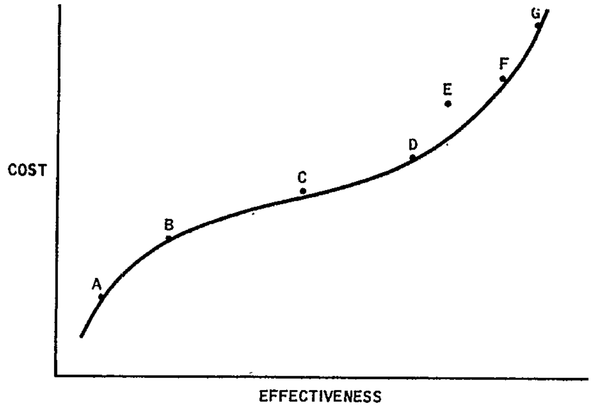

FIG 2 BOUNDARY FORMED BY ACCEPTABLE ALTERNATIVES

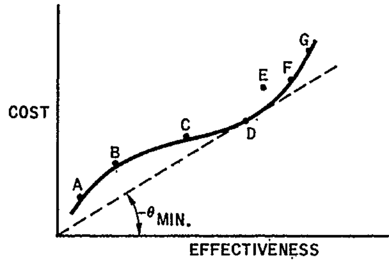

FIG 5

ADDITIONAL CONSTRAINTS REDUCING ACCEPTABLE SET OF ALTERNATIVES

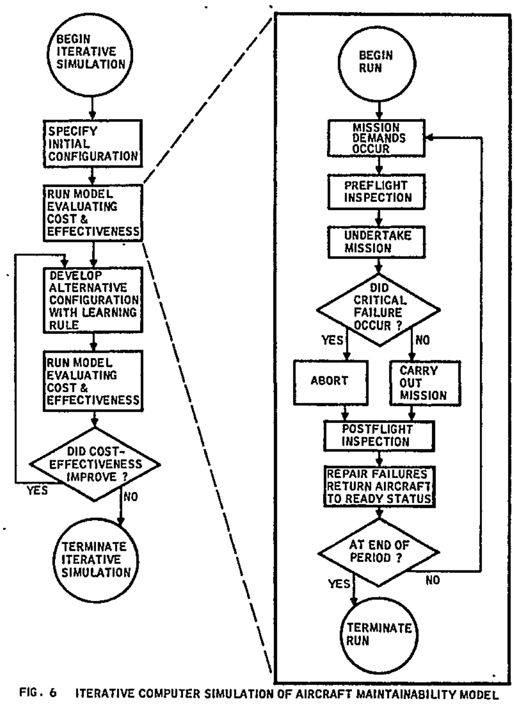

FIG. 6 ITERATIVE COMPUTER SIMULATION OF AIRCRAFT MAINTAINABILITY MODEL

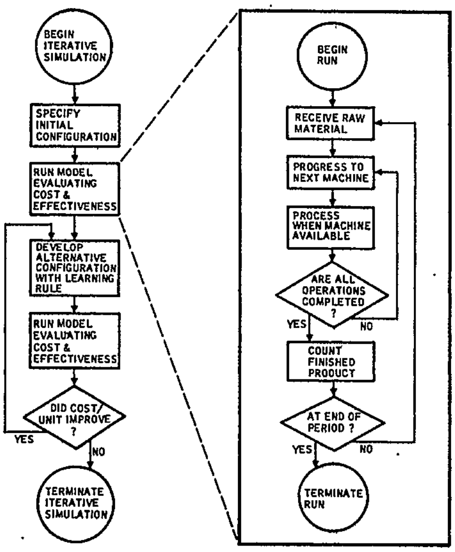

FIG 8 ITERATIVE COMPUTER SIMULATION OF ASSEMBLY LINE MODEL

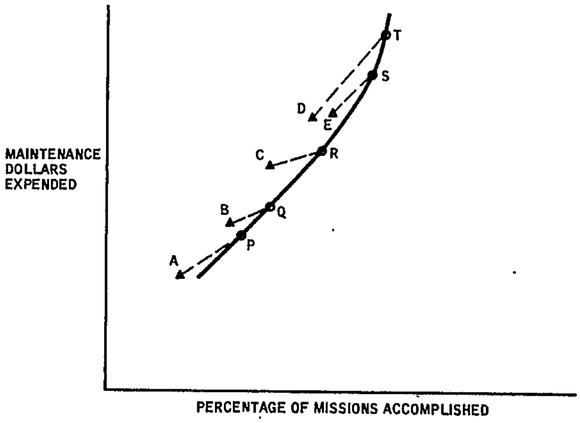

FIG 7 RESULTS FROM ITERATIVE COMPUTER SIMULATION OF AIRCRAFT MAINTAINABILITY MODEL

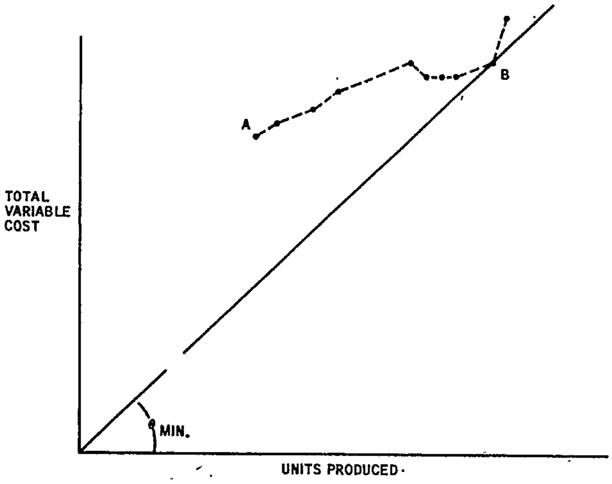

FIG 9 RESULTS FROM ITERATIVE COMPUTER MODEL SIMULATION OF ASSEMBLY LINE