UNDERSTANDING DELTA CHARTS

by

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INTRODUCTION

In presenting various system methodologies, we use a type of graphical representation that applies to describing each of them: the DELTA chart. Supplemented by verbal descriptions, a DELTA chart for each methodology captures that methodology in a combined graphical and verbal map.

The purpose of this paper is to explain thoroughly the DELTA chart terminology and use.

The term DELTA is an acronym for the following:

- Decision
- Event
- Logic
- Time
- Activity

The members of this list are the major ingredients of a DELTA chart, as will be explained in the following. Before examining the ingredients in detail, an overview of DELTA charts will be given.

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OVERVIEW OF DELTA CHARTS

Every methodology is characterized by at least one sequence of activities. It is often true that several sequences are possible, depending on which of several intermediate choices is made by the user as the sequence evolves. Also certain events may occur in the sequence, which are worth spelling out. The DELTA chart allows one to portray sequences that involve a mix of activities, decisions, and events. It also incorporates some other flexibilities that will become clear as the description evolves. The carrying out of the sequences amounts to following the methodology to its logical conclusion. Thus a DELTA chart can be viewed as a prescription for action. In a sense, a DELTA chart is like a recipe (which is also a prescription for action), but unlike a recipe a DELTA chart may include decision points where different courses of action are followed depending on the choice of the user. Some of the advantages to users of DELTA charts include:

- Common Language. Once the user masters the DELTA chart language and format, the user will be able to read with facility all of the graphical methodology descriptions, and won't have to learn a new format every time another methodology is discussed.
- Compact Description. Once the user learns a methodology, the DELTA chart can serve as a compact reminder and descriptor of the methodology, and this

description can be hung on a wall, or used in a notebook in a flexible way. Also it can be a teaching aid.

- Clarity of Sequencing. In contrast to a strictly verbal description of a methodology, wherein long sequences are hard to present and hard to remember (especially when there are options in the sequences), the DELTA charts show clearly most or all of the sequencing involved in using the methodologies, and thus lend a clarity that is very hard to get without the graphical language.

COMPARISON OF THE DELTA CHART WITH THE ENGLISH LANGUAGE

The DELTA chart can be thought of as a new language, a graphical language. It can be compared with English as follows. The English language is made up of building blocks such as nouns, verbs, pronouns, adverbs, adjectives, etc., while the graphical language includes the English expressions together with boxes that represent decisions, events, logic, and activities. Also the graphical language includes directed lines representing time precedence, and includes ending symbols that show the end of a sequence.

In order to understand how sentences are put together in English, one learns to distinguish the building blocks and how they are related.

Likewise, in order to understand how sequences are created using the graphical language, one learns to distinguish the various kinds of boxes from one another, how to read sequences represented by graphical paths, and how to interpret the meaning represented by a path.

Fortunately, it doesn't take nearly as long to learn the graphical language as it does to learn English. However, it does require some effort and practice. The reader who is willing to take the time to learn the DELTA chart terminology and use should find that the investment is amply repaid by the convenience of using the DELTA charts.

ELEMENTS, CONNECTIVES, AND CONTEXTUAL RELATION

The three main ingredients of DELTA charts are elements, connectives, and a contextual relation. The elements are of three types: decisions, events, and activities. There are two connectives: OR and AND. The contextual relation shows the order in which elements occur in time, and is designated as "time precedence." In this section the meaning of the letters in the DELTA acronym will be discussed as a way of showing how these relate to the ingredients just identified.

The D. The D in DELTA stands for decision. One wants to be able to portray on a chart the need for and nature of a particular decision, and (if known) who will make the decision.

The E. The E in DELTA stands for event. One wants to be able to portray on a chart an event that occurs when a methodology is used. Typically there will be a starting event that initiates the use of a particular methodology, intermediate events that occur during its application, and one or more ending events. Also the immediate consequence of a decision will be expressed as an event, of which there may be several associated with a given decision type.

The L. The L in DELTA stands for logic. The logic is expressed by the use of the connectives AND and OR. The use of the logic will be examined in dealing with specific examples.

The T. The T in DELTA stands for time, more specifically for time precedence. One wants to be able to portray the flow of time, not in specific time units, but rather in terms of time precedence. One needs to show what happens in what order, in order to describe the sequences that occur in using a methodology.

The A. The A in DELTA stands for activity. By an activity is meant something that is carried out over time in using a methodology. An activity has a beginning, an end, and a duration. Typically one must pay for an activity, so an activity often has a cost attached to it.

In order to portray these various ingredients effectively, we make use of some graphics principles.

GRAPHICS PRINCIPLES

Three graphics principles are applied to the extent possible in the DELTA chart concept. They are as follows:

- A different graphic symbol should be assigned to each distinct type of entry on a graphic chart, to help the reader make a visual discrimination among the different entries
- The symbols should be as easy to draw as possible, preferably using only straight lines
- The number of different kinds of symbols should be no more than seven, if possible

All of the DELTA chart symbols can be drawn with only straight lines, and the symbols are intended to be compatible with simple computer-drawn graphics programs. Each symbol is distinguished in some way from other types, but simplicity is the goal rather than elaborate means of discriminating.

PORTRAYING AN ACTIVITY

An activity is portrayed on a DELTA chart by a rectangular activity box, divided into an upper cell and a lower cell. The form of the box is shown in Figure 1.

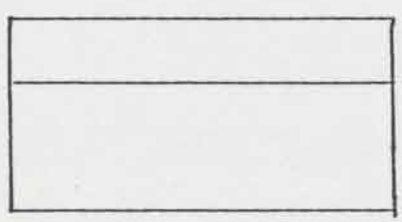

Figure 1. Activity Box

The lower cell of the activity box will contain a verbal description of the activity. The description will always be written so that an action word appears first. For example, if one is discussing carrying coals to Newcastle, an activity would appear as follows:

Carry coals to Newcastle

Note that the action word "carry" appears first. The presence of the action word at the beginning identifies the phrase as the description of an activity.

The upper cell of the activity box is sometimes left empty on a DELTA chart, but if it is, it is still shown to make sure that the box can be visually identified as an activity box. More frequently the upper cell contains the name or title of an "actor." An actor may be a person, a group, an organization, a specific kind of social role, or a collection of organizations. Whatever designation appears, it is intended that the actor be the one to carry out the activity.

Figure 2 shows an example of an activity box that is completely filled in. In this example, the actor is the Jones Moving Company

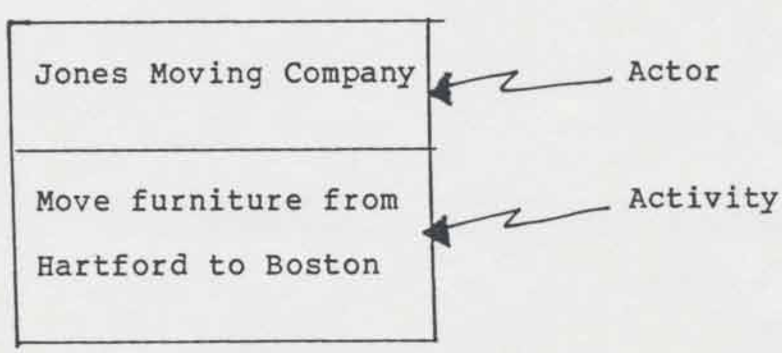

Figure 2. Filled-in Activity Box

and the activity is "Move furniture from Hartford to Boston." Note that the action word "move" appears first in the statement.

In planning for a future activity, sometimes one does not know who would carry out the activity. Figure 3 shows an activity box that does not carry the identification of an actor, but does leave space for it in anticipation that an actor can be identified in the future.

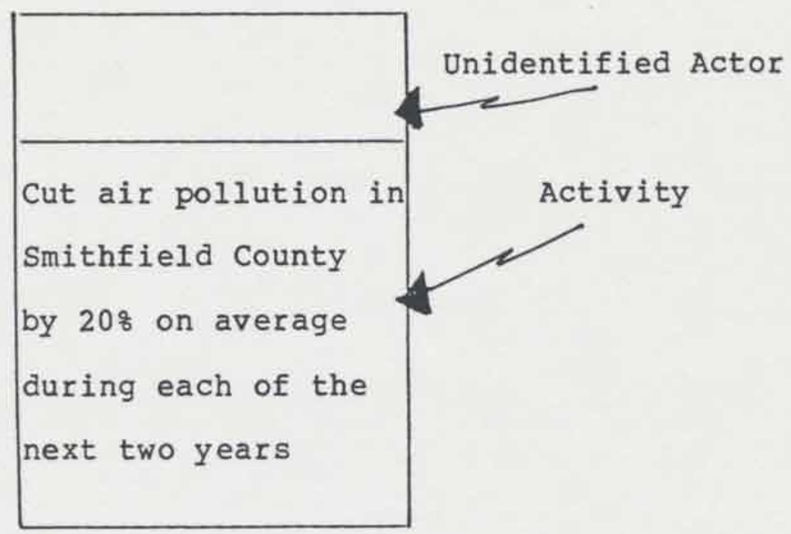

Figure 3. Activity Box with Blank Upper Cell

If a DELTA chart has been prepared that shows an actor in terms of some characteristic, e.g., "analyst", it may turn out later on that one can identify a particular person who can serve as an analyst, whereupon one might desire to put that person's name in the chart instead of the more general designation of analyst.

PORTRAYING TIME PRECEDENCE

Generally on DELTA charts, it is desired to show sequences, hence one portrays a time precedence relation graphically. The way this is done is simply to draw a straight line and put an arrow head on the line to show the flow of time. Figure 4 shows how the time arrow is used to portray that Activity 1 precedes Activity 2 in time.

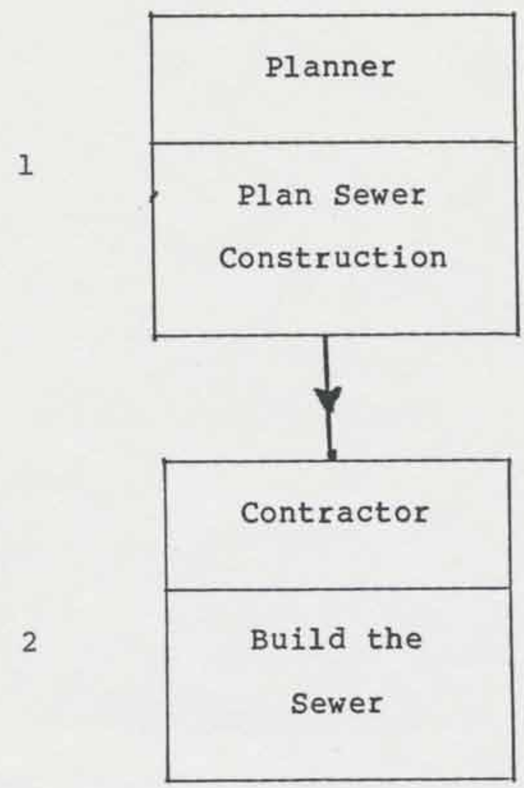

Figure 4. Showing Time Precedence

PORTRAYING AN EVENT

An event is an outcome, a result, a consequence, a happening, or in general, something that normally is considered to have occurred at some particular time. Unlike an activity which has a beginning, a duration, and an end, the event is specified as a point in time.

To show an event, an <u>event box</u> is used. It is simply a rectangle with a single cell. It is distinguished from an activity box, which has two cells.

In describing an event (or <u>writing</u> an event), the action word is intermediate, and the primary object appears first. In discussing coals and Newcastle, one might show an event thus:

Coals reach Newcastle

or alternatively one might say

Newcastle receives coal

Notice that the first word in the event statement is <u>not</u> a verb.

The distinction between activity and event by way of phrasing is particularly helpful when one has to deal with a large number of activities and events in a common context.

Now an example DELTA chart will be shown that portrays two activities and one event. Figure 5 builds on Figure 4 by adding an event to that chart.

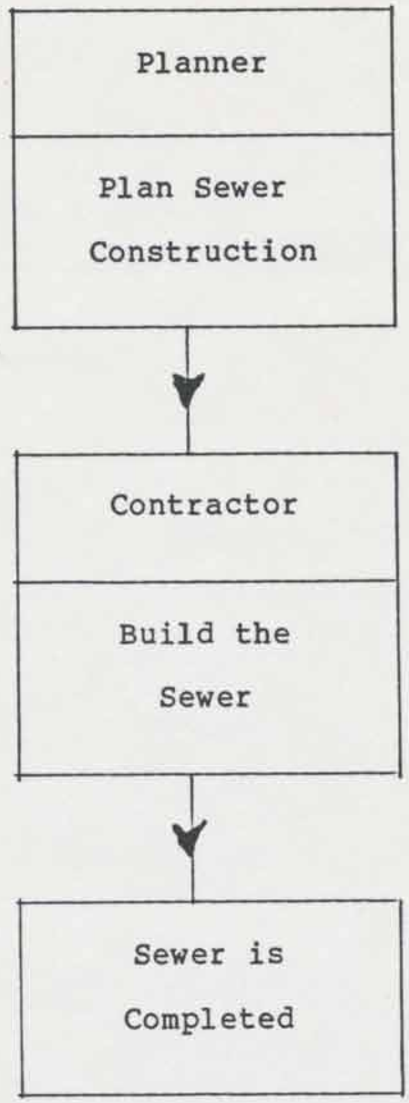

Figure 5. Example DELTA Chart Showing an Event

The event "Sewer is Completed" in Figure 5 comes about because of preceeding activities. Thus one might say that the event is produced by those activities.

Figure 5 illustrates again the time precedence relationship. First the sewer is planned, then it is built, and finally it is completed.

However the most important reason for including this symbol is to assure that errors in drafting do not suggest misleadingly that an event is a concluding event when it is not. Addition of the ground symbol is intended to help assure that concluding events are properly identified.

Initiating Event. Normally a DELTA chart sequence will begin with an initiating event. No special symbol is used for such an event. However such an event will not have any entering lines, and so it can be distinguished in that way. The initiating event will always appear either at the top or at the left of the DELTA chart. Unlike the concluding event, which may appear in several places, and thus requires special designation, the initiating event is detectable by position.

Consequence (Event). When a decision is made, the possible consequences are always formulated and portrayed as events in the DELTA chart terminology. Hence, for example, if there are three possible options associated with a decision, each of these three would be shown as an event.

In addition to the standardization this arbitrary requirement provides, it also permits rectangular portrayals to qualify for certain automatic computer programs for making highly-readable drawings.

PORTRAYING A DECISION

By a decision is meant a choice of one option from a set of two or more options. In some graphical portrayals, a diamond box is used to represent a decision. This portrayal has the advantage that it makes decisions stand out rather sharply from other kinds of boxes, but it has the disadvantages of placing artificial restrictions on the number of options that can be conveniently represented, as well as of requiring an unusual shape, from the point of view of drafting.

In the DELTA chart terminology, a decision will be represented by a rectangle with an interior vertical line parallel to and adjacent to each outer edge, as well as a cross line perpendicular to these. The cross line separates the decision box into an upper and lower portion. The upper portion will state who (an individual, organization, or combination) is expected to make the decision in a typical case, while the lower portion will state the nature of the decision to be made. In addition, following the decision box, there will be event boxes, each of which will show one possible consequence of the decision.

Figure 7 illustrates these points by showing a decision box arrayed for 3 possible options, as indicated by the three outgoing lines, each of which connects directly to an event box. Each event box will contain one consequence of the decision, but one keeps in mind that when the decision is made only one of the consequences will be elected.

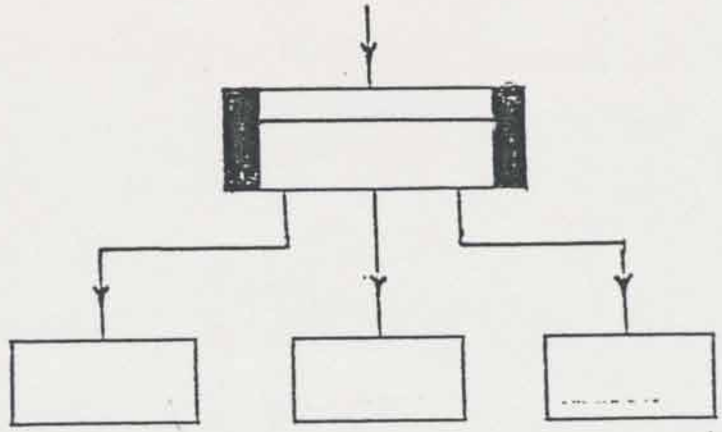

Figure 7. Decision Box with 3 Options

Now that the form of the decision box has been seen, along with the way in which the options (events that are possible consequences of a decision) are shown, it is possible to incorporate this arrangement into the example that was shown in Figure 5. Again it is supposed that the City Council plans to build a sewer and that there are three contractors. Note that the decision box in Figure 8 shows who is expected to make the decision, and that the three options appear in the event boxes following the decision box.

PATHS ON A DELTA CHART

A path on a DELTA chart is a sequence found by following the arrows. As illustrated in Figure 8, every time a decision box appears there will be alternate paths leaving the decision box. As a result there will often be several paths from the initiating event to the concluding events.

For example, let us suppose that in Figure 8 the last three events are concluding events, just for purpose of illustration (even though the symbol for concluding event isn't shown there). Then, using the element numbers shown in Figure 8, we can trace 3 paths from the initiating event to a concluding event. These are identified as:

- 1-2-3-4-5-6
- 1-2-3-4-5-7
- 1-2-3-4-5-8

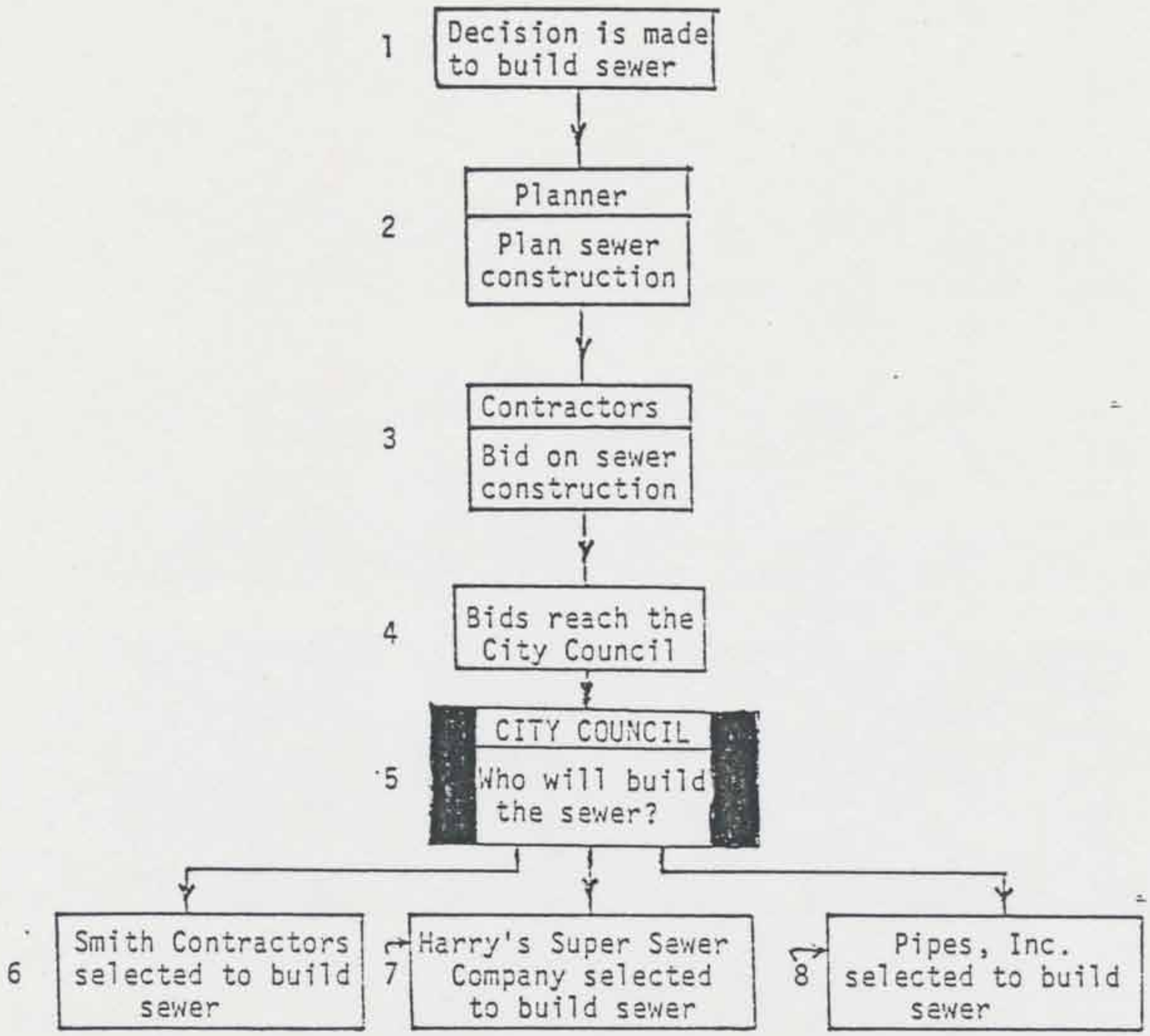

Figure 8. Illustrating the Use of a Decision Box

The paths just identified are called the <u>major paths</u> of the DELTA chart, as they go from beginning to end. Any other paths on the chart would be called <u>minor paths</u>. There are usually many paths. Any part of a major path would be a minor path, so in Figure 8 some minor paths would be 1-2-3-4-5, 2-3-4-5-7, 2-3, 4-5-8, etc.

<u>Realization of a Path</u>. It is said that a path on a DELTA chart has been <u>realized</u> if all the elements of the path have been carried out or have occurred. With reference to Figure 8, suppose that event 1 has occurred, and that activities 2 and 3 have been completed, and that event 4 has occurred, but the decision 5 has not yet been made. Then one could say that the path 1-2-3-4 has been <u>realized</u>, while the remaining parts of the effort have not yet been realized. Some may never be realized (e.g., if Pipes, Inc., is selected to build the sewer, then Smith Contractors and Harry's Super Sewer Company would not be selected, barring unforeseen difficulties or changes).

<u>WHEN IS A LOGIC BOX USED?</u>

The reader may observe, by going back over all the figures in this paper, that two things characterize all of them:

- No logic box has been used so far
- Every box on each figure has no more than one <u>input</u> line

Further it may be observed that the only box with more than one <u>output</u> line is the decision box.

The charts developed so far might be called DETA charts, since they have incorporated decisions, events, time precedence, and activities. In any instance, one could make a DETA chart and not show the logic. It will be our practice here to describe the DELTA chart as a DETA chart that is converted to a DELTA chart by the addition of logic boxes.

The general rule for use of logic boxes is as follows:

LOGIC BOX(ES) ARE USED WHENEVER, ON THE DETA CHART, AN ACTIVITY OR EVENT BOX HAS MORE THAN ONE INPUT LINE OR MORE THAN ONE OUTPUT LINE, OR WHEVER A DECISION BOX HAS MORE THAN ONE INPUT LINE

After the logic boxes have been properly added to the DETA chart, the resulting DELTA chart will have these properties:

- o Every event box, activity box, and decision box will have at most a single input line
- o Every event box and activity box will have at most a single output line

The logic boxes to be added will be of two types. One is called an AND box, and the other is called an OR box. These will be explained shortly. However, we can also say at this point that after the logic boxes have been properly added to the DETA chart, the logic boxes on the resulting DELTA chart will have these properties:

- o Every AND box will have either more than one input line or more than one output line or both
- o Every OR box will have more than one input line, but it will have only one output line

It can be seen from these statements that the logic boxes are used to assure that the three elements (events, activities, decision) have only single inputs, and that two of them have only single outputs. The main reason for this is to reduce ambiguity on the DELTA chart by clarifying the logic associated with these elements.

Next the use of logic elements will be developed in more detail, and examples will be given.

THE LOGIC BOXES

The two types of logic boxes used on DELTA charts are the OR and the AND boxes. It is convenient to explain them together, since a main reason for using logic boxes is to distinguish them from each other on the charts.

The symbols for the boxes are shown in Figure 9. While the rectangular symbol is also used for other ingredients, the word appearing in the box clearly identifies it is a logic box.

Figure 9. Symbols for Logic Boxes

To help explain the use of the logic boxes, an example will be given that illustrates their use in portraying an iterative process.

Iteration. Iteration is frequently used when the results of some chain of activities cannot be assessed until the chain has

has been realized, and when an assessment indicates that it is necessary to repeat some or all of the activity chain.

As an example, one may mention part of the process of making reeds for oboes. An oboe player must carve reeds to use in playing the instrument. The player carves the reed (from cane) for a while, then blows to check the tone with a tuning fork. If the proper tone is attained, the reed may be set aside for a full scale test with the instrument; otherwise, additional carving is done until the proper tone is attained. Thus the process of reed-making is iterative (even more so than this example illustrates!). A part of this process may be DELTA-charted as shown in Figure 10, to illustrate iteration, and to show how the AND and the OR logic boxes are used to help portray this process.

Observing point 1 in Figure 10, there is seen an incoming line from some previous event, activity, or decision. The OR box labeled 3 can be interpreted as allowing one to move on a path right through the box without interference, whether the arrival path is via line 1 or line 2. Thus the sequence begins with the player carving the reed. The AND box 4 is meant to indicate that both of the two following activities need to be carried out, though either could be done first. If one had to be done before the other, there would be no reason to use the AND box labeled 4. The AND box labeled 5 means that both of the preceding activities must be carried out before proceeding to the next activity. This is clear also from the nature of the activities, since the player cannot compare the reed tone with

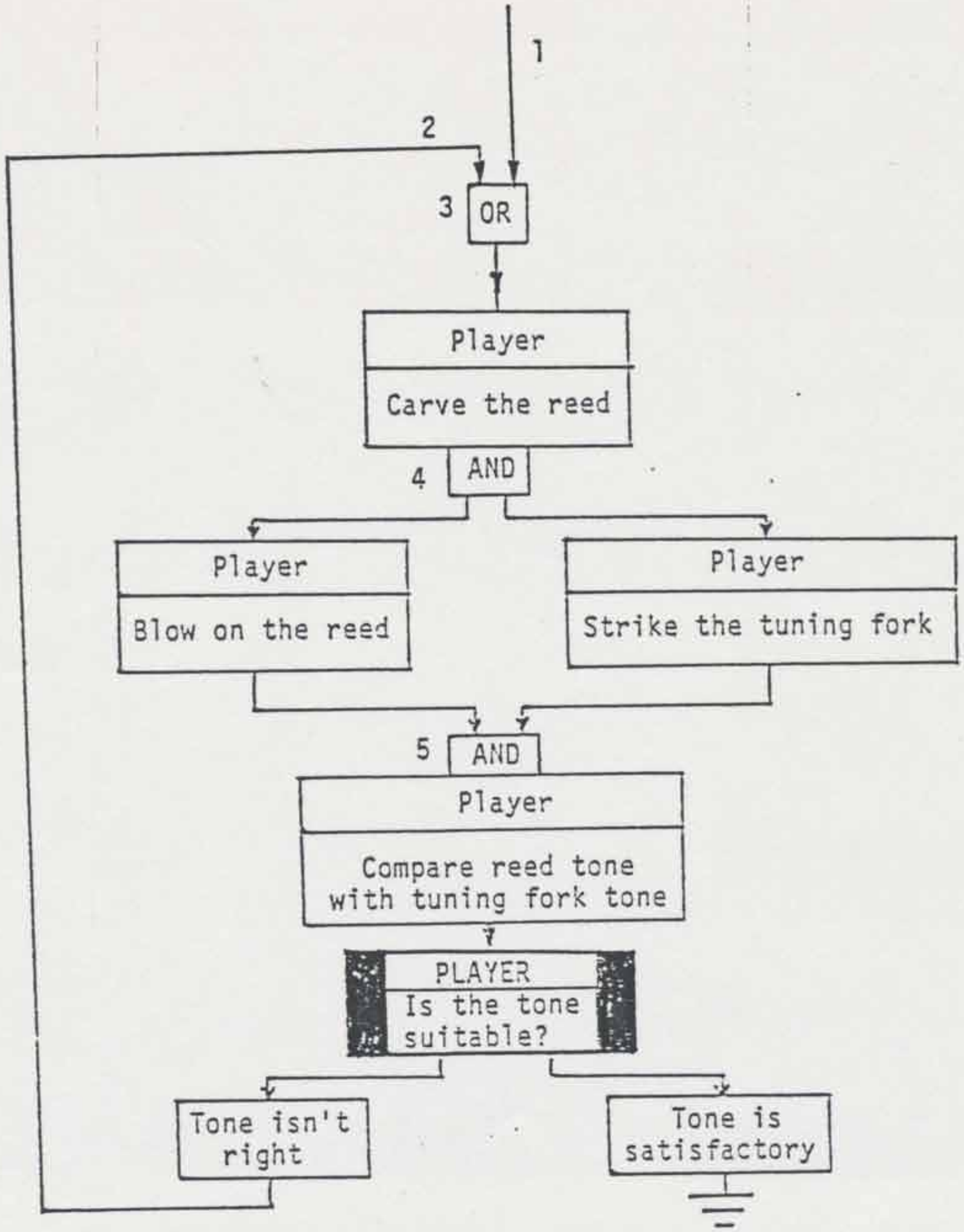

Figure 10. DELTA Chart of Part of Oboe-Reed-Making Process

the tuning fork tone unless both preceding activities have been carried out.

The AND box labeled 5 thus acts to block a continuation of a sequence unless both of the preceding activities that furnish input arrows to the AND box have been done. This should be contrasted with the OR box which allows a sequence to go on as long as any one of the inputs represents the tail end of a realized sequence.

Upon completion of the comparison, the player makes a decision as to whether the reed tone matches the tuning fork tone. If it does so, and the tone is satisfactory, the DELTA chart indicates that the sequence is finished. If it does not, i.e., the tone is not right, then there is a return line or feedback line going back to the OR box, with the input labeled 2. This feedback line allows for the iteration. The whole process may begin again, and may be repeated several times until it is judged that the tone is satisfactory.

Figure 10 thus illustrates the use of logic boxes as means of establishing some path conditions, illustrates the use of the OR box to help show an iteration condition, and also shows how one approximates a real situation. Clearly other alternatives could occur beyond those shown. For example, it might be that in carving the reed the player would damage the cane so badly that further carving would be fruitless. This possibility is not shown on the DELTA chart. It could be, however, depending on the extent of detail desired.

A LARGER EXAMPLE

At this point, all the ingredients of the DELTA chart have been illustrated and explained. As a final thrust in developing the understanding of DELTA charts, an example will be given of a larger DELTA chart to review the use of the various symbols, their interpretation, and the paths and their realizations.

This example will use one symbol that is no longer recommended for use on DELTA charts, and will give an opportunity to distinguish the recommended notation from the older notation.

Figure 11 shows the DELTA chart for the example. This DELTA chart was prepared to help describe a recommended method for doing program planning.

Initiating Event. The initiating event, shown on point 1 on the chart, is "Program Planning Phase Commences". Within program planning, one of the steps is "problem definition". At point 2 is shown another event, namely "Problem Definition Step

Commences". Next, at point 3, there is an activity box with an undefined actor (the upper cell is blank). Following the activity Define Program Title, there appears an AND box near point 4.

AND Logic. The AND logic near point 4 means that all three of the paths leaving the AND box must be traversed as part of the overall sequencing. Thus all three of the activities in line with the digit 5 and succeeding the AND box are to be carried out. As indicated by AND box 6, two of the three activities must be done before event 8 Problem Definition Step Completed can be said to have occurred. However, one of the three activities in line with 5 need not be completed in order to allow event 8 to occur. Nevertheless it must be completed before point 11 in the chart can be passed in a sequence, as illustrated by AND at point 10.

OR Logic. The OR logic appearing at point 7 would no longer be considered appropriate for use on a DELTA chart. As mentioned earlier, an OR box has only one output line. This one has two. In the present context, the OR box at point 7 would be replaced with a decision box, and the decision would be either to review the normative scenario axiological component or to review the criteria and/or constraints. The latter pair would then be phrased as events. For example, one might write "Resources allocated to carry out criteria or constraint revision". This would replace the activity box below and to the left of point 14.

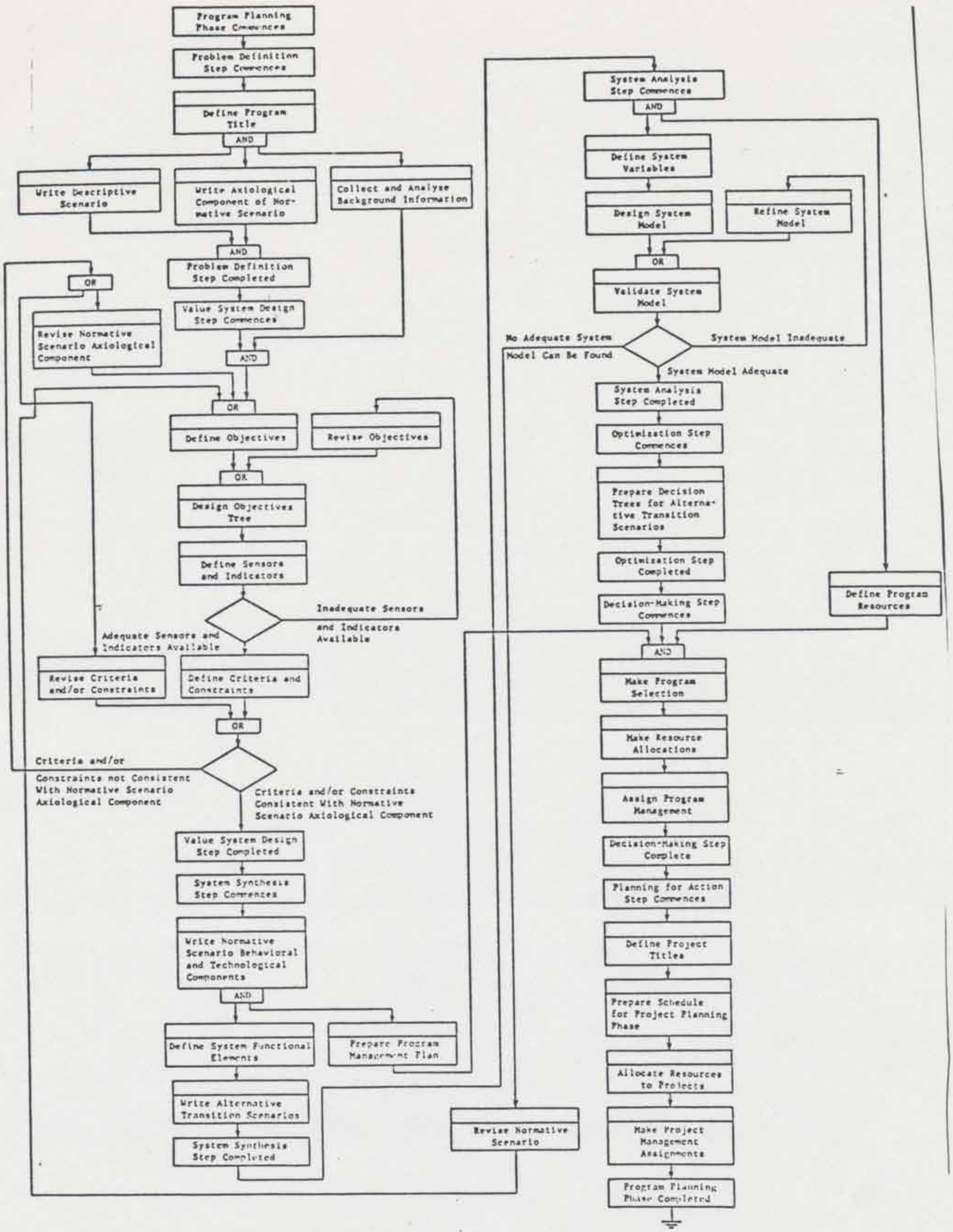

Figure 11. Example DELTA Chart for Program Planning

The OR logic at point 11 is consistent with present usage. It shows that a path can proceed through box 11 when it is entered from any of three prior origins.

Similar applications of the OR logic appear at points 12, 16, and 26. Note that if the OR box was not used, it would not be clear whether the logic indicated was AND or OR logic. Similarly one may note that AND logic is used at points 6, 10, and 31 in situations where there are multiple inputs, and that the AND designation distinguishes the logic from the OR logic. At points 6, 10, and 31, all immediately preceding paths must have been realized before proceeding, while with the OR logic only one such path must have been realized.

In spite of the distinctions just discussed, many people who make charts somewhat like DELTA charts do not bother to portray the logic. As a result, their charts do not fully communicate what is essential information to understanding their content.

Decision Box. The example chart uses the old symbol for a decision box. This old symbol is a "diamond", as seen at 14, 16, and 27.

The diamond symbol works best when there are 2 or 3 options, and it will be noted that there are only 2 options at points 14 and 16, and three options at point 27. However, as mentioned earlier, there are objections to this symbol and it is no longer recommended for use.

Note that no one is named to make the decisions shown, as indicated by the absence of any identification within any of the decision boxes.

Concluding Event. Note that there is a single concluding event on the diagram, namely "Program Planning Phase Completed", as shown at point 33.

Iteration. Note that a significant amount of iteration is shown in the chart. A short iteration path is found in the vicinity of points 25, 26, and 27, where a system model is undergoing validation efforts, followed by a decision as to adequacy, by refinement if necessary, and continuing scrutiny until it is judged adequate.

Iteration is also seen in the area of point 12, where the OR logic is used as described earlier.

CONCLUSION

In conclusion, the reader is reminded that this paper has been prepared to help the reader understand DELTA charts. The reader is cautioned that this paper is not intended to be a complete guide to the construction of DELTA charts. That is a more extensive topic.

<u>APPENDIX</u>

Since the original DELTA chart paper appeared in 1971, followed by this update in 1978, other authors have carried out research that lends itself to providing automated assistance to people who formulate such charts.

One example of this work is the following:

T. Inagaki and E. M. Himmelblau, "Hierarchical Determination of Precedence Order and Representation of Digraphs," <u>IEEE Trans. Systems, Man, and Cybernetics</u>, 13(3), May/June, 1983, 406-413.

This article deals with how to place the logic elements in the structure systematically.

Another example is the following:

K. Sugiyama, S. Tagawa, and M. Toda, "Methods for Visual Understanding of Hierarchical System Structures," <u>IEEE Trans. Systems, Man, and Cybernetics</u>, Feb., 1981, 109-125.

This article presents algorithms for the machine construction of digraphs, and shows examples of digraphs produced with these algorithms in comparison with digraphs drawn without the benefit of them. (A digraph is the mathematical type of structure that underlies DELTA charts, data flow charts, "bubble" charts, and <u>many</u> other kinds of charts that are often presented as being unique. In fact, the uniqueness in these charts is mostly in the mind of their inventor, since most of them fall into a group of charts that can be treated as a class, which means that software developed for the class can be applied to each of its members, perhaps with minor special conditions.)