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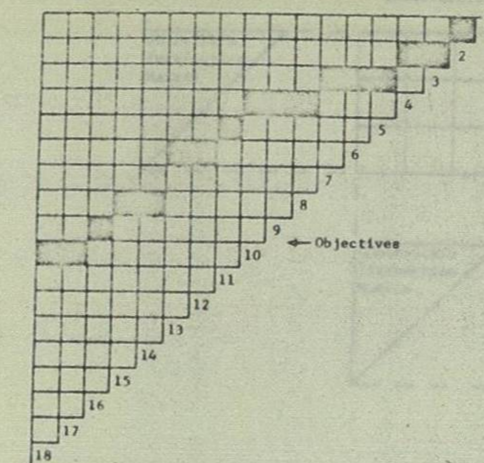

Fig. 6. Objectives self-interaction matrix corresponding to objectives tree shown in Fig. 5.

interaction matrix method of portrayal is not as clear as the objectives tree for viewing the relationships among objectives, but it incorporates significant advantages in relating objectives to constraints, alterables, and needs. The method suggested for portraying these relationships is the use of cross-interaction matrices as depicted in Fig. 7. This figure relates objectives to needs; to alterables, which can be modified to bring about attainment of the objectives; and to constraints, within which the objectives must be attained. In one concise figure, a complete outline of a rationale to support the objectives and a great deal of information needed to plan a program for attaining them appears.

A particular advantage of the method shown in Fig. 7 is the ease with which the interaction of the objectives can be traced through the needs back to the societal sectors with which the objectives interact. If the interactions are categorized as either significant or insignificant (i.e., binary), then a simple Boolean multiplication of the objectives × needs interaction matrix with the needs × societal sectors interaction matrix will result in an objectives × societal sectors interaction matrix.

The Boolean multiplication of cross-interaction matrices can be extended to the mathematical generation of some of the matrices shown in Fig. 7. For example, if the four cross-interaction matrices that lie closest to the self-interaction matrices were filled in by hand, the three remaining cross-interaction matrices shown in Fig. 7 could be generated mathematically. Such a formal procedure has considerable merit. Without it, one tends to end up with a set of cross-interaction matrices which are not mutually consistent and it is not always easy to spot the inconsistencies. Checking of logic is especially useful when the matrices form a loop as will be discussed later in relation to an example.

The need for defining a set of measures on the objectives by which to determine their attainment is an important concern in program planning. Too often, people define objectives without thought as to how they will measure their accomplishment. Upon examination of the objectives tree, one usually finds that some of the objectives are axiological (rooted in value judgments), while others are not. The axiological objectives usually lie at the top of the objectives tree. An example of such an objective is: "to improve the public schools." The word "improve" makes this objective axiological in nature, since whether this objective is attained or not is a matter of subjective opinion or value judgment. A nonaxiological objective is one like "to teach children to distinguish a Mozart composition from a Beethoven composition." The achievement of this objective is determinable, and not a matter of opinion as to whether the children can or cannot make the distinction. The axiological objectives serve an inspirational purpose, but the nonaxiological objectives are more useful in planning because they are more readily converted into planned activities.

One may examine the objectives tree to see which objectives are measurable, and how they may be measured. For the musical objective mentioned above, the measure is the agreement between the child's answer and the correct answer. The determination as to whether the public schools have been improved is vastly more difficult to make, and such an objective is virtually immeasurable within any reasonable cost. However, the attainment of lower level objectives that are contributory to that one may suggest that progress is being made.

For example, it should be possible to measure the attainment of an objective such as, "To improve the method of teaching reading to sixth graders to the extent that at least 70 percent of the students exceed the fiftieth percentile performance on a standardized sixth-grade reading achievement test." The corresponding objective measure could be "Percent of sixth-grade students, whose performance exceeds the fiftieth percentile performance on a standardized sixth-grade reading achievement test."

The total process of measurement involves more than just the selection of the measure or unit by which the attainment of objectives will be assessed. Often, as in the above example, a threshold for judging acceptable performance can be defined and built into the objective and objective measure. The balance of the process of measurement includes planning for how the data required for evaluation are to be *sensed* and how they are to be analyzed to generate an *indication* on the selected measurement scale. In the above example, planning for the sensing function would involve selection of the achievement test, planning when, to which students, and under what conditions the test would be administered and planning for how the resulting tests would be interfaced with the test-scoring activity. Planning the indicator function would involve selection of procedures for analyzing the test scores and reducing them to standard achievement scores in a timely and efficient manner.

Thus the planning of objectives and objectives measures is tightly interwoven with the process of determining how the measures are to be obtained, i.e., how the data are to be sensed, and how the indication on the scale of measurement is to be attained.

The measures of objectives may be conveniently related to the objectives through the use of a cross-interaction matrix as indicated in Fig. 8. Measures 1 and 2 relate to the attainment of objective 6; measure 3 to the attainment of

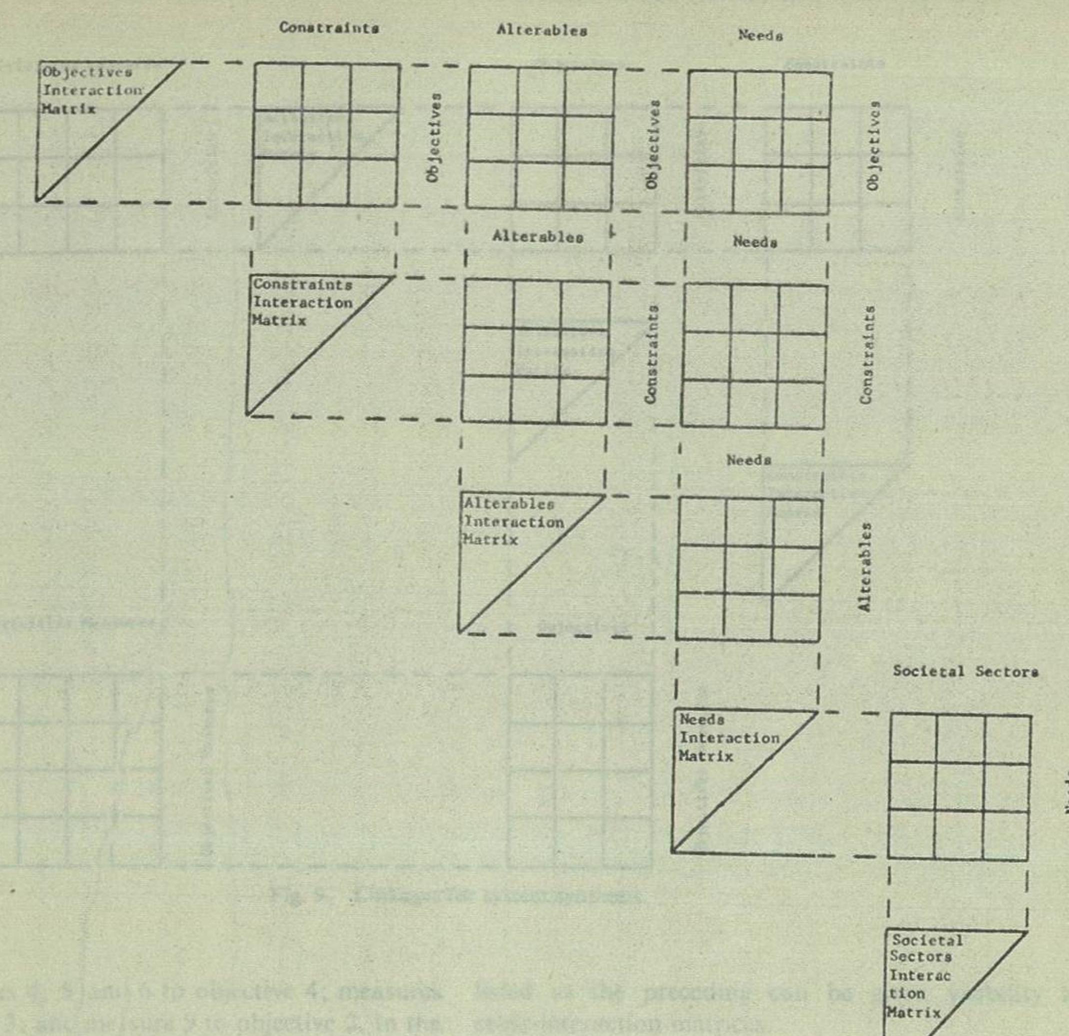

Fig. 7. Interaction of objectives with constraints, alterables, needs, and societal sectors.

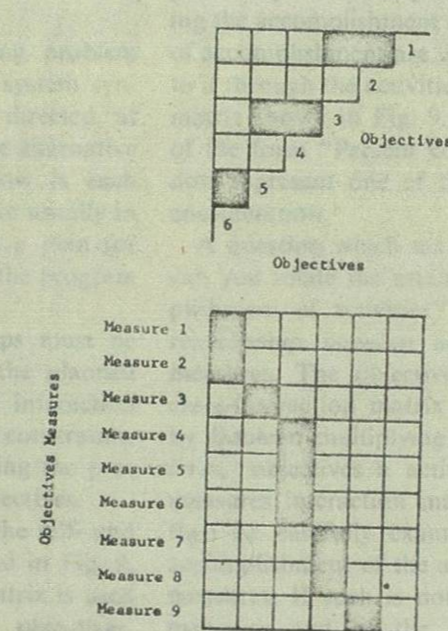

Fig. 8. Relating objectives measures to objectives.

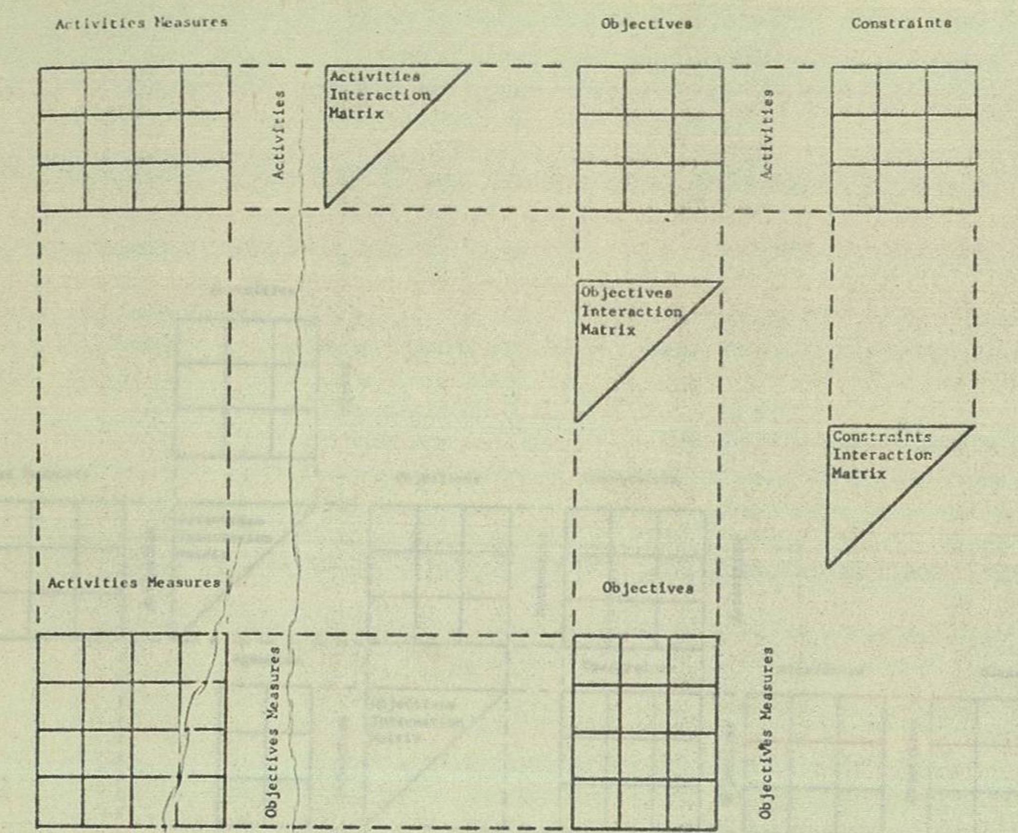

Fig. 9. Linkages for system synthesis.

objective 5; measures 4, 5 and 6 to objective 4; measures and 8 to objective 3; and measure 9 to objective 2. In the example, no measure relates to objective 1, the assumption being that the highest level objective, in this case, is not directly measurable.

System Synthesis Linkages

Hall's matrix, Fig. 1, shows that following problem definition and value system design comes the system synthesis step. System synthesis activities are directed at answering the following questions. What are the alternative approaches for attaining each objective? How is each alternative approach described? The answers are usually in the form of a series of activities which form a plan for evaluating alternative approaches for attaining the program objectives.

Three major linkages to the preceding steps must be given visibility. 1) The relationship between the planned activities and the program objectives. 2) The interaction between the planned activities and the program constraints. 3) The measurement system required for relating the progress on the activities to the attainment of objectives.

Again, when faced with a linkage problem, the self- and cross-interaction matrices are used as illustrated in Fig. 9. The activities × objectives cross-interaction matrix is used to relate the proposed activities to specific objectives. Similarly, the interactions of the constraints with the activities are illustrated by the activities × constraints interaction matrix. Thus the first two of the major linkages listed in the preceding can be given visibility through cross-interaction matrices.

Next, the measurement of progress on activities is related to progress on attainment of the program objectives. Development of a set of objectives measures was discussed previously. An analogous procedure is followed in measuring the accomplishment of activities. One or more measures of accomplishment are defined for each activity and related to it through the activities × activities measures interaction matrix shown in Fig. 9. Often, the activities measures are of the form "Percent completion of ···" where the three dots represent one of the products of the activity under consideration.

A question which management is likely to ask is "How can you relate the attainment of objectives to the accomplishment of activities?" One method is to examine the relationship between activities measures and objectives measures. The objectives measures × activities measures cross-interaction matrix can be generated mathematically by Boolean multiplying the objectives measures × objectives, objectives × activities, and activities × activities measures interaction matrices. The resulting matrix must then be carefully examined to ensure that measures of accomplishment of the activities do relate to the objectives measures. If such is not the case, a reexamination of all measures and of the activities × objectives interaction matrix must be made. Either the matrix must be changed or the measures redefined so the activities measures relate to the attainment of objectives.

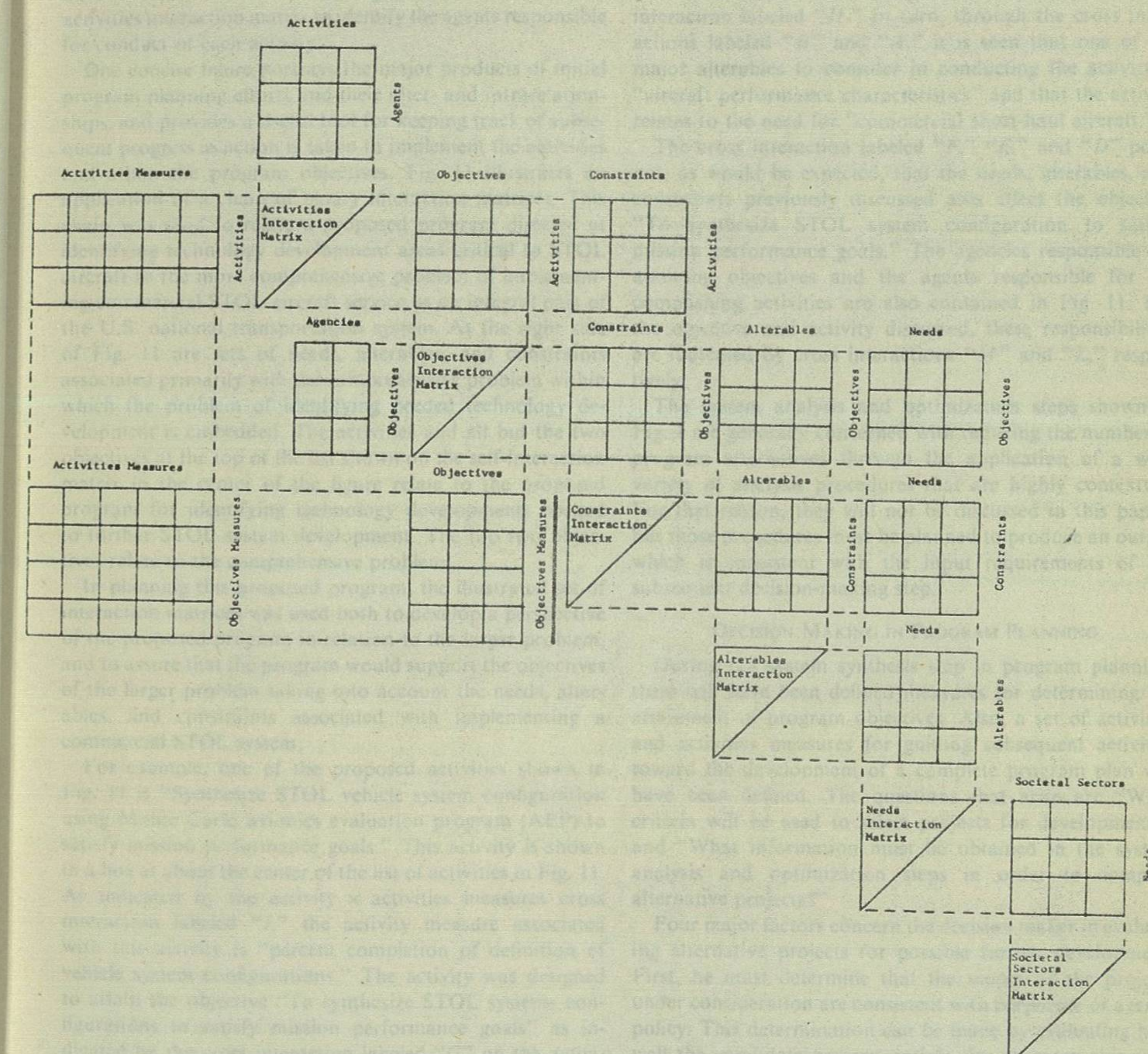

Fig. 10. Program planning linkages.

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To this point, a series of related linkages for the problem definition, value system design, and system synthesis steps of program planning has been discussed. An overall view of a program as planned at the end of the system synthesis step is obtained by combining Figs. 7 and 9 as in Fig. 10. Added to Fig. 10 is an objectives × agencies interaction matrix to portray which government or industrial groups have an interest in the defined objectives and an agents × activities interaction matrix to identify the agents responsible for conduct of each activity.

One concise figure portrays the major products of initial program planning efforts and their inter- and intrarelationships, and provides a useful tool for keeping track of subsequent progress as action is taken to implement the activities and attain the program objectives. Fig. 11 illustrates an application of a chain of binary interaction matrices. This chain was used to relate a proposed program directed at identifying technology development areas critical to STOL aircraft to the more comprehensive problem of implementing commercial STOL aircraft service as an integral part of the U.S. national transportation system. At the right side of Fig. 11 are sets of needs, alterables, and constraints associated primarily with the comprehensive problem within which the problem of identifying needed technology development is embedded. The activities and all but the two objectives at the top of the list shown on the self-interaction matrix in the center of the figure relate to the proposed program for identifying technology developments needed to further STOL system development. The top two objectives relate to the comprehensive problem.

In planning this proposed program, the illustrated set of interaction matrices was used both to develop a perspective of the proposed program in relation to the larger problem, and to assure that the program would support the objectives of the larger problem taking into account the needs, alterables, and constraints associated with implementing a commercial STOL system.

For example, one of the proposed activities shown in Fig. 11 is "Synthesize STOL vehicle system configuration using Monte Carlo avionics evaluation program (AEP) to satisfy mission performance goals." This activity is shown in a box at about the center of the list of activities in Fig. 11. As indicated by the activity × activities measures cross interaction labeled "*I*," the activity measure associated with this activity is "percent completion of definition of vehicle system configurations." The activity was designed to attain the objective "To synthesize STOL systems configurations to satisfy mission performance goals" as indicated by the cross interaction labeled "*G*" on the activities × objectives cross-interaction matrix.

By following around the loop of interaction matrices at the left side of Fig. 11, one sees that the interaction labeled "*J*" in the objectives measures × activities measures cross-interaction matrix relates the activity measure to the objective measure "percent completion of mission performance goals definition" which, through interaction *K*, is related to the objective mentioned above. In this way, the activity and its measure of accomplishment is tightly connected to the attainment of a corresponding objective or objectives and their measures of attainment.

One can also see from Fig. 11 how the proposed activities relate to the more comprehensive problem. For example, the aforementioned activity must take into account the constraint "system operating costs" since it is directly related to that constraint by the activities × constraint interaction labeled "*H*." In turn, through the cross interactions labeled "*B*" and "*A*," it is seen that one of the major alterables to consider in conducting the activity is "aircraft performance characteristics" and that the activity relates to the need for "commercial short-haul aircraft."

The cross interaction labeled "*F*," "*E*," and "*D*" point out, as would be expected, that the needs, alterables, and constraints previously discussed also affect the objective "To synthesize STOL system configuration to satisfy mission performance goals." The agencies responsible for attaining objectives and the agents responsible for accomplishing activities are also contained in Fig. 11. For the objective and activity discussed, these responsibilities are indicated by cross interactions "*M*" and "*L*," respectively.

The system analysis and optimization steps shown in Fig. 1 are generally concerned with reducing the number of program alternatives through the application of a wide variety of analysis procedures that are highly contextual. For that reason, they will not be discussed in this paper; but those procedures must be planned to produce an output which is consistent with the input requirements of the subsequent decision-making step.

Decision Making in Program Planning

During the system synthesis step in program planning, there will have been defined measures for determining the attainment of program objectives. Also, a set of activities and activities measures for guiding subsequent activities toward the development of a complete program plan will have been defined. The questions that arise are "What criteria will be used to select projects for development?" and "What information must be obtained in the system analysis and optimization steps in order to compare alternative projects?"

Four major factors concern the decision maker in evaluating alternative projects for possible further development. First, he must determine that the scopes of the projects under consideration are consistent with corporate or agency policy. This determination can be made by evaluating how well the candidate projects satisfy the program objectives which are assumed to be in consonance with corporate or agency policy. (A program whose scope is not consistent with corporate or agency policy would be rejected on the basis of this alone.) Those projects that pass this initial screening are then rated in terms of the remaining three factors discussed below.

The second major factor is the comparative economics of the alternative projects. The analysis should look at the