FILE:
TABULAR
PROGRAMMING

A STANDARDIZED REPRESENTATION FOR BUSINESS PROBLEMS

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Abstract

A system of standardized procedure charts is proposed for the representation of data-processing procedures. Although the proposed approach is nontechnical, it will lead to a representation of business problems as logical structures of uniform building blocks which can easily be expanded into machine-programs. The method may thus be expected to facilitate the preparation of business problems for automatic data processing.

1. Introduction

Many difficulties in the preparation of business problems for data-processing are commonly attributed to the fact that such problems involve a comparatively large amount of heterogeneous detail, and that, furthermore, an adequate method of representing business problems uniformly and systematically does not seem to be available. In the area of scientific and technical computing, by contrast, the situation appears to be more favorable in both respects. The problems in this area are less intricate, and they lend themselves well to a transparent representation in terms of compact and powerful mathematical formulas. In this paper, a standardized method for the representation of business problems is proposed to improve the efficiency in preparing business problems for data-processing.

The proposed method is based on very simple logical notions which are so "natural" that they should appeal to persons who are not particularly interested in formal reasoning. The method makes extensive use of charts in order to avoid complicated formulas as far as possible; this, again, should make it attractive to individuals who would rather not use a mathematical notation. Although the method may thus be considered a common-sense approach, it will produce a systematic representation of business problems in terms of uniform building blocks. This representation will reflect clearly the logical structure of the problems, and it will be easily expanded

into machine-programs.[1]

2. Procedure Charts

The two principal elements which tend to make data-processing procedures complicated are repetition and decision. A procedure which consists of a single straightforward sequence of steps is easy to describe and to understand, no matter how many steps it may comprise, because a person thinking through such a procedure need not consider more than one thing at a time. Ordinarily, however, a procedure contains repetitions of some of its parts, or "subprocedures", and repetitions of sub-subprocedures within the subprocedures, as well as decisions as to which of its subprocedures are to be executed in different cases. In such a procedure the different steps are interrelated by repetition and decision in a more complicated manner so that a person thinking through the procedure cannot consider only one thing at a time. The procedures, however, have a logical structure in

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1. Readers experienced in programming will recognize immediately that the system of procedure charts to be proposed for the formulation of business problems is merely a variation of the hierarchy of basic forms used for the representation of programs. This subject was briefly discussed in "Programs as a Tool for Research in Systems Organization" by J. Jeenel, IBM Journal of Research and Development, Vol. 2, No. 2, April 1958, and is comprehensively treated in a forthcoming book on programming for stored-program calculators by this author.

the sense that certain repetitions are within other, "higher order" repetitions, and certain decisions are on a "lower level" below other decisions. A representation which adequately reflects the logical structure of a procedure and clearly separates its different levels of repetition and decision would then enable a person to think about a single level of the procedure at a time and thus facilitate the construction and description of data-processing procedures.

To represent repetition, and repetition within repetition, one may use a "repetition chart" whose general form is illustrated by Figure 1. The chart is subdivided into columns, and each column except the rightmost one is subdivided into an upper and a lower part. The steps to be performed according to the procedure are shown in the appropriately labeled columns to indicate how frequently they are to be repeated.

The "Daily Operations" are shown in the right-most column whose heading indicates that these operations are to be performed once per day. The next column to the left shows the operations to be performed once per week. These weekly operations are subdivided into the ones that are preparatory to the set of daily routines for the week, and the ones that are to be performed after the daily routines have been completed for the week. The first group of these weekly operations are shown in the upper part of the column "Once per week"; they might be performed on Mondays before the first daily routine of the week is executed and would include the weekly "set-up operations" for the daily routines. The second group of weekly

operations is shown in the lower part of the column "Once per week"; these operations might be performed on Saturdays to sum up the information produced by the daily routines throughout the week. The monthly, quarterly and annual operations are shown in the respective columns in an analogous manner.

The significance of the columns of the repetition chart, and of their upper and lower parts, may be summarized as follows. The operations in the column "Once per week" are repeated each week. For a given week, one would first execute the operations in the upper part of the column. One would then go to the column to its right, which is labeled "Once per day", and repeat it the appropriate number of times, such as five times for five work-days of the week. Finally one would return to the lower part of the column to the left, that is, to the "Once per week" column. This column "Once per week" would in turn be repeated four times within each month, that is, four times within each repetition of the column to its left. This example illustrates how a given column, such as the "Once per week" column, is related to its neighbors on either side.

Alternatively one may trace the execution pattern of a repetition chart by considering a number of adjacent columns from left to right. Starting, for instance, with the column "Once per month" one would first perform the operations in the upper part of the column. One would then proceed to the right and perform the four repetitions of the "Once per week" column. For any given repetition of the column "Once per week" one would first perform its upper part, then go five times through the daily routines in the column

to its right, and then return to the lower part of the "Once per week" column. After this has been repeated for four weeks, and for four times five days, one would finally return to the lower part of the column "Once per Month".

Another possible set of designations for the columns of a repetition chart is shown in Figure 2. This chart might be used to represent a procedure which involves the personnel data for the individual employees of a company and requires the data pertaining to the individuals to be processed within departments, the departments within divisions, and finally the data for the divisions to be combined for the entire company. Starting in the upper part of the leftmost column one would perform the initial steps for the entire process which pertain to the company as a whole. This might include printing the title of the report and the period to which it applies. Proceeding to the right, one would then perform the initial operations indicated in the upper part of the Division-Column for the first division. Proceeding further to the right one would then execute the initial departmental operations in the upper part of the Department-Column for the first department in the first division. Proceeding again to the right, one would then reach the Employee-Column and process the data for the first employee in the first department of the first division. This column would then be repeated for all employees in this department. After all employees in this department have been covered, one would return to the lower part of the Department-Column to perform the summarizing operations pertaining to the first department as a whole. Next, one would commence the second execution of the Department-Column with the

initial operations in its upper part for the second department of the first division. After the Department-Column, and with it the Employee-Column to its right, has been repeated for all departments in the first division, one would return from the lower part of the Department-Column to the lower part of the Division-Column and perform the summarizing operations for the first division. The operations for the second division would then commence in the upper part of the Division-Column. After the Division-Column, and with it the Department- and Employee- columns, has been repeated for all divisions of the company, one would finally return from the lower part of the Division-Column to the lower part of the Company-Column which would contain the summarizing operations for the entire company.

For a more concrete example of a repetition chart one may consider Figure 3 which represents some operations typical of payroll processing. (The designations "Chart 1.3" in the title and "Chart 1.3.1" in the Employee-Column should be ignored during the present discussion.) It is assumed that the gross pay for each employee has already been computed. The objective of the procedure is to compute the net pay and to prepare an earnings statement and a pay check for each employee. The year-to-date figures for items such as gross pay, net pay, withholding tax, and savings bond balance, are to be updated; the procedure is to be performed for the employees by departments.

The Employee-Column shows the steps of the procedure that are to be gone through for each employee. For checking purposes, a count of the number of pay checks issued is kept per department. This count is increased by "one" at the bottom of the Employee-Column, that is, once per pay check issued.

The title of the entire procedure is given as "Payroll". The heading "Once per - " for the leftmost column implies that the title for the entire procedure is to be substituted for the dash. This heading thus indicates that the leftmost column of the chart is to be executed "Once per Payroll", that is, once for the entire process represented by the chart.

The execution of any repetition chart starts in the upper left-hand corner. In the present example, one would start with the steps preparatory to the whole process such as printing the title of the procedure and the date. Proceeding to the right, one might then print the identification of the first department and, in view of the checking operations indicated above, the number of employees in this department. Proceeding to the right, one then reaches the the Employee-Column and executes it repeatedly, once per employee in the first department. After the last employee in this department has been covered, one returns to the lower part of the Department-Column. There one verifies the count of pay checks issued, which was kept during the successive executions of the Employee-Column, by comparing it with the number of employees in the first department which was printed initially in the upper part of the Department-Column. The Department-Column, and with it the Employee-Column, is then repeated for all departments to be covered. After the

operations for the last department have been completed, one returns from the lower part of the Department-Column to the lower part of the leftmost column. In the present example there are no operations indicated that would pertain to all departments and would have to be performed at the end of the entire process represented by the procedure chart. The execution of this or any repetition chart ends in the lower left-hand corner of the chart.

To represent decisions in a procedure one may use a second type of procedure charts which may be termed "decision charts". Frequently, however, decisions are not very complicated and can easily be represented in the columns of repetition charts in the form of "if's", or "skips", and "branches". Such simple cases of decisions will be illustrated first before the general form of repetition charts is discussed.

For an example consider Figure 4 which may be visualized as a repetition chart consisting of only one column. (The designations "Chart 1.3.1" and "Chart 1.3.1.1" should be ignored for the time being.) This column represents the computation of the net pay for an employee. It is assumed that the net pay is to be computed by subtracting from the gross pay the following items: Tax, Social Security, and possibly deductions for hospitalization insurance, savings bonds and pension plan. For a given employee, a certain combination of these three deductions will apply. The employee may, for instance, have hospitalization insurance taken out of his pay, but not the other deductions for bonds and pension plan. The necessary choices are indicated by the designation "If authorized" in the respective

boxes representing the steps of the procedure. These "if's" represent the decisions to be made in a very simple manner. The execution of the procedure would simply follow the rule: if yes, perform the operations in the box; - if no, skip the box.

For another example of a simple decision consider Figure 5 which represents a procedure for bond deductions as a column of a repetition chart. (The designation "Chart 1.3.1.1" in the title should be ignored.) It is assumed that the employee has for each pay-period a certain amount deducted from his pay and added on to his bond balance. Every time the bond balance reaches or exceeds the purchase price of a bond, the company purchases a bond for the employee and reduces his balance by the purchase price of the bond. For every pay-period, that is, every time the bond balance is increased by the deduction, one has thus to decide whether a bond is to be purchased or not. This decision is represented in the column of the repetition chart by the "decision box" containing the question "Does bond balance equal or exceed the purchase price of a bond?" This box will cause the execution of the procedure to follow the appropriate "branch" of steps as indicated by the arrows on the chart. In case of "Yes", the boxes "Reduce bond balance" and "Type message" will be executed; in case of "No", these two boxes will be by passed.

When a column of a repetition chart contains no branches at all, as in Figures 3 and 4, one need not show any arrows since it is understood that the execution of the procedure proceeds from box to box downward within each column, or within its upper part and within its lower part in case the column is subdivided into parts. When, on the other hand, a column of a repetition chart contains any branches represented by arrows, it is usually advantageous to connect all boxes in the column appropriately with arrows in order to avoid ambiguities. In the present example of Figure 5, for instance, arrows are shown connecting the first two boxes on top although no branching is indicated in this part of the column. In order to make charts with arrows more readable one should adhere to the convention that the execution of a column proceeds downward. Lines should therefore not be run upward. Lines should enter boxes at the top of the box and leave boxes at the bottom. This was indicated by Figure 5 and will also be illustrated by Figure 6.

For an example of a more complicated configuration of decisions consider Figure 6. For this example it has been assumed that a procedure to be executed for a given employee depends on the following conditions: A) Whether or not the employee is a resident of the state in which the company is located; B) Whether the employee is paid a monthly salary or according to an hourly rate; C) Whether the employee is single or not. According to the particular combination of these conditions applying to a given employee, a certain sequence of steps will have to be performed.

The different possible steps are represented by procedure charts which are identified by three-digit numbers such as 1.6.1. (The reason why the three-digit numbers 1.6.1 through 1.6.4 rather than the numbers 1 through 4 have been chosen for this example will become apparent later on.)

The combination of decisions pictured in Figure 6 could, of course, be shown in the appropriate column of a repetition chart analogous to Figure 5. For more intricate combinations of decisions, however, one would prefer to use a "decision chart" like the one illustrated for the present example by Figure 7. (The designation "Chart 1.6" in the title should be ignored for the time being.) The chart contains a description of the symbols used for the conditions, such as "A ... Resident of State". Each row in the lower part of the chart represents one of the possible combinations of conditions and the corresponding sequence of steps to be taken. The second row from the bottom, for instance, says: If A is true, and B is true, and C is not true, - execute the procedure represented by Chart 1.6.2 and then the procedure represented by Chart 1.6.4 . The dashes in the chart represent "don't care" conditions, that is, conditions irrelevant for the present purpose. The bottom row, for instance, says: If A is true, and B is not true, execute procedures 1.6.1 and 1.6.3, - regardless of whether or not C is true.

3. Systems of Procedure Charts

The preceding discussions have shown how procedures can be represented by repetition charts and decision charts. A complete business

problem would ordinarily comprise a collection of such procedures. This collection of procedures would have a logical structure in the sense that certain procedures are subprocedures of others, and that the subprocedures in turn contain sub-subprocedures. A complete problem should therefore not be viewed as a more or less chaotic collection of steps but rather as a logical system of procedures. Such a system of procedures can be easily and clearly represented by means of a corresponding system of procedure charts.

The process of combining individual procedure charts into a logical system is based on the simple notion of a "detail chart", and on the fact that, formally, any procedure chart can serve as a detail for any other procedure chart . Consider, for example, the procedure chart shown in Figure 3. This chart contains in its rightmost column the box "Compute Net Pay" with a brief description of this process in general terms. A more detailed description of how the net pay is to be computed was given by the chart in Figure 4. This chart thus describes in more detail the operations inside the box "Compute Net Pay" on Figure 3.

The detail-relationship between procedure charts is easily and uniquely indicated by the labeling shown in Figures 3 and 4. The Payroll-Chart given in Figure 3 was labeled "Chart 1.3" for reasons which will soon become apparent. All details of this chart would then be labeled with numbers starting with 1.3 as, for instance, 1.3.1, 1.3.2, 1.3.3, 1.3.4 and so on. The detail "Compute Net Pay" shown in Figure 4 was according to this convention labeled "Chart 1.3.1". The fact that this detail chart for the

box on Figure 3 exists is indicated in square brackets inside this box. Instead of briefly writing [Chart 1.3.1] in this box one could say more explicitly [See Detail Chart 1.3.1].

The significance of a detail chart may also be viewed as follows. The detail shown as Figure 4 fits completely into the box on Figure 3 by which it is represented. It "fills" this box completely in the sense that there is nothing else in this box besides the operations represented by the detail chart. In other words, one could delete the single box "Compute Net Pay" on Figure 3 and substitute for it everything that is shown on Figure 4.

For an illustration of a "detail of a detail" one may now consider Figure 5. The designation "Chart 1.3.1.1" identifies this chart as a detail of the Chart 1.3.1 which was shown as Figure 4. In the fourth box on Figure 4 one finds [Chart 1.3.1.1] which indicates that Figure 5 is a more detailed representation of the operations in this particular box. To see again how the details of different order fit into each other one may visualize first the entire Figure 5 substituted for the fourth box on Figure 4, and then this modified Figure 4 substituted for the first box in the right-most column of Figure 3.

As mentioned before, any procedure chart might serve as a detail for any other procedure chart. The repetition chart of Figure 4 was used as a detail for the repetition chart of Figure 3. The detail in Figure 4 happened to consist of only one column, but it could just as well have served as a detail of Figure 3 if it had been a repetition chart comprising, say, four columns. The labeling in Figure 7 identifies the Charts 1.6.1 through

1.6.4 as details of the Decision Chart 1.6. Each of these detail charts could be either a repetition chart or again another decision chart. Finally, the Repetition Chart 1.6 would in turn be a detail of some "Chart 1" on which it would be represented by a box saying briefly "Decisions on Status of Employee [See Detail Chart 1.6]". This "Chart 1" could be either a repetition chart or a decision chart. It is thus seen that a procedure chart of either of the two types may be a detail of a chart of either the same or the other type.

For a more complete illustration of a system of procedure charts consider the following problem. A payroll and labor distribution is to be prepared for a company in which employees from different departments work for a number of different projects. The departments are not identical with the projects so that, for instance, employees from Department 5 might contribute to Projects B, F, G, and so on, and that, on the other hand, Project B might have work done by employees from Departments 1, 2, 5, and so on. The objective is to prepare a payroll for the employees by departments and a labor distribution by projects. The necessary information is given in the form of job tickets issued for each individual task performed by each employee during the period of time to be covered. Each job ticket would state which employee did the work, which department he belongs to, for which project the work was done, and how many hours he spent doing the work. The hourly rate of pay for the employees would be given in the form of a rate table. The gross pay corresponding to each job ticket would then be computed as the product of (hours worked) times (hourly rate). The total gross pay for each employee would be used for the payroll computations,

and the total gross pay to be charged against each of the projects would constitute the labor distribution.

The major phases of this data-processing problem are represented by the procedure chart shown as Figure 8. This chart has for its title the designation of the entire problem. The column heading "Once per - " indicates that this column is executed once for the entire process of preparing a payroll and labor distribution. The chart shows that the problem is composed of three major parts each of which is described in more detail on a separate detail chart.

Chart 1.1 in Figure 9 shows that the gross pay corresponding to a given job ticket is added to the cumulative total for the particular employee in preparation for the payroll computations, as well as to the cumulative total of the approximate project for the labor distribution. Before the first job ticket is processed, the table giving the hourly rates of pay for the personnel is updated to include all increases that imight have become effective since the last payroll was prepared. After the last job ticket has been processed, the grand total of gross pay for all employees is checked against the grand total of gross pay for all projects which should be the same amount.

The person preparing the system of procedure charts for this problem may now consider it necessary or desirable to show any or all of the boxes on this chart in more detail. For the purpose of illustration it has been assumed that checking the grand totals should be described more explicitly.

Figure 10 shows the detail Chart 1.1.1 of the box in the lower lefthand corner of Figure 9.

Assuming that the first box of Chart 1 has thus been developed into sufficient detail, one may proceed to the second box of this chart. The inside of this box is shown as Chart 1.2 in Figure 11. The boxes of this chart could then in turn be developed into as much detail as necessary.

Possible details of the remaining third box of Chart 1 have been discussed previously. The group of Charts 1.3, 1.3.1, and 1.3.1.1 shown in Figures 3, 4, and 5, respectively, illustrates how this part of the problem might be developed.

The particular manner in which the problem was here developed into a system of procedure charts was quite arbitrarily chosen to facilitate the discussion of the subject matter. In practice one would, of course, carry the degree of detail shown just far enough in each part of the problem to define the procedure sufficiently well.

A system of procedure charts may be considered to represent a problem in terms of stages or levels which are arranged from the highest, or most general, to the lowest, or most specific. The relative position of a chart within the system is reflected by its designation as, for instance, Chart 1.3.1.1, which identifies this chart as a detail of Chart 1.3.1 which in turn is a detail of Chart 1.3 which in turn is a detail of Chart 1. This structure can be pictured as a "cross section" through the system of procedure charts like the one shown in Figure 12. The most general chart, Chart 1, represents the highest stage of the system. The next stage comprises

the details Chart 1.1, Chart 1.2, and Chart 1.3. which are more specific. At the bottom of each branch of the cross section one finds the lowest-order, most specific, details. The broken lines in Figure 12 were inserted to indicate that in practice the system of charts would be more fully or differently developed than it was developed here for the purpose of illustration.

4. Representation and Development of Problems

The preceding discussions have shown how business problems may be represented by systems of standardized procedure charts. The degree of detail considered in each part of a problem can be adjusted to the particular purpose of the analysis. A person might, for instance, wish to know only what major phases a certain data-processing procedure consists of and how these phases relate to each other. In this case he would consider only a high-order chart like the one shown in Figure 8. Alternatively, a person may have to define and prepare a procedure in sufficient detail for automatic data-processing equipment. For this purpose he would use a representation with high "resolution", that is, a system of charts developed down to the lowest-order details which describe the steps of the procedure most specifically. The opposite extreme would be illustrated by a case in which a person wishes to know how a complete problem, such as payroll and labor distribution, fits into the various data-processing operations for an entire company. For this purpose, the complete problem might be represented by a single box in the "Once per Week" or "Once per Month" column of a repetition chart like the one shown in Figure 1 which would

provide a survey of all data-processing operations in the company. The complete payroll and labor distribution procedure as represented by Figure 8 would for this purpose be considered one of the details of this survey chart. Representing the problem by a box in the appropriate column of the survey chart will also define its frequency of repetition, that is, it will define the column heading "Once per - " in Figure 8 to mean "Once per week" or "Once per month".

The representation of procedures in terms of systems of procedure charts facilitates the process of incorporating an existing procedure into a new problem as well as the process of modifying an existing procedure. In order to incorporate an existing procedure into a new problem one merely represents the entire procedure by a single box in the appropriate place in the system of charts for the problem and considers it a ready-made detail which does not require any further attention. When a procedure is to be modified one usually must trace the effects of a change through many parts of the procedure. This process would be facilitated by the system of procedure charts, supplemented by a cross section like the one shown in Figure 12, which would indicate into which parts of the procedure the effects of a change at a certain point might propagate.

A system of procedure charts represents a problem as a logical structure of standardized building blocks. Different problems would thus be represented in a compatible manner and could therefore be more easily described and discussed by different people. The fact that the systems of

charts are arranged in stages from the most general down to the most specific will furthermore help to keep a particular discussion on the appropriate level of generality.

A system of procedure charts will not only facilitate the representation of a data-processing procedure but it is also a valuable tool in creating a data-processing procedure. It is usually most efficient to proceed from the general to the specific, one stage at a time, as one constructs a procedure. This corresponds to developing a system of procedure charts roughly by the horizontal layers of its cross section as illustrated by Figure 12. Proceeding in this manner one gets gradually into more and more detail for the procedure as a whole. With the alternative approach of carrying separate parts of the procedure one by one into much detail one is likely to find that details worked out previously for certain parts of the procedure are not compatible with detailed requirements in other parts.

Once a data-processing procedure has been defined in terms of a sufficiently detailed system of procedure charts, the transition to a machine-program should in most cases be merely a matter of routine, and, consequently, from the programming researcher's point of view a promising area for automation. The system of procedure charts would already constitute a hierarchy of basic forms [1] showing the productive operations

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1. (This refers again to the footnote at the beginning of the article.)

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required by the problem. After the necessary read- and write-operations for input-, output-, and storage-devices have been entered on the basic forms, the program represented by the flow charts could then be processed by an automatic coding system to yield the machine instructions.

Once per Year	Once per Quarter	Once per Month	Once per Week	Once per Day
Annual Operations (before first quarter of the year)	Quarterly Operations (before first month of the quarter)	Monthly Operations (before first week of the month)	Weekly Operations (before first day of the week)	Daily Operations
Annual Operations (after last quarter of the year)	Quarterly Operations (after last month of the quarter)	Monthly Operations (after last week of the month)	Weekly Operations (after last day of the week)	

FIGURE 1: Repetition chart for processing by time units

Once per Company	Once per Division	Once per Department	Once per Employee

FIGURE 2: Repetition chart for processing by administrative units

Chart 1.3: Payroll

Once per -	Once per Department	Once per Employee
Print heading including date, etc.	Print department identification and number of employees in this department	Compute (Net Pay) = (Gross Pay) - (Witholding Tax) - (Social Security) - (Deductions) [Chart 1.3.1]
		Add current figures to year-to-date totals to obtain new year-to-date totals for this employee
	Verify number of employees in this department for which an earnings statement and a pay check were prepared	Prepare earnings statement and pay check
		Increase count of employees for which statement and pay check were prepared

FIGURE 3: Repetition chart for payroll by departments

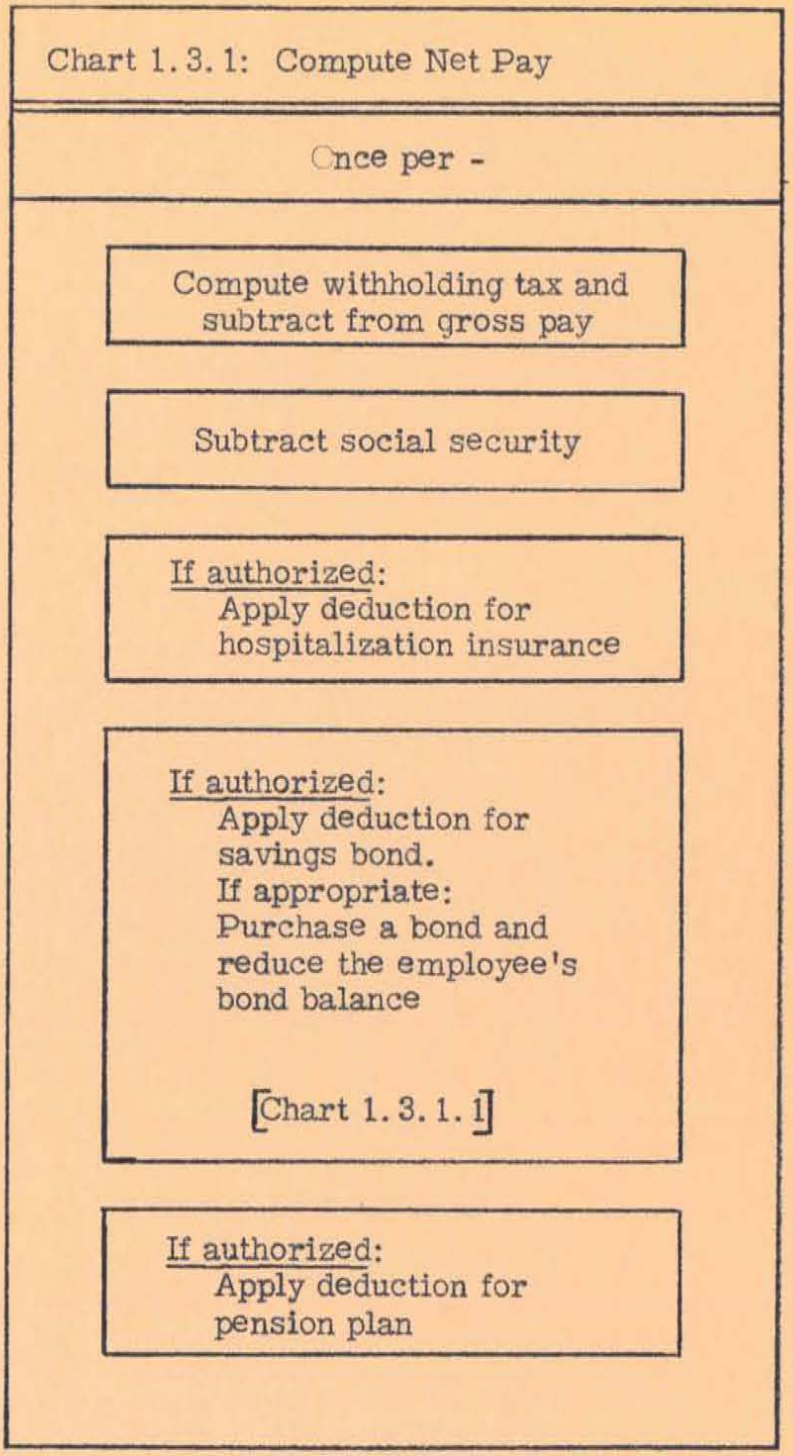

FIGURE 4: Decisions represented by skips on a repetition chart

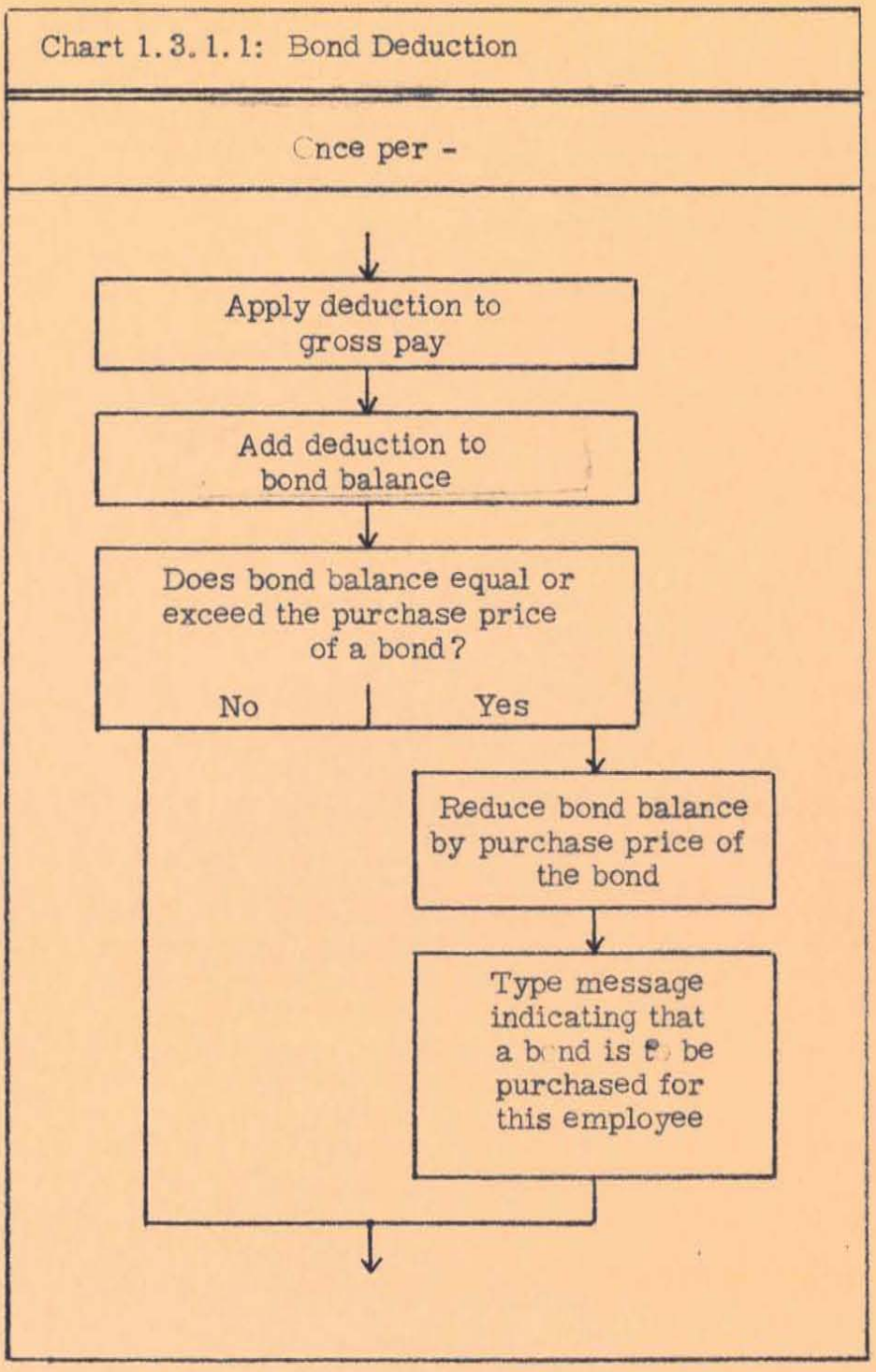

FIGURE 5: Decision represented by a branch on a repetition chart

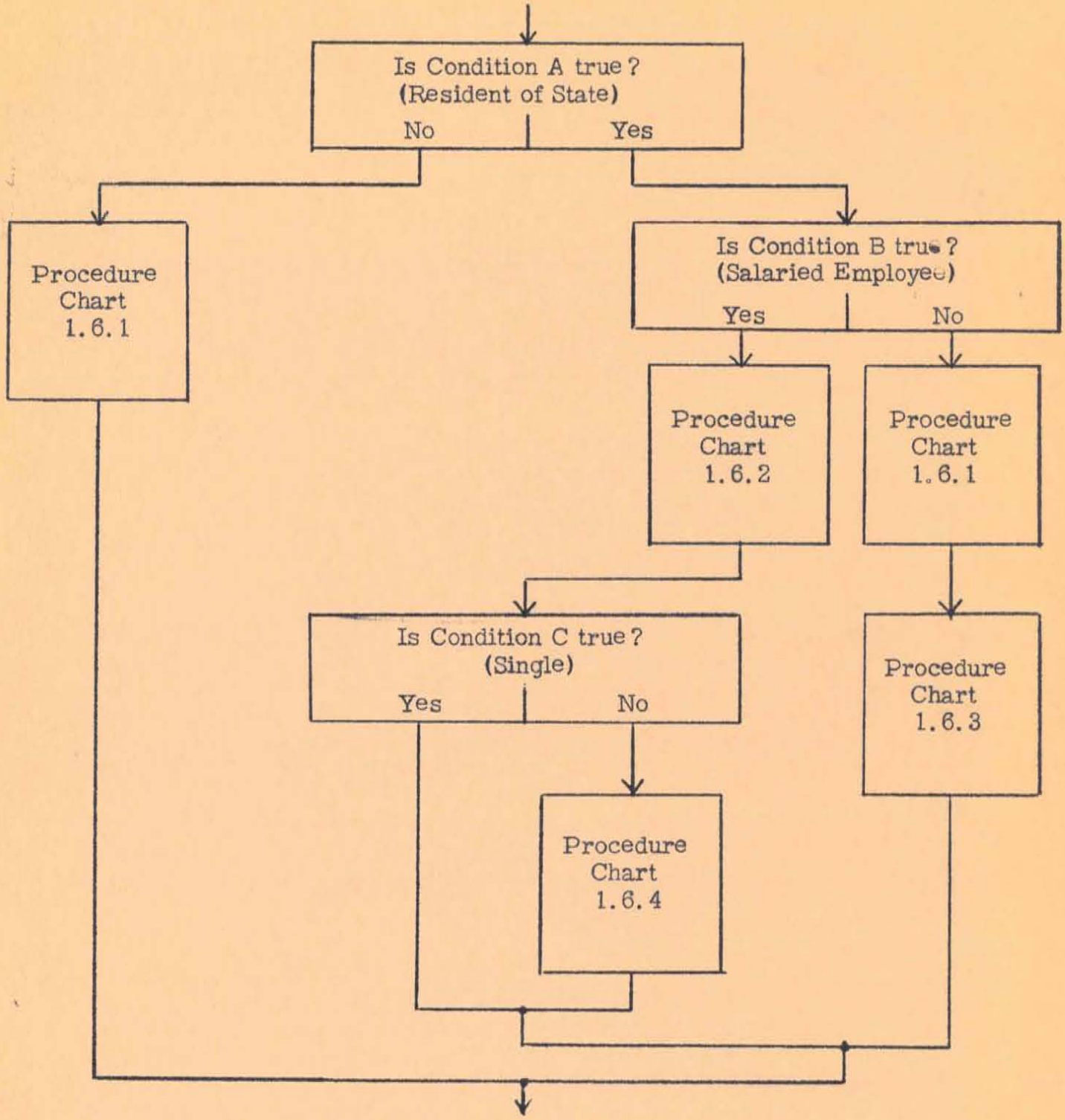

FIGURE 6: Group of decisions

Chart 1.6: Decisions on Status of Employee

A . . . Resident of State

B . . . Salaried Employee

C . . . Single

If the following combination of conditions is present			Execute the following sequence of procedure charts
A	B	C	
No	-	-	1.6.1
Yes	Yes	Yes	1.6.2
Yes	Yes	No	1.6.2 and 1.6.4
Yes	No	-	1.6.1 and 1.6.3

FIGURE 7: Decision chart representing the group of decisions shown in Figure 6

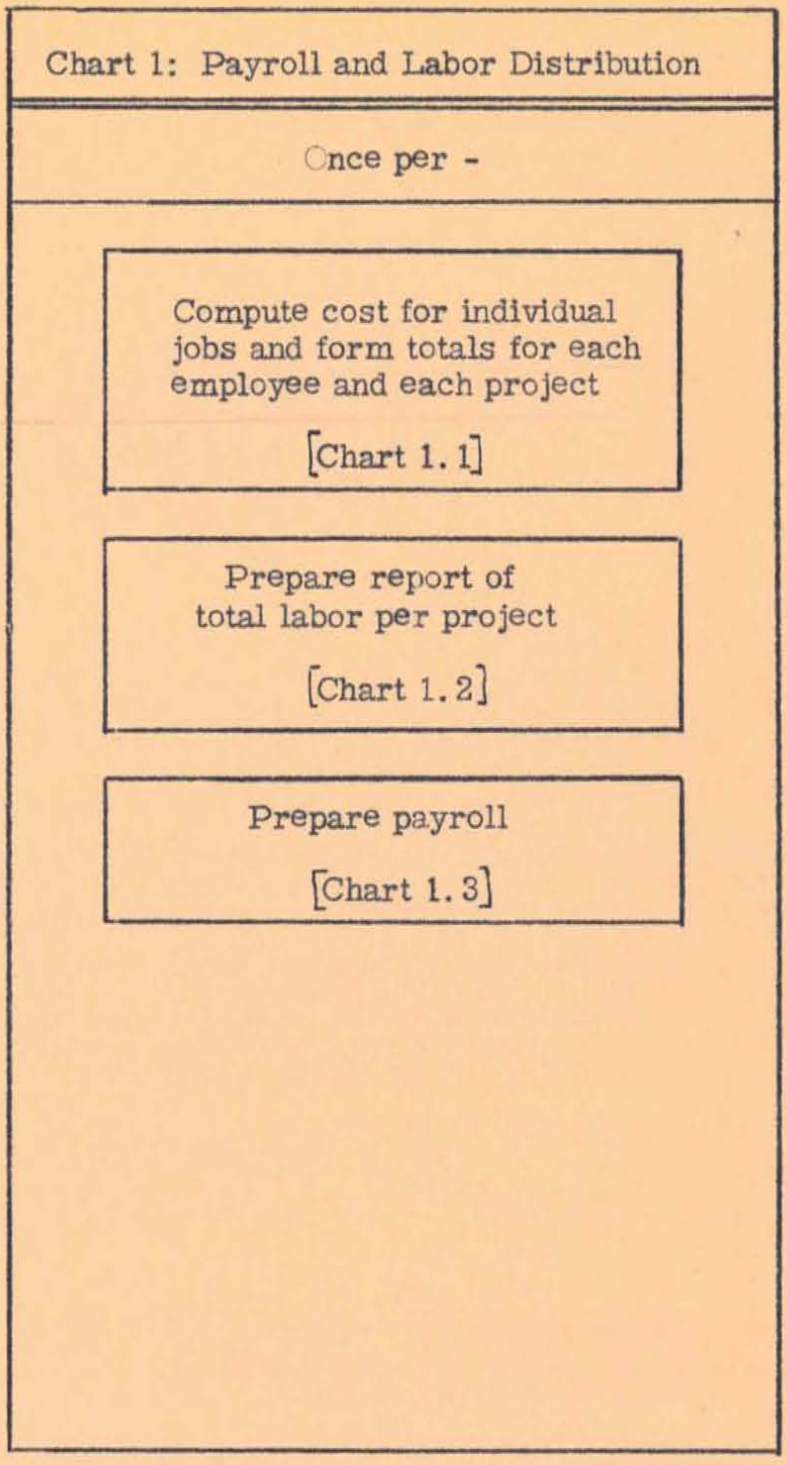

FIGURE 8: Procedure chart showing the major phases of a problem

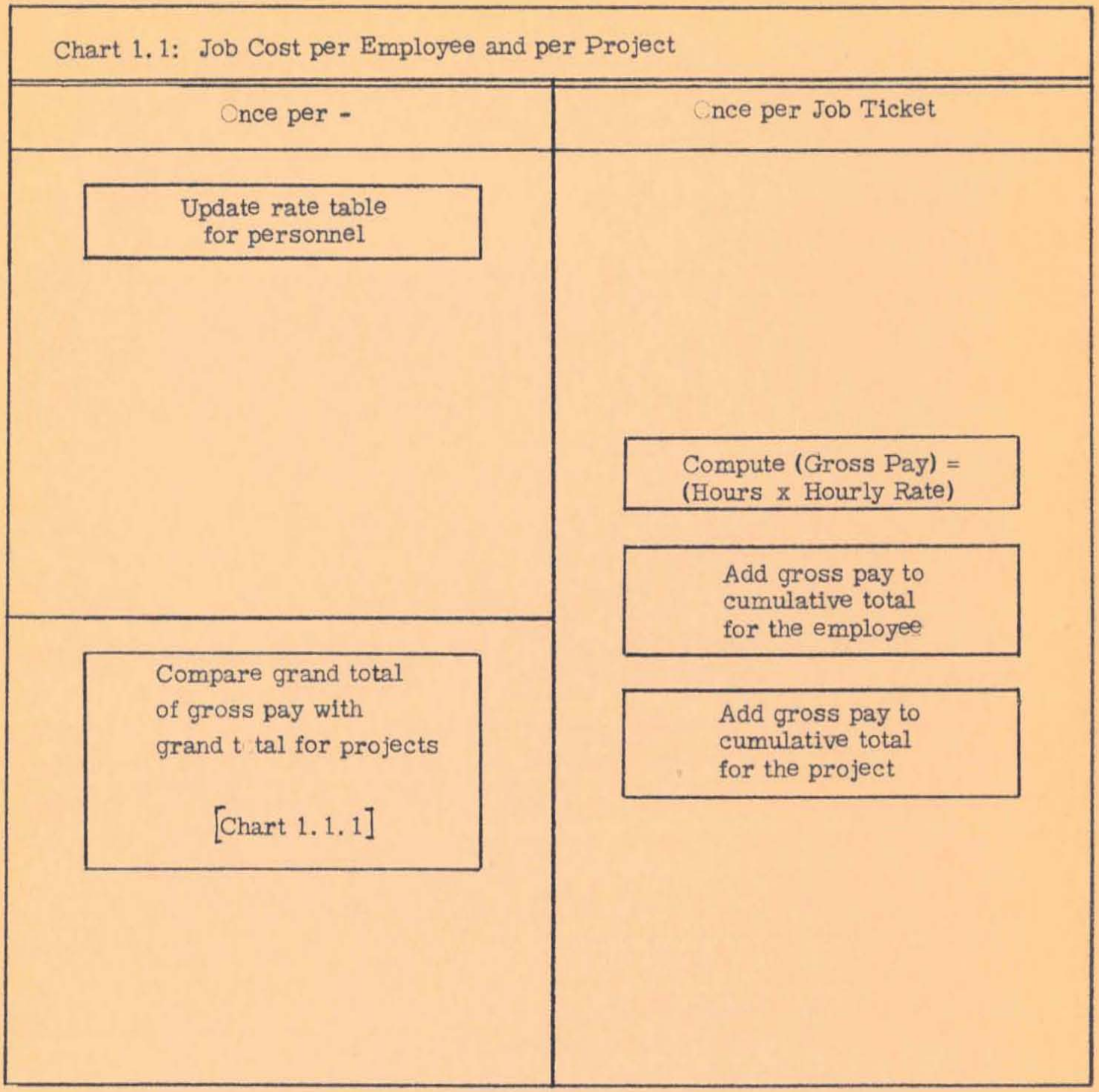

FIGURE 9: First detail of the chart shown in Figure 8

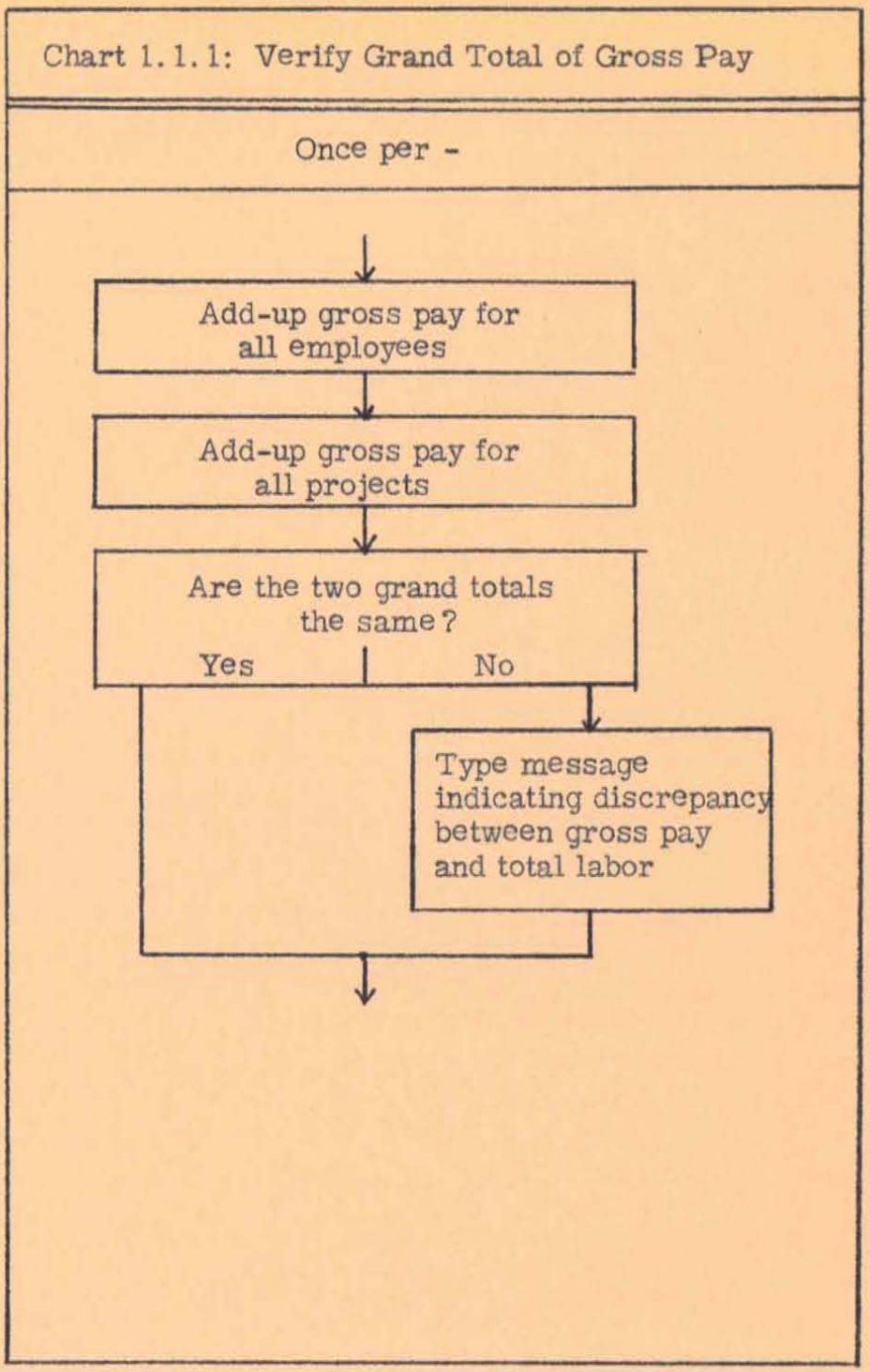

FIGURE 10: Detail of the detail chart shown in Figure 9

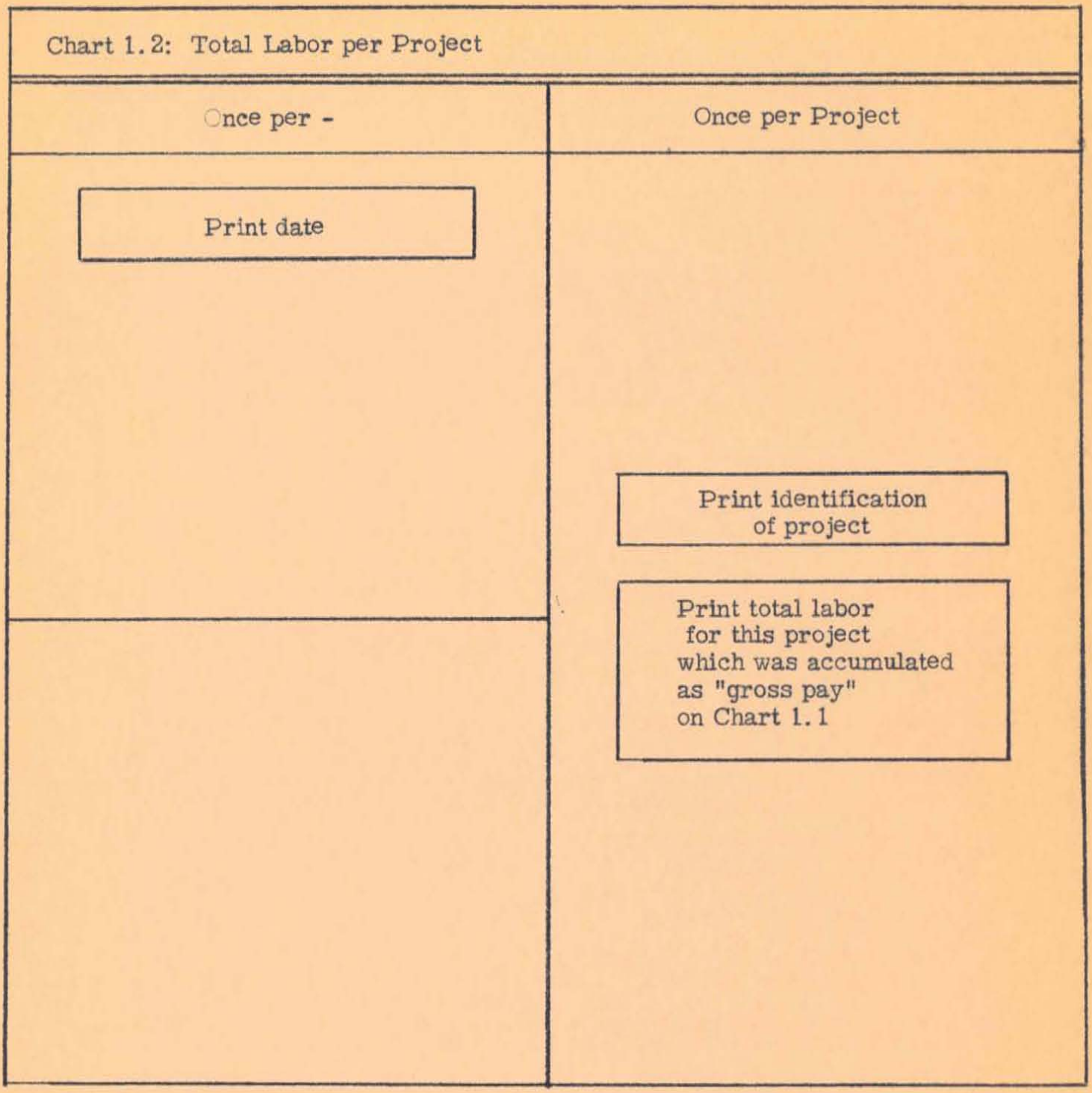

FIGURE 11: Second detail of the chart shown in Figure 8

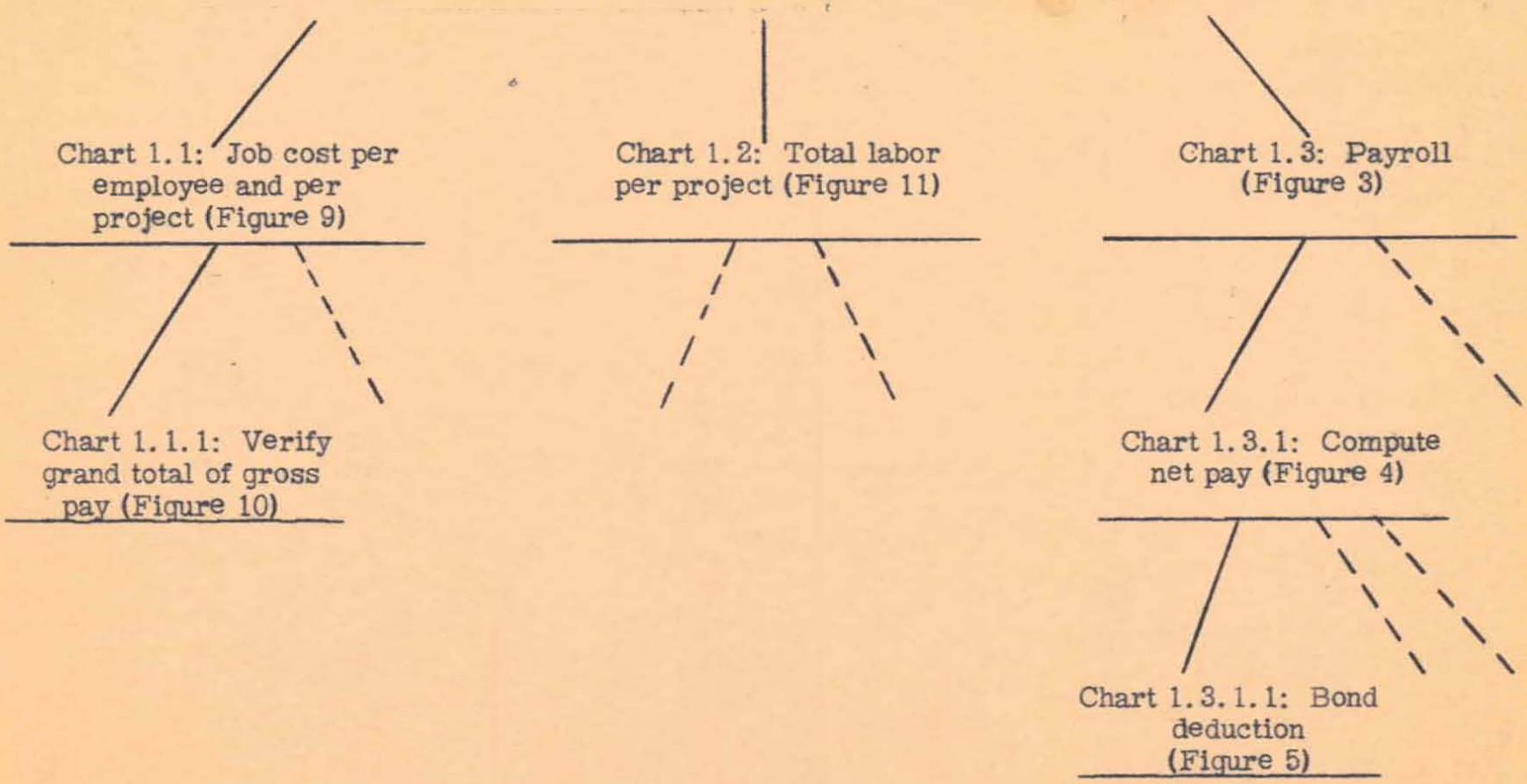

FIGURE 12: Cross section through a system of procedure charts