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SOFTWARE DESIGN FOR AN OPERATING MANAGEMENT INFORMATION AND DECISION SYSTEM BASED ON LINEAR PROGRAMMING

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This is a minor revision of a paper presented at the Research Conference on Management Information Systems, Carnegie-Mellon University, June 17 - 19, 1968; and to be published in the proceedings volume. It is based substantially on my Ph.D. dissertation. I am indebted to D.C. Carroll, J.D.C. Little, and L.S. White for their aid.

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SOFTWARE DESIGN FOR AN
OPERATING MANAGEMENT INFORMATION AND DECISION SYSTEM
BASED ON LINEAR PROGRAMMING

by

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ABSTRACT

While Linear Programming (LP) is acknowledged to be a powerful technique for obtaining optimal production rates, there remains the problem of making an LP model usable as the basis for day-to-day decision-making. This paper describes the design and construction of a support system allowing a group of managers to use an LP model as a decision-making tool. The particular context is meat-packing, but the work is relevant in any situation where an optimization technique is to be used as the basis of a planning and control system involving many controllable variables and a need for timely information.

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Introduction and Overview

The Aggregate Production Scheduling problem may be thought of as the determination of the rates of resource utilization in the production process. This paper attacks the design of an interface between a powerful Aggregate Production Scheduling technique, Linear Programming or LP, and the information and decision system used by a group of managers charged with responsibility for day-to-day resource allocation decisions. The context is the (pseudonymous) Peerless Packing Company where a group of men called provisioners plan and control the rates at which raw materials are bought and allocated to production, by-products are sold, and finished goods are placed into inventory. The provisioners control roughly 1,000 different rates, and LP offers them the potential for a truly global and economic planning model. Moreover, LP by-product information is useful for making decisions about marginal changes in the plan.

The existence of a good technique like LP, or even of an LP model of the Peerless Operations still leaves us short of a useful tool for management. Two problems arise which must be resolved:

First, prices of raw materials change rather rapidly. Like any profit optimization technique, LP is sensitive to price changes. This fact forces us to design our system both to respond quickly when necessary and to produce plans with inherently long life. While this paper considers these points, they are more fully discussed in Sprague (16).

Second, the LP model must be made easy to use, e.g. the reports prepared for the managers must be clear and meaningful, etc. This paper is concerned primarily with this part of the task.

In the following sections we describe the provisioning environment at Peerless and the LP model constructed to aid in planning. We then propose an "ideal" system for making the LP model useful to management. While we believe that the "ideal" system is feasible, given sufficient resources, it could not be built at Peerless. At a second level of consideration, then, is the problem of how much of the "ideal" system could be realized where adequate resources were unavailable. We detail the design and construction of our LP-support system which did indeed preserve most features of the "ideal" system with severely limited resources.

The Provisioning Environmnet at Peerless

Peerless is a pork-oriented meat packer which lost several millions on sales of $300 million in fiscal 1966. For the purposes of this study, Peerless may be considered to be a pure price-taker* in both buying and selling, and to have only one plant (located in Cedarton, Iowa), though neither is strictly true. The manufacturing process at Peerless begins with live hogs and ends with several thousand finished products ranging from whole fresh pork loins, through processed meats such as bacon, hams and sausage, to portion-controlled frozen foods.

In order to balance out its production process, Peerless also does

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*I.e. unable to influence market prices.

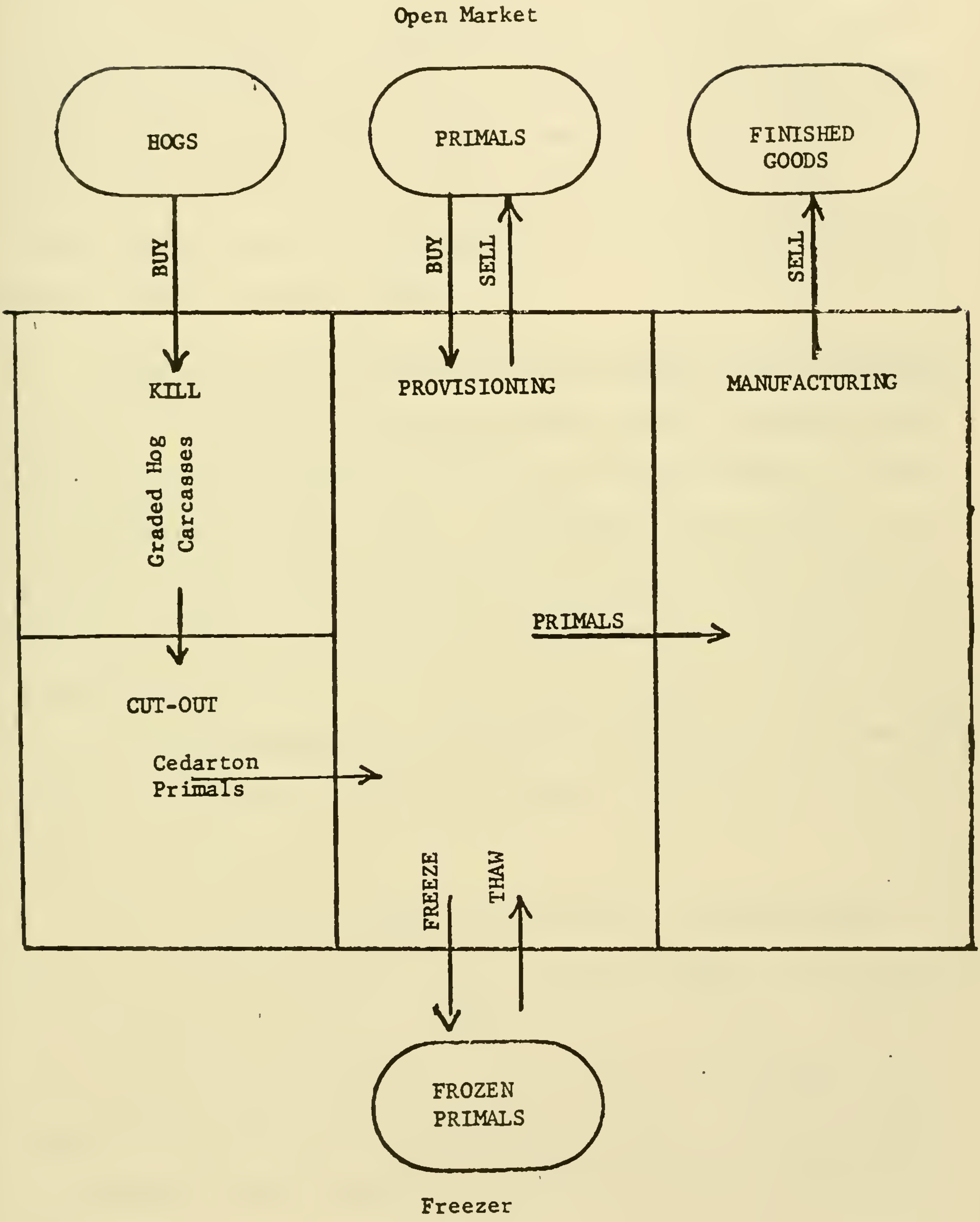
substantial trading in primal cuts (major components of hogs, such as green (uncured) hams, green bellies, and loins). For example, Peerless has a considerable consumer franchise for its bacon, so has long been a net buyer of bellies; but it is always selling loins, since it is weak in fresh meat. There are also several components purchased for use in manufacturing, such as cans, cure, and beef for sausage. Similarly, many by-products are sold, including relatively unprocessed items like skin and hair, and highly refined products like lard.

A description of the organization which now solves the aggregate production scheduling problem for Peerless is in order; imbedded within it will be considerable information about the nature of its production process (see Figure I). We should begin at the end of the production lines since this is a convenient aggregation point -- many of the thousands of final products already mentioned differ from one another only in final packaging, and many others are insignificant in volume. There are perhaps 300 unique and important final products.

The production scheduling function for these final products is performed by several men known as product managers. Each product manager serves as the interface between the sales and production operations for one particular category of product. He is responsible for translating a demand figure supplied by sales into a feasible production schedule, and for deciding what priorities should be attached to each individual product when all demand cannot be met. He must also cope with overstocks, old meat, and so on. While he does not have the final say on pricing, he is always consulted before price changes are promulgated and before special marketing efforts are undertaken. When

Figure 1

GROSS PRODUCT FLOW
PEERLESS PACKING COMPANY



the product manager is dealing with a perishable product such as fresh sausage (bologna, etc.), his life is complicated by short inventories, high spoilage costs, and market demand fluctuations. When he is dealing with a long-lived product like canned ham, he is spared some of the day-to-day fire-fighting. But he must work against long-term forecasts of demand and prices, making the daily decision as to whether or not to put meat into cans, based on his raw material replacement cost which fluctuates hourly.

Each product manager depends for his raw materials on the provisioners, who are responsible for supplying primal cuts to the manufacturing operations. The provisioners' major sources are the internal kill-and-cut operation and the open market. Unfortunately, every primal cut is available in several sizes at different prices and different yields in manufacture. The provisioner cannot control the mix of primals produced internally, but he can control the mix of purchased primals; he has access to freezer space for hedging and filling gaps in availability, and he is responsible for selling any primals not required by the manufacturing operations.

The provisioner has another sensitive duty: he must allocate finite raw material resources among the product managers in those cases where there is not enough of a desirable size to go around. This involves substitution of other sizes, with corresponding changes in expected yields and in the quality of finished product. The provisioner is faced with rapidly varying prices for primals, both in buying and

selling; the quantities available for purchase and wanted by potential buyers also vary daily. Finally, the quality of purchased primals is variable but generally lower than that achieved internally because of the tendency of sellers to cull their excess primals before offering the lower-quality ones to the market.

It is not surprising that provisioners prefer their own product, for which they are dependent on the hog buyer. The hog buyer acquires hogs on the open market for the kill-and-cut operation. He determines how many hogs are to be killed by day and by week. He has considerable flexibility because there are three ways to control the daily rate of kill-and-cut: overtime, extra shifts, and chain speed. He need not work a full week, but Peerless pays each worker in cut-and-kill for 35 hours per week at minimum, so he tries to keep the facilities and men busy.

Hogs are a highly variable commodity and, while prices are quoted on 108 different sizes and grades of hog, each of which tends to cut out differently, the hog buyer has no effective control over the mix of hogs purchased at any time. He is aided by the law of large numbers in that the mix tends to be relatively constant from day to day, changing over the year to reflect stages in the growth cycle.

The hog buyer's most potent decision tool is a daily report showing the profit which would have been earned on every hog killed yesterday is the hogs had been bought at the Chicago market price, killed and cut at exactly standard cost, and immediately sold as primal cuts and offal at the Chicago market price. The usefulness of this tool is ob-

viously limited by the simple fact that Peerless is not primarily in the business of selling primal cuts, and by the fact that nothing is ever done at standard cost, especially when guaranteed wages enter the picture.

Thus, the hog buyer feeds the provisioners, and they feed the product managers. It is clear that the provisioning function is the center of the whole operation. We shall assert that this three-stage decision-making process is a reasonable attempt at coping with the complexity of the manufacturing process and the uncertainty of market prices.

There are about 1,000 important levels to be controlled in the conversion of hogs to money at Peerless, including several hundred within the production process which arise from the many alternative ways in which one single finished product can be created. These make the aggregate production scheduling job entirely too much for one man; but one alternative, decentralized decision-making with local data (_Cf_ the hog buyer), is _a priori_ suboptimal.

In fact, the provisioning function at Peerless is currently handled by several men under the general supervision of the Chief Provisioner whose responsibilities include both "provisioning" and "production." The individual provisioners have individual product-line responsibility and, except for the odd phone call, they operate independently of one another. Once a week, they meet to plan for the following 10-day period. Conflicts are resolved by consultation among the Chief Provisioner and the affected provisioners and/or product managers.

Using Carroll's* terminology, we may characterize the provisioning system at Peerless as a set of local-real-time systems, tied by a loose communication net, and supervised by a global-periodic system (the weekly meeting). It is doubtful whether any other organization would be more effective. At the risk of sloganeering, we should point out that such an arrangement is modular and open-ended, and that it permits the Chief Provisioner to manage by exception. Unless one wishes to completely overthrow the present system, thereby incurring what are presumably large changeover costs, one must support the local-real-time systems by means of better plans and better tools with which to fight fires, and one must support the global-periodic system with better information. With LP, one can supply the global-periodic system with truly global, truly optimal results.

But the present system permits the provisioners to gather whenever there is a crisis of sufficient size to justify a meeting. The production/provisioning planning system should also be able to help with such <u>ad</u> <u>hoc</u> meetings. Thus, it must be capable of quick response as well as transparent to a variable time between operations of the global-periodic system (meetings).

So far we have considered the needs of the provisioner only in general terms, and this consideration has yielded a very general outline of the system needed to support him. We will now use the term "provisioner" to include the functions performed by the hog buyer and

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* See (9).

product managers, and we go into more detail about the function of the provisioners.

First, we consider the routine global-periodic provisioning functions:

1. Acquisition: How many hogs should be purchased? On what schedule? In which markets? How many of each of 25 types and sizes of primal cuts should purchased?
2. Allocation: How much of each primal cut produced, purchased, or removed from the freezer should be allocated to the production of each final product?
3. Disposal: How much of each primal cut should be sold on the open market? At what price? On what schedule? To whom? How much of each primal cut should be frozen for later use?

These decisions are constrained by such factors as cash available, primals available in the market, demand for primals in the market, hogs available, plant capacities, demand for finished product, and so on. They are obviously highly interactive one with another.

Now we consider a sampling of local-real-time provisioning functions:

4. Acquisition: Another packer has offered us a carload of picnics at one cent off market price. Do we accept?
5. Allocation: A sudden order for a large amount of some finished product cannot be filled by present stocks of finished product, in-process product, or even allocated raw materials. Do we acquire more raw materials? Do we acquire more raw materials (primals), substitute another size of the needed primal, refuse the order, or do some combination of these?
6. Disposal: A carload of loins is growing old, but at present market price we take a loss of two cents on each pound. Do we sell at a loss?

7. Price Change: Green hams are up two cents this morning. We suspect that this is a temporary rise which will never be reflected in increased price for finished product. Do we suspend ham processing and/or sell off our green hams?

We now proceed to describe what will be referred to, for want of a better term, the "ideal" system. In so doing we indulge in two fantasies. First we assume that the payoff from the use of this system will justify its running cost. For this purpose we assume that it will consume about 1/8 of the available time on a data-processing system costing $400,000/year, or $50,000 in data-processing costs/year. In addition, we allow $50,000 more for maintenance and special data collection. Routine data-collection costs are assumed to be absorbed elsewhere (as described below). In order to justify its costs then, it must save (or produce) $100,000/year, or 0.04% of sales. Our second fantasy is to assume that Peerless can support the $400,000 data processing system mentioned above. This is about 0.16% of sales and is not a priori unreasonable, but it is unreasonable in Peerless' present situation. Nonetheless, we must assume it for now.

Several more assumptions are necessary, all of which are reasonable. First we assume that certain key pieces of data are available at no incremental cost from the accounting system. When this project was begun Peerless was in the process of building and implementing PYRAMIDS (Plant Yield Reporting and Management Information Dissemination System). PYRAMIDS (which at this writing is in regular operation) was to contain all price, inventory, shipment, and yield information as a matter of course, thus eliminating the need for separate routine

data collection. Another assumption is that the role and nature of the men now serving as provisioners will not change substantially.

Finally, we adopt a convention for describing the LP model on which the system is based. The model will be described in terms acceptable to the "bounded variable algorithm"* in which upper and lower bounds may be attached directly to the columns, primarily because the majority of limitations encountered in formulating this model appropriately affect only a single column. In the few cases where a real inequality row is needed, it costs only one new column to convert it to an equality row with explicit bounds on the newly-created column. This results in a much more compact model (in this case, there would be 2500 or more rows if every bound required a new row), and means that, since every row is a structural equality not subject to the control of management, the important shadow prices -- those for real resources -- are grouped naturally with the remaining information about the columns. Thus the user need not maintain any sort of dictionary to guide him from a particular column to corresponding bound rows. The compactness means that the model can be made to work on a smaller machine than would otherwise be required, though no reduction in solution time is implied. The output is somewhat more compact, since it is unnecessary to present information about the rows. For all these reasons, the model will be built and maintained as if it were in the bounded variable form, even though it may well be run on a machine for which no such code currently exists.

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* Hadley (3).

Model Description

Before describing the "ideal" system we should discuss the LP model underlying the planning process. The general LP problem, cast into a form consistent with our model formulation is:

$$\text{Maximize} \qquad Z = \sum_{J=1}^{N} C_j X_j$$

Subject to:

$$\sum_{J=1}^{N} a_{ij} X_j = 0 \; ; \qquad i = 1, M$$

$$L_j \leq X_j \leq U_j \; ; \qquad J = 1, N$$

where X_j is the value of the j^{th} variable or quantity to be determined (e.g., pounds of a primal to be bought); C_j is the price of variable j; a_{ij} is the coefficient in column j and row i; L_j is a lower bound for variable j; U_j is an upper bound for variable j. There are N variables or columns and M rows or equations.

An LP solution is feasible when the values of the X_j's satisfy all M equations and fall within their respective bounds. An LP solution is optimal when there exists no feasible change in the values of the X_j's which increases the value of Z. When a solution becomes optimal, each variable has associated with it a level or recommended quantity and a C-range or range over which, cet. par., the price of this variable may vary without loss of optimality. The level and the C-range are the two most important elements of the plan drawn for each variable.

The actual model (see Figure 2) is divided into ten logical units:

1. Kill: one variable representing total hogs purchased is divided up into 108 quantities of "live weight" of different kinds of hog. The model is also given the opportunity to purchase one pound of each kind of hog separately. This section requires approximately 220 columns and 110 rows.

2. Cut-out: 108 types of hog are converted to 35 types of primal. Labor costs are assessed and by-products accounted for. This section requires approximately 100 columns and 40 rows.

3. Hams: cut-out primal hams are summed with purchased and thawed hams to give total ham availability. This is distributed between sales, freezing, and production. Hams to production are allocated to smoking and/or canning. Each ham is allocated to a particular process ending in one or more finished products. Labor costs and by-products are accounted for. This section requires approximately 300 columns and 170 rows.

4. Bellies

5. Picnics

6. Loins

7. Butts

8. Ribs: These sections are somewhat less complex than hams, but the same general formulations are used. These sections total approximately 300 columns and 160 rows.

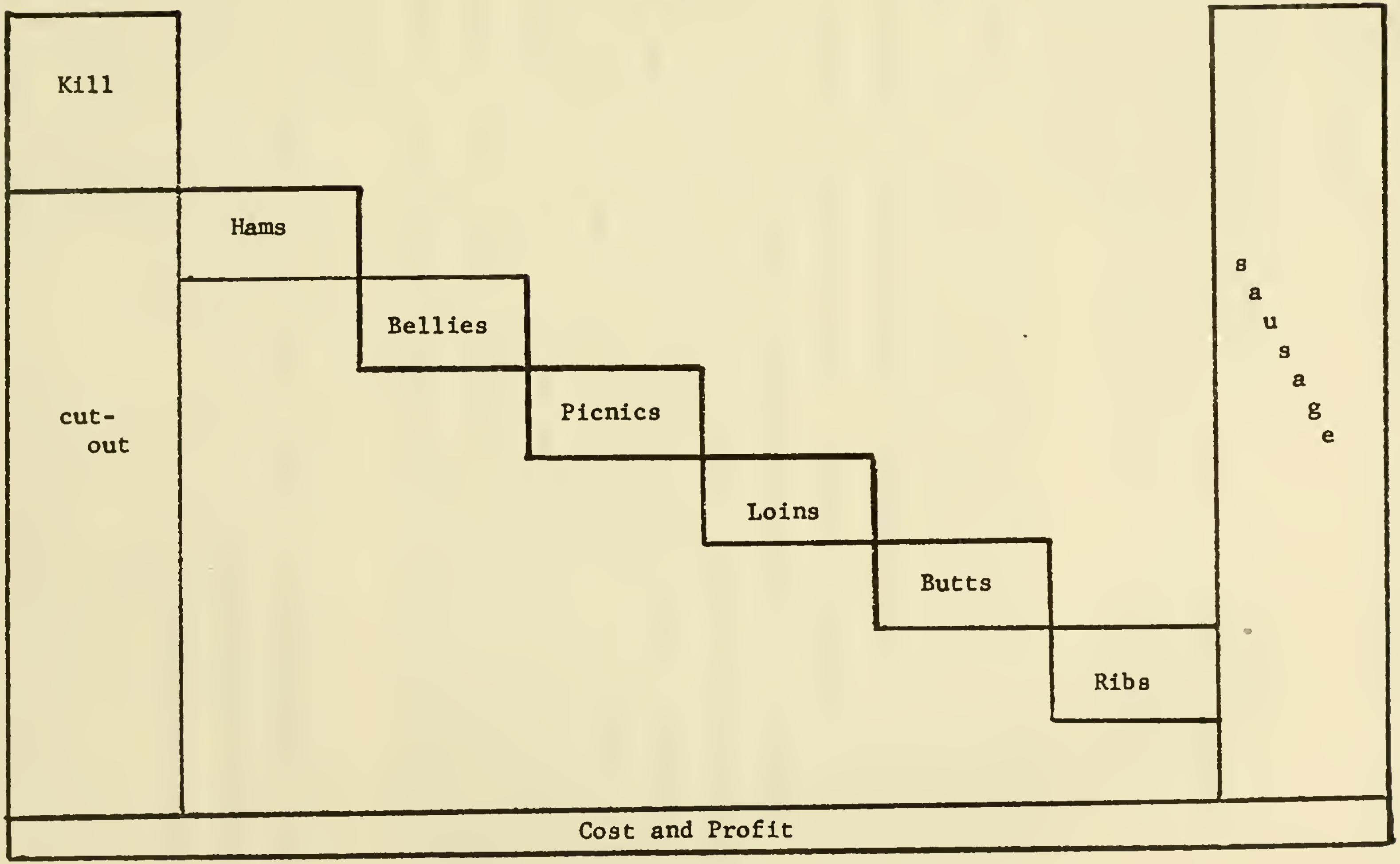
9. Sausage: This section serves as a sink for by-products produced in all other sections. Because each material is at least potentially usable in every sausage, each separate kind of sausage requires approximately 50 columns and 10 rows, for a total of 1000 columns and 200 rows.

10. Cost and Profit: This section merely sums up various labor costs and facility usage data for management use. It requires only about 10 extra rows and 10 extra columns.

Figure 2 accurately shows the relationship between these sections; e.g., it is true that hams and bellies interact only at the points of

Figure 2

LP MODEL STRUCTURE



cut-out, sausage, and cost and profit; and it is true that all sections feed the sausage section.

The Ideal System: General Philosophy

Having described both the provisioning environment and the form of an appropriate LP model, we now describe the "ideal" system and its role as an interface.

One possible requirement of the ideal system is that it dominate the present system. This is relatively easy to accomplish, since it is always possible to invoke the present system for any task which is better accomplished by present methods. However, the power of the present system comes in some part from the fact that the individual provisioners are always in possession of quite recent information about the current status of their product areas. So an obvious requirement on the ideal system is that it supply provisioners with information at least as current as what they now have and, conversely, that they be able to supply it with current information when such would help. Along this dimension, the ideal system looks like an information storage and retrieval system.

Another desirable characteristic is that the system be able to answer such questions as "What would happen if an extra carload of bellies were made available to the plant?" This is the essential characteristic of a simulation system.

And, we want to be able to ask the system for the optimal plan for the following week, based on current or projected information.

In this regard, we are talking about a conventional optimization technique.

Since the Chief Provisioner can call a special meeting to invoke the present system at any time, it is not unreasonable to expect the ideal system to respond as quickly. So the ideal system must consist of data-collection and editing subsystems, an optimization subsystem, and report generation subsystems. It must operate as a true on-line system or at worst as a remote job-entry system with rapid turn-around to provide the requisite level of response time.

The following sections describe the required subsystems. The descriptions are written as if the data-processing system available had massive random-access storage capability and the ability to create and use symbolically-named files. While neither of these features is strictly necessary, both are great conveniences for the system designer. The descriptions also assume a command language which can be used to drive the subsystems. Such command languages are an integral part of modern remote-job-entry oriented operating systems such as OS/360.

The Ideal System: Data Generation and Editing

The data-generation and editing subsystems have at least the following capabilities:

1. FORECAST:

> Using the PYRAMIDS files of shipment and order data, the system generates forecasts of sales for all finished products for some arbitrary period. It places these forecasts in a file called:

MACHINE . FORECASTS . MMDD

where MMDD is today's date.

2. FCSTUPDATE:

The system delivers the information in the latest file named MACHINE . FORECASTS . MMDD or HUMAN . FORECASTS . MMDD to the user's console or remote printer. It then accepts the user's revisions to these forecasts. It enters the modified forecasts in a file called:

HUMAN . FORECASTS . MMDD

3. MODSTRUCTURE ALPHA BETA

The system accepts changes to the LP structural equations contained in file

ALPHA . STRUCTURE

and places the changed structural equations in file

BETA . STRUCTURE

4. DRAWSTATUS GAMMA DELTA

The system searches the file

GAMMA . STRUCTURE

to find what price and quantity information is required to run the model. It then searches the PYRAMIDS file and the latest version of

HUMAN . FORECASTS . MMDD

to fill in prices and quantities. Some prices will require special manipulation. For example, PYRAMIDS keeps all prices as positive numbers. Some will need to be made negative for the purposes of the LP. In the case of long-life products, some deduction from selling price will be required to account for holding costs until expected sale. For guidance in these operations, the system will refer to file

DELTA . PRICERULES

The result will be a complete LP problem ready to be run in the file

GAMMA . STATUS

It can be argued that this subsystem permits great generality in model structure (via MODSTRUCTURE) and in price manipulation (via DRAWSTATUS), but that it is slavishly tied to price and quantity information contained in the PYRAMIDS files. This is desirable because the PYRAMIDS files must be correct for proper functioning of the accounting system. However, to correct the occasional error and to allow the user to try out "What would happen if . . . " questions, we also require:

5. EDSTATUS GAMMA EPSILON

This permits the user to change the information in GAMMA STATUS, filing the result as EPSILON . STATUS.

The Ideal System: Optimization

The optimization subsystem supports the single command:

OPTIMIZE GAMMA

The system takes the file

GAMMA . STATUS

and converts it into the required input format for the manufacturer's LP package. The LP code then takes over, returning control to the OPTIMIZE command when done. This output is then filed under the name

GAMMA . SOLUTION

It is worthwhile to note here that one would not normally write his own LP package, because many major manufacturers (IBM, CDC, UNIVAC, etc.) supply truly excellent LP codes for their larger machines. Such codes are characterized by large capacity, availability of comprehensive start-up and post-optimality procedures, and, just as important, embody control languages allowing a limited amount of external logic to be performed by the code itself. Thus special procedures in case of in-

feasibility or wildly unlikely solutions can be specified by the user as part of his input.

The Ideal System: Report Generation

The report generation subsystem has at least the following capabilities:

1. REPORT GAMMA ZETA

Produces for the user a report of the model described in GAMMA . STATUS. For each column of the model (remember that we have no need for row information), the report should confirm:

Alphabetic description of the variable
Objective-Function Coefficient (price)
Lower Bound if any
Upper bound if any
Recommend Level (Solution Value)
Activity Status (in solution or not, at upper/lower bound)

Maximum Price (Algebraically maximum value of objective function coefficient at which this column's solution status remains unchanged)

Activity Limiting Maximum Price

Solution Status of Limiting Activity

Minimum Price

Activity Limiting Minimum Price

Solution Status of Limiting Activity

Marginal Return for Increase (Net change in Objective Function for One-Unit Increase in Activity Level)

Maximum Level (Before Marginal Return for Increase Will Change)

Activity Limiting Maximum Level

Solution Status of Limiting Activity

Marginal Return for Decrease (Probably has, but may not have, same magnitude and opposite sign as Marginal Return for Increase)

Minimum Level

Activity Limiting Minimum Level

Solution Status of Limiting Activity

This represents most of the information available about a solution short of parametric runs. It suffices to allow the user to:

a. Base a plan on the recommended levels

b. Base marginal decisions on the price-and-constraint range information.

In order to prepare this report, the system will have to use both files

GAMMA . SOLUTION
GAMMA . STATUS

and

For convenience in later use, the complete report should be placed in a file

GAMMA . REPORT

It is likely that the user will wish to suppress some of the output and/or aggregation techniques. In order to allow this, the REPORT command allows the parameter ZETA which, if present, causes the system to build the user's report according to tables stored in file

ZETA . FORMAT

2. COMPARE GAMMA OMEGA ZETA

Using the report files from <u>two</u> solutions i.e.

GAMMA . REPORT and
OMEGA . REPORT

the system prepares a difference report according to

ZETA . FORMAT

and presents this to the user.

3. PLAN GAMMA IOTA

The system presents file

GAMMA . REPORT or
GAMMA . PLAN

to the user, who enters planned levels and prices wherever his plan differs from the levels and prices in the input file. Whenever he does not enter a new value, the number given in the input file is taken as the planned number. The result is filed under the name

```
IOTA . PLAN
```

4. CONTROL IOTA ZETA

The system searches the PYRAMIDS files for actual performance figures (amount produced or allocated, prices realized, etc.). It then searches

```
IOTA . PLAN
```

for the planned numbers and produces a control report contrasting planned and achieved numbers, according to format file ZETA.

How the Ideal System is Used

Let us suppose that the system is now in use. The current plan is based on files

```
CURRENT . STATUS
CURRENT . SOLUTION
CURRENT . REPORT
CURRENT . PLAN
 NORMAL . PRICERULES
CURRENT . STRUCTURE
 NORMAL . FORMAT
```

and is now a week old. It is time to prepare next week's plan. The sequence

```
FORECAST
FCSTUPDATE
```

has been run. Slight changes are expected in plant yields due to a change in the average characteristics of hogs available; so, we have to modify the structural equations of the model accordingly. Therefore, we

```
MODSTRUCTURE  CURRENT  NEXT
DRAWSTATUS  NEXT  NORMAL
OPTIMIZE  NEXT
REPORT  NEXT  NORMAL
COMPARE CURRENT  NEXT NORMAL
```

Examining the difference report comparing CURRENT and NEXT, we see that several quantities have changed greatly. On further investigation, we see that prices for 2 primals have been reversed in the PYRAMIDS file. We cope by issuing

```
EDSTATUS  NEXT  NEXT
OPTIMIZE  NEXT
REPORT  NEXT  NORMAL
COMPARE  CURRENT  NEXT  NORMAL
```

This time, our examination convinces us that the model NEXT is satisfactory. We, therefore, hold our weekly planning meeting during (or at the conclusion of) which we issue

```
PLAN  NEXT
```

and enter the plan for the week ahead.

From this point on, any product manager or provisioner can find out the current plan and how he is doing in comparison by issuing, say,

```
CONTROL  NEXT  HAMS
```

where the file

```
HAMS . FORMAT
```

contains instructions to select just the ham sector of the report.

Now suppose the provisioner wants to know whether or not to accept an extra carload of picnics. In most cases, the regular report gives him the marginal value of extra pcinics. If he doesn't feel confident about this, however, he can try

```
EDSTATUS  NEXT  SPECIAL
```

and create a new file

```
SPECIAL . STATUS
```

containing the information that extra picnics are available. He then issues:

```
OPTIMIZE SPECIAL
REPORT  SPECIAL  NOPAPER
COMPARE  SPECIAL  NEXT  NORMAL
```

where the file

```
NOPAPER . FORMAT
```

suppresses actual production of the regular report, but does allow creation of the necessary file

```
SPECIAL . REPORT
```

He must be aware that the sequence above compares only two *recommended solutions*, not two *plans*, but he does get an excellent idea of the consequences of accepting the extra picnics.

The system as described above is thus able to answer virtually all questions of the type posed above. In addition, we need only require that forecast information and realization information (the latter from PYRAMIDS) be converted into *weekly rates* to make the system absolutely transparent to whether planning is done daily, weekly, monthly, or at any intermediate interval.

The system's response time is, of course, dependent on the speed and size of the machine(s) on which it is resident, and also on its mode of operation (on-line, remote batch, normal batch, etc.); but, in most cases, one day would seem to be an upper bound on a complete re-planning.

On the other hand, such a system would be expensive to build. (How expensive it would be is impossible to estimate at this level of detail in description and without a particular machine and operating system in mind.) Once built, system maintenance would be modest, since the system itself consists mainly of very general data-manipulation subsystems. Maintenance of the data base is largely absorbed by PYRAMIDS. The major flaw in this "ideal" system is that its use would require either some substantial change in the roles of the provisioners or the interposition of a cadre of technicians between them and the system. While neither is strictly desirable, the latter alternative is costly and likely to introduce errors. In the long run, the provisioners probably would find it desirable to become intelligent system users themselves.

There will have to be technicians, of course, to step in when solutions are infeasible, unbounded, or unreasonable. These people should preferably combine computer, LP, and provisioning expertise. Their salaries are part of the cost of running this system.

Available Resources

In reality, Peerless had neither the large EDP installation called for, nor the personnel corresponding to such an installation. It will be convenient to organize our description of resources which were available into machine and human categories.

Machines: Peerless had two UNIVAC 1050's, each of which had five tape drives, reader, punch, and printer. While the project was in progress the core storage sizes of these machines were in flux, but

neither was ever larger than 24,576 bytes of storage. Initially, Peerless also had a UNIVAC 1004, which is a general data-conversion machine permitting translation between any valid combinations of cards, magnetic tape, paper tape and printed output. The 1004 was removed when one of the 1050's was augmented by a paper-tape subsystem. In addition, Peerless had card-handling equipment oriented toward UNIVAC 90-column cards, including keypunches, sorters, duplicating punches, and the like.

EDP Personnel: Peerless had an EDP organization consisting of three departments (operations, programming, research) reporting in parallel to the Vice President for Administration; the operations section was the largest. The programming section averaged about six men; the research section was in fact one man. Since both 1050's had been too small to support meaningful use of FORTRAN or COBOL until recently, the programming and operations sections were familiar only with PAL, an assembly-language system.

Non-EDP Personnel: Peerless had a major asset (for building an LP-based planning system) in its Process Design group. The group varied in size (averaging around six) and had responsibility for a wide range of analytic activity (e.g. calculating yields, analyzing hog purchase, etc.). Also, this group regularly ran LP-based sausage formulations. The group had some knowledge of LP and access to the information needed for constructing the LP model, but they were organizationally independent of and isolated from the provisioners, which reduced their effectiveness somewhat.

How Limited Resources Affect System Design

Preliminary estimates indicated that the LP model underlying the planning model would need about 1500 equality rows and/or upper bounds. While there existed a small-capacity LP package for the 1050's, there was no real hope for installing the LP on one of Peerless' machines. We had to look elsewhere for a machine to run the model.

We planned initially to use a UNIVAC 1107 located in St. Paul, Minnesota, 150 miles from Cedarton. Data transmission at Peerless was to be handled by a high-speed paper-tape system, or by a communication subsystem attached to one of the 1050's. Assuming five-level code, 1500 columns, 1500 rows and/or bounds, and an average of 200 characters of information about each structural variable and bound row, an ordinary 2400 baud telephone line would have permitted transmission of output back to Peerless in less than half an hour. We found, however, that there would be a large expense associated with such a communication subsystem and that the high-speed paper tape device had been removed. The alternative was a teletype 35 ASR for paper-tape punching; this would require about ten hours to punch all the output. Transmission of input to St. Paul was estimated to require another two hours.

It would not have been feasible to accept twelve hours of transmission time per run, especially since the probability of having to make at least two attempts per successful run seemed high. One possible solution was to transmit to St. Paul only changes in input data and to transmit back from St. Paul only changes in solution values, after

stripping out all excess blanks and other unnecessary characters. Preliminary estimates (and later experience with the actual LP model as tested elsewhere) indicated that this would reduce transmission time to about one and one-half hours. This was thought acceptable.

In order to achieve this reduction in transmission time it would have been necessary to maintain data files and file maintenance programs at St. Paul as well as at Cedarton. Starting with a new input file at Cedarton, we would have gone through the following procedure:

At Cedarton:

Using Old Input File and New Input File, produce paper tape containing changes

Transmit change tape to St. Paul

At St. Paul:

Receive change tape

Using change tape and Old Input File, create New Input File

Run LP with New Input File Producing New Output File

Using New Output File and Old Output File, create paper tape containing changes.

Transmit change tape to Cedarton

Rename New files as Old

At Cedarton:

Receive change tape

Using change tape and Old Output File, produce New Output File

Rename New Tapes as Old.

As can be seen, this procedure would have required nearly complete duplication of both information and programs in two widely separated locations. On reflection, therefore, it seemed unattractive. An alternative was carrying tapes to and from St. Paul by air. The time involved for this method would have been about the same as for teletype transmission, but, if necessary, someone could have accompanied the tape, thus allowing a number of possible tries at solution before returning. Planning thus began for a system with basic turn-around time of one full day.

Issues Raised by Long Turn-Around Times

The expected one-day turn-around time for the system imposed an absolute requirement that a plan drawn by the system be usable for two days after data input, if re-planning was to occur every day. Prices, however, can change hourly, and this caused some fear that no plan drawn could ever be implemented. Much hangs on our use of the word "usable." Under the present normal system, plans were drawn once a week and real-time modifications made as the week progressed. Certainly, a system which could draw a "better" plan once a week would be "usable" in the context of real-time modifications.

This thinking led to a proposed method of operation: the LP would be run on a basic weekly cycle. The provisioners would meet over the output to make their normal plan for the coming week. During the week of operation, the provisioners would have available the by-product information from the LP as well as a supplementary report detailing plans and achievements, and flagging major deviations. The normal real-time adjustments would be made, but, at some level of discomfort, the entire

planning process could be invoked with one-day lead time, regardless of whether it were early or late in the week.

Previously, we assumed that changeover costs were absorbed in the cost of planning. In fact, we were unable to determine changeover costs for the Peerless manufacturing operation. We were assured that in many cases these were minimal, since machines typically had to be cleaned and set-up each morning anyway. Clearly, however, a large change in the rate of hog-killing would cause costs to be incurred. We decided to leave this to the user of the system by giving him the approximate cost of <u>not</u> following a new plan. He could then decide whether or not to actually change production costs involved. This number also provides feedback to the user as to how necessary re-planning really was.

We expected that initial use of the planning system would show re-planning much more often than once a week, but that the proportion of times when new plans were implemented on the production floor would be relatively low. We also expected that, as users became more familiar with the system, their demands for re-planning would fall, while the proportion of implementation would rise. These expectations were based on the belief that humans are efficient pattern-recognizers and on the belief that profound changes in the structure of a solution would have relatively small effects on the value of the solution.

Design and Construction of the LP Support System

The LP support system was designed to give the users as many features of the "ideal" system as could be achieved on a small tape-oriented computer, given the necessity of carrying tapes back and forth between the "home" computer and the large machine required for the LP. Three major features had to be sacrificed entirely, though partial compensation was possible. (Other features, recognized as worthy but not absolutely essential for operation, were deferred and, as a result, never implemented.) The three lost features were:

1) On-line editing and modification of coefficients;
2) On-line calls for special reports; and
3) Monitoring by partial solution.

In our view, the most serious loss was the third. All question as to whether or not a solution remains optimal in the face of multiple price changes becomes unimportant if the LP code itself is available for monitoring. The process is simplicity itself: using the old basis inverse and the new set of prices, perform one matrix multiplication to determine the new set of reduced costs. If these are all non-positive (except for variables at upper bound which must be non-negative) then the solution remains optimal. Since the basis inverse really specifies a set of row transformations sufficient to change the initial simplex tableau into the final (optimal) tableau, it matters very little whether the inverse is kept in terms of the actual inverse (around 400,000 numbers), product form (usually many fewer numbers), or just as a list of variables and their solution status together with

the original tableau (least of all because of the sparseness of the original matrix). In any of these cases, the time required to recalculate the reduced costs in on the order of a minute or two on the class of machine needed to support the LP code itself. However, on a UNIVAC 1050 with 24K core and no random-access mass storage, this task becomes huge.

In this section we describe the design of the system in broad terms. It is appropriate to begin with the most important artifact of the system.

<u>The LP Master File</u>: The LP Master File is a single reel of tape containing all information required to run and/or interpret two different versions of the model. We will call these two models the <u>current</u> or A-model and the <u>new</u> or B-model. Both models are on the same tape for reasons of simple data-handling ease. The file is in column order, and for each column contains:

Column Coefficients for A-model
Alphabetic description of column
Solution information for this column of A-model
Column coefficients for B-model
Alphabetic description of column
Solution information for this column of B-model

Let us consider the use of the Master File throughout the planning cycle. Suppose we have just implemented a plan based on the most recent solution of the LP. At this point (take it on faith) the A-model and the B-model are identical. We now consider functions of the

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[*] See the Appendix for samples of many system artifacts.

support system, given this initial situation.

Modify Prices and/or Bounds: A new set of prices and bounds are prepared and punched on cards. These cards are used to update the coefficients and solution information corresponding to the *most recent* run of the LP, while the B-sector contains coefficients for the *next* run of the LP. B-model solution information is now meaningless.

Modify Model Structure: The same as above, except that coefficients other than prices and bounds may be changed, and whole columns and/or rows may be added or deleted. These two functions, which are handled by the same program, are the equivalent of MODSTRUCTURE (and EDSTATUS).

Monitor Changes: A report is drawn showing the net difference between the coefficients in the A-model and the B-model. That is, every coefficient which is either:

> Different in B from value in A; or
> Present in B but not in A; or
> Not present in B but present in A

is written out in a report giving before-and-after values.

Monitor Prices: Every column whose B-price is outside its C-range as defined by the A-solution is noted on a report, together with full information from both models.

List Model: The complete B-model is listed in column and/or row order.

Draw Input Tape: The B-model is transformed into a tape suitable for use as input to the LP package.

Optimize: Not a part of the support system, this step consists of carrying the LP input tape as prepared above, the optimal basis (on cards) from the last run, and any changes deemed necessary by the user, to the machine on which the LP code is resident. The output is a new optimal basis deck, an LP output tape, and printed reports.

Update B-Solution: The LP output tape is used to update the B-solution in the Master File. The Master File now contains the most recently implemented model (A-model) and the most recently unimplemented model (B-model). Solution information for each model corresponds to its coefficient information and includes the quantities called for previously.

Report: The entire B-solution, together with alphabetic descriptions, is written in a report suitable for use by the provisioners and product managers.

Report Solution Changes: The entire Master File is scanned, and whenever the B-solution differs in any way from the A-solution, both are written out. By means of this function, the user can judge how profound the changes in solution actually were. In addition, this report contains the three objective function values mentioned above, namely:

A-model objective function;
B-model Abjective function; and
A-B objective function (A-quantities at B-prices)

Accept Solution: This routine (actually the same as the Report Solution Changes routine) produces a new Master File whose A-section has been replaced by the B-section; that is, the B-model is declared to be current.

Dump Model: The entire B-section, including coefficients, descriptions, and solution information is dumped in a single report to the major user. This gives him a superior ability to trace out any unusual result. In fact, this is the same routine which is used to create a listing of the model in column order. The difference is in the timing; the column list comes before the solution, the dump afterwards.

This completes the description of the main parts of the LP support system. In addition, there are two routines designed to prevent errors.

Monitor Inconsistencies: Every alphabetic description begins with a single character giving the class of variable (e.g. B for buy, S for sell, A for allocate, etc.). This routine checks every column description against its new (B-model) price and flags inconsistencies such as a positive price for a bought quantity.

Manipulate Prices: Designed to prevent errors by reducing the task of data input, this routine accepts a table of relationships between one master price (say the Chicago market for a primal) and many dependent prices (cost of purchase, return from sale of the same primal at Cedarton). It then accepts master prices and punches change cards to correspond.

Implementation of Variable Planning Interval Through Human Decisions: There are obviously two decision points in the replanning process. The first comes in deciding whether or not to re-plan. This decision is made by the provisioners using certain system functions already described. Remember that the B-model has the cumulative changes in coefficients since the A-model was run. At any time, the provisioners can invoke the Monitor Prices routine to get a list of all columns whose prices fall outside their C-ranges. The provisioners must still decide whether or not to re-plan. They will be aided by the report from the Monitor Changes routine. For instance, if there are a large number of columns appearing on the Monitor Prices report, but the Monitor Changes report shows them all to be proportional changes in the prices of various versions of one single primal, the odds are good that the current solution in fact remains optimal.

It is also true that, at any time, the provisioners can invoke the Draw Input Tape routine to initiate the remote procedure for obtaining an LP solution. Having done so, and having obtained an LP Output Tape and run Update B-solution, the provisioner is forced with deciding whether or not to accept (implement) the new solution. To aid in this procedure, he has three documents: the LP report as produced by the LP code itself; the LP report produced by the Report routine; and the Change report produced by the Report Solution Changes routine. He must judge whether the return from changeover to the new plan justifies its costs. These reports, and (later on) his experience in previous decisions of the same sort, should allow him to make good decisions on the question of acceptance.

Construction of the System: The system was constructed as a set of modules, some of which were programmed by UNIVAC personnel, the rest by Peerless. (See Figure 3.) The major modules were:

1) Create sorted change tape. Cards are accepted in a variety of formats, converted to a single consistent format, and sorted into column-row order for updating the Master File. One problem arose here -- the sort, a standard merge procedure, would not necessarily preserve the order of tied entries. As a result, no duplicate column-row combination could be tolerated in a single batch of change cards. This meant that change cards from two separate days (or, for that matter, hours) could not be batched together. A normal procedure for pulling duplicates was instituted temporarily, but the long-term solution was to append the serial position of each card in a batch to the sort key before sorting.

2) Update B-model. A sorted change tape is passed againt a Master File, and a new Master File created whose B-model embodies the changes specified. As above, no duplicate changes were tolerated in the first version; later versions were to ignore all but the last such duplicate.

3) Extract Extended Master File. The Extended Master File, consisting of complete B-model information in an easy-to-process form, is extracted from the Master File. This is used by several other modules (see below), and, as a bonus, is in the same format as a sorted change tape, so that it can be used to create a whole new B-model if necessary.

Figure 3

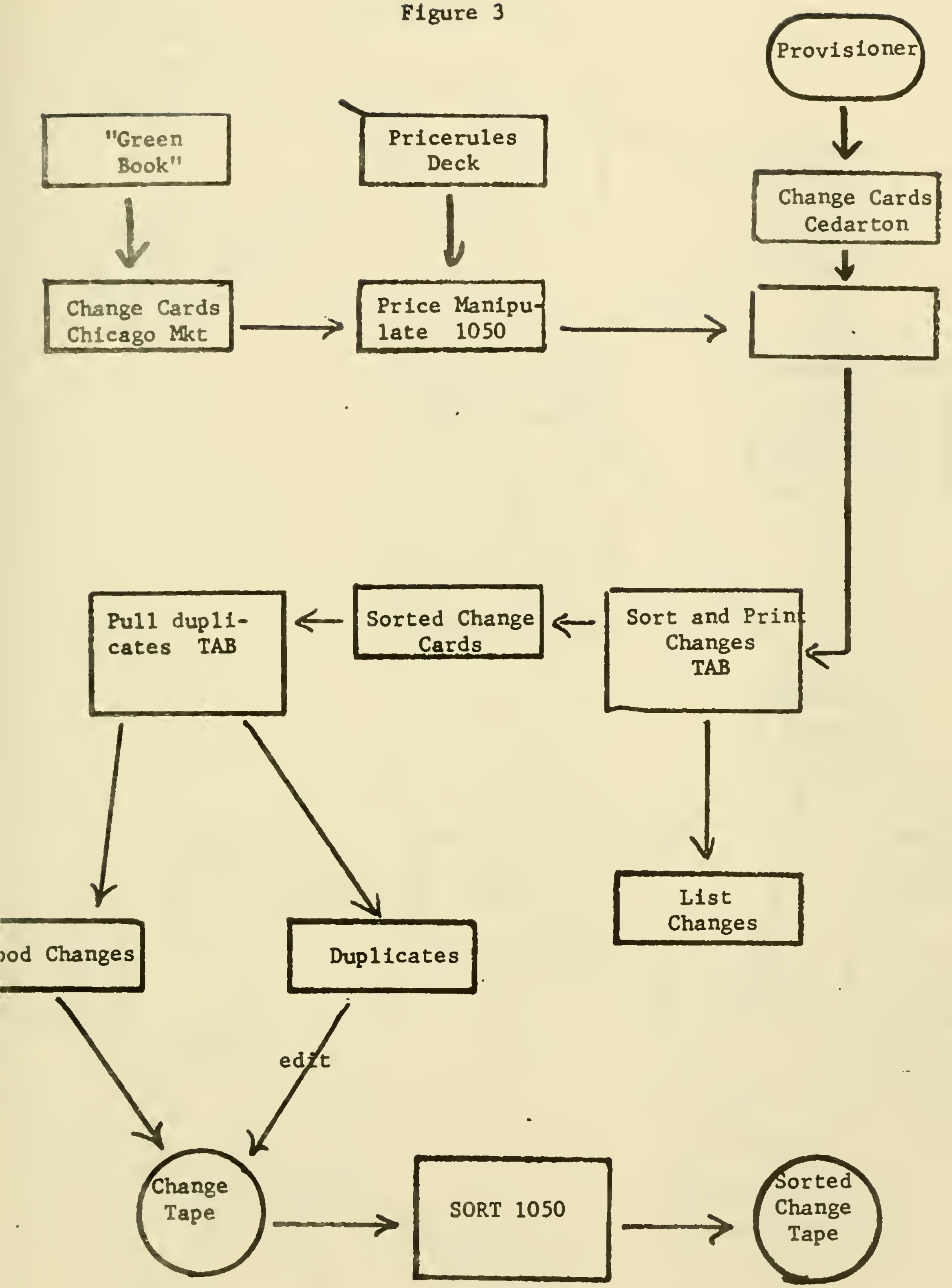

Provisioner
"Green Book"
Pricerules Deck
Change Cards Cedarton
Change Cards Chicago Mkt
Price Manipulate 1050
Pull duplicates TAB
Sorted Change Cards
Sort and Print Changes TAB
od Changes
Duplicates
List Changes
edit
Change Tape
SORT 1050
Sorted Change Tape

Figure 3 (continued)

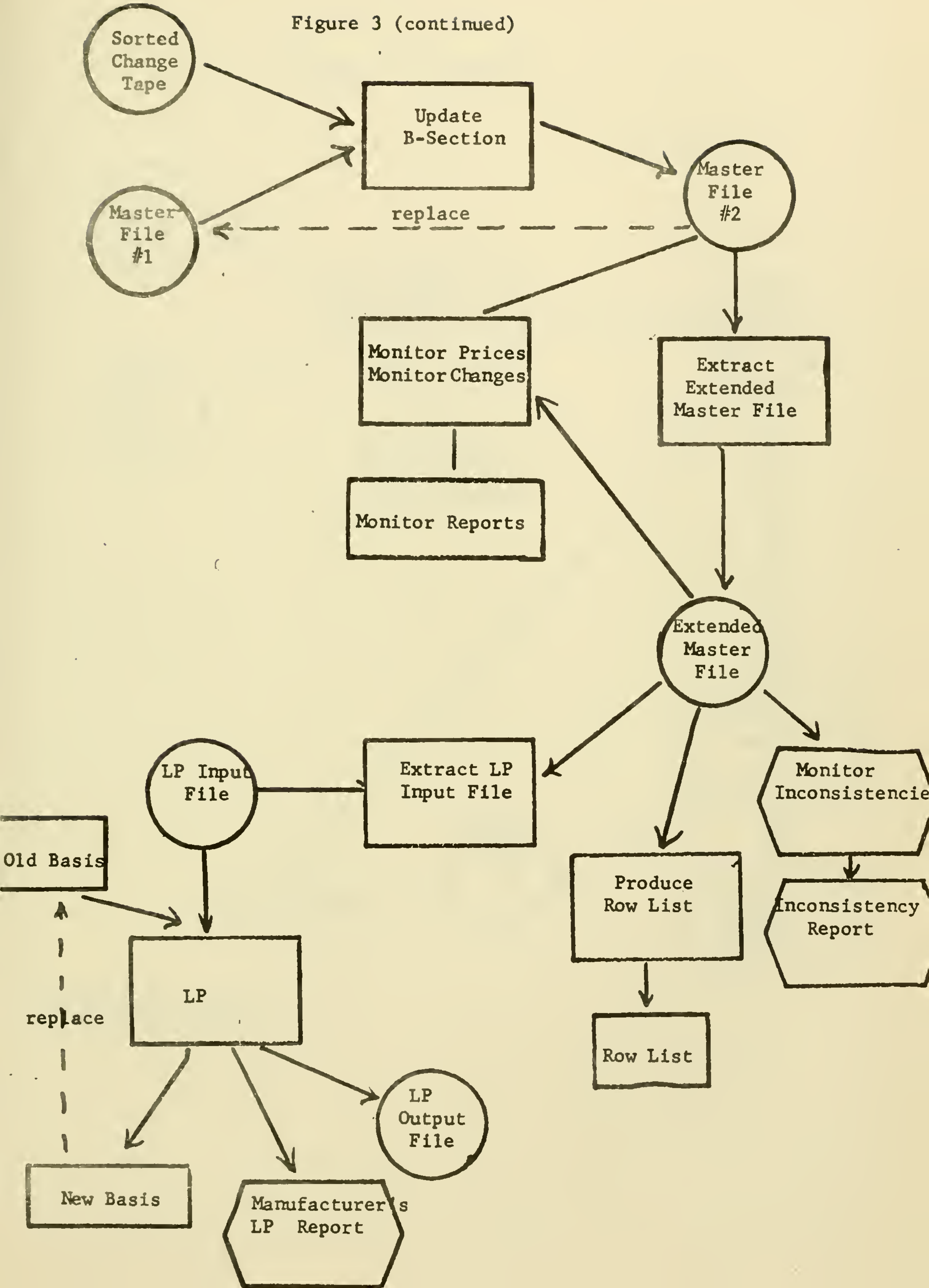
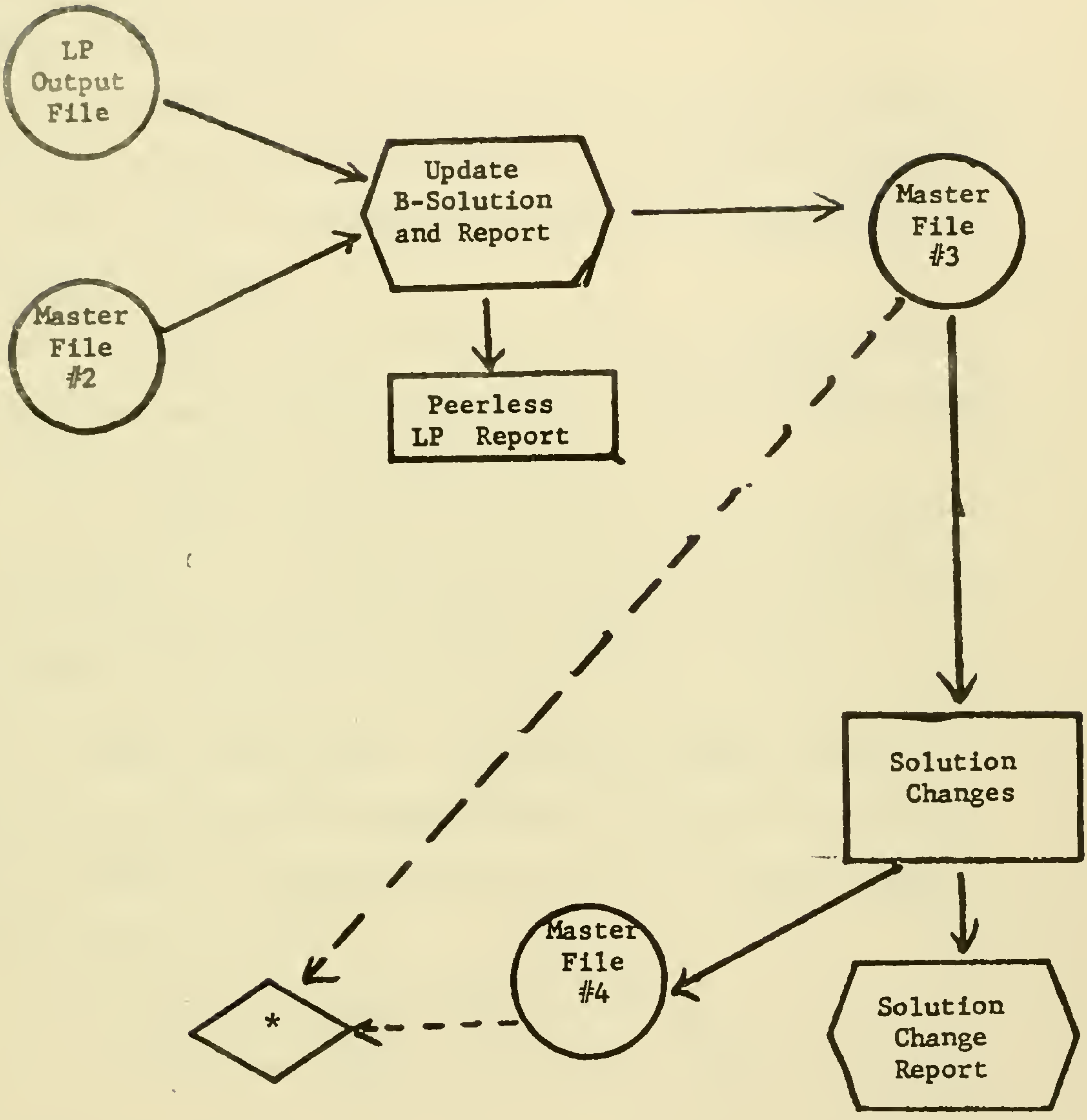


Figure 3 (continued)



* pick one to replace
Master File #1

4) Produce LP Input File. The Extended Master File is passed and a tape acceptable to the remote LP code is written. This program was to exist in three versions:

a) Produce full input tape for 1107 code. Each coefficient becomes a card image in 1107 format. Each column bound becomes a new row and a coefficient card image and a right-hand-side element card image.

b) Produce change tape for 1107 code. As above, but, by comparing against Master File A-model, program suppresses card images which have not changed since last run.

c) Produce full input tape for 360 code. As a) above, but bounds do not become new rows; rather, they are held in one special row acceptable as input to the 360 LP code.

5) Compare coefficients. A comparison is made between the Master File A-model and the Extended Master File (drawn, of course, from the B-model). Depending on the setting of a switch, this comparison results in either;

a) Report of changed coefficients; or

b) Report of prices outside their C-ranges.

6) Check inconsistencies. Performs the function called "Monitor Inconsistencies" above, using the Extended Master File as input.

7) Produce row list. The Extended Master File is sorted in row-column order and printed.

8) Dump Master File. The B-model of the Master File is printed verbatim. This is used both as a column listing of the model and as a model dump after updating.

9) Update B-solution and report. The LP Output Tape is scanned and information collected by column. This collected information is then inserted into the B-solution area of the Master File. Each updated B-solution line is printed. Because of the format of the Master File, these printed lines become the Peerless LP report. There were to be two versions of this routine:

a) Process 1107 output. This version would have to associate four pieces of information with each column:

i) Column solution information

ii) Row solution information for special rows created as bounds

iii) Post-optimality information by column

iv) As iii) for rows.

b) Process 360 output. As a) but types ii) and iv) not required because of use of bounded variable algorithm.

10) Print Changes. Described above as "Print Solution Change Report."

In addition to the major modules described above, several others had been designed and partially programmed by December, 1967. These were:

11) Extract price information from PYRAMIDS.

12) Produce control report from PYRAMIDS.

13) Manipulate prices.

14) Produce special reports (table-driven).

Testing of the LP Support System and Parallel Operation of the Planning System

Testing of the LP support system and first use of the planning system were carried out together, because it was felt that there could be no better test of the support system than coping with an actual model in a closely simulated planning context. Accordingly, testin of the whole system began, even though it was far from complete.

At the outset we had one stroke of good luck. A 360/50 with 138K bytes of core was found in Cedarton itself. The company leasing the machine (call it the Nonpareil Company) had already brought the 360 LP code, MPS/360, to fully usable status and was willing to let Peerless use several hours per month on very reasonable terms. The availability of MPS/360 significantly reduced the programming required for many of the modules described previously. More important, the "remote" machine was now only 20 minute's drive from Peerless. The tape-carrying procedure required by the system began to look more and more feasible.

One complication arose. The Peerless equipment used 90-column cards and 7-track tapes, while the Nonpareil equipment used 80-column cards and 9-track tapes. This problem was resolved when Peerless agreed to subsidize Nonpareil to the extent of one 7-track tape unit, and, in addition, installed one IBM Keypunch on the Peerless premises.

Another minor problem was the difference in character codes between the UNIVAC and IBM equipment. This was handled by substituting a non-standard conversion table for the normal one built into UNIVAC software. In short, data transmission problems were solved reasonably quickly.

Operating procedure at Nonpareil: The operating procedure at Nonpareil became a well-established routine:

1) Mount LP Input File on 7-track drive.

2) Run MPS CONVERT routine to convert LP problem to internal format on a new tape file PROBFILE.

3) Run MODIFY routine to enter any changes to model (usually errors detected and punched after the preparation of the LP Input File).

4) Run SETUP routine to prepare to solve.

5) Run INSERT routine to insert optimal basis from last run.

6) Run PRIMAL routine to solve.

7) Run SOLUTION routine to write solution information on LP Output Tape.

8a) (If infeasible) Run TRACE routine for diagnostic information; or

8b) (If unbounded) Skip to 9; or

8c) (If feasible-optimal) Run RANGE routine for C-ranges, etc.

9) Run COBOL program (written for the purpose) to print LP Output Tape and copy the relevant subset onto the 7-track drive (where a blank tape should have been mounted during PRIMAL) for carrying back to Peerless.

10) Examine output. If infeasible, unbounded, or unreasonable, correct errors and return to step 3. Otherwise, go home.

It should be noted that all the above steps (except for numbers 1 and 10) are performed automatically via the MPS/360 control language and the OS/360 Job Control Language.

In early runs, the whole procedure required an average of three or more tries on the machine, 2 hours of 360/50 time, and 10 hours of effort by each of two or three men. By December, 1967, error detection and correction and general knowledge of the model had progressed so that a typical Nonpareil run required one or two tries, a total of 45 minutes of computer time, and perhaps 6 man-hours of effort.

The timing figures given are for the complete model which was in flux throughout the testing period, but which averaged 700 rows and 2100 columns. Some of the problems encountered in debugging the whole system were:

1) Infeasibility: because of the model structure, infeasibility was usually the result of errors in the change cards. Because of the structure of MPS/360, such errors were easy to trace. But each occurrence forced additional delay.

2) Unbounded Solutions: change card errors were again responsible for most unbounded solutions. However, MPS (or at least the version we used) had no facility for revealing which variable was being brought into solution at the time unboundedness was detected. Our first cut at ameliorating this problem was to modify the "Prepare LP Input Tape" procedure to supply a large upper bound for all variables

without natural upper bounds. Then any unbounded solutions were easily traced after optimality. Our second approach also involved a modification to "Prepare LP Input Tape." MPS permits the definition of a new row as the linear combination of any two other rows. We defined such a row to be identical to the objective function, but to be a less-than constraint with a right-hand-side value roughly four times the largest expected objective function value. Thus, when an unbounded solution occurred, the next variable entered into solution raised the extra row to its maximum value and, there being no further way to increase the objective function, the simplex procedure terminated. The trace of iterations leading to solution would then have, as its *last* entry, the identification of the unbounded variable. The advantage of this method over the first is that it would typically waste less time. That is, the detection of an unbounded solution terminated the simplex procedure.

3) Huge volume of data input: Our preliminary estimates were that, on average, 200 to 500 prices and bounds would change between runs. In fact, running on a weekly cycle (with the option of running sooner if required), we found that 700 to 1200 numbers had to be input for each run. The major cause of excess data input was that the product managers found it easier (or at least safer) to send in, *as changes*, every price and bound under their control, whether actually changed or not. This put a heavy load on the time and patience of everyone concerned in the input process, not least the product managers themselves.

The long-term solution, of course, was to use the PYRAMIDS file as a data source, thus eliminating almost all manual input. In the short run, however, we designed a set of computer-prepared input forms, so that the product managers could see what the old value of each price or bound was as they were writing in new values. This was expected to reduce changes to the originally estimated level, but there were enough technical problems in producing such input forms so that this feature was never fully implemented.

4) Consistently incorrect coefficients: System testing uncovered what was apparently a long-standing disagreement between the "official" cut-out yields and the yields used by provisioning to predict primal production. The "official" yields were re-worked and entered into the model four times, but the model was never able to be even qualitatively as accurate as the provisioners' estimates. There was a carefully controlled test in which the "official" yields operated upon <u>actual</u> hog kill experience for a week, and even then there was only fair agreement between actual production and model predictions. The "official" yields were being reqorked for the fifth time when work on the project was suspended.

There were many other problems -- human, hardware, and software -- but the four above were the major obstacles. There were also several benefits, but the outstanding gain came from the involvement of Peerless personnel in the model-building and error-tracing processes. The Process Design group was the greatest beneficiary, but, as each new run

was examined and criticized, even the provisioners and product managers gained insight into the hog-to-final-product process. There is some evidence that this effect, at least, will be long-term help to Peerless.

The End of the Project

Financial difficulties forced Peerless to cancel all projects "not now fully implemented" in December, 1967. The LP-based planning system fell into this category and was accordingly "suspended indefinitely." But, as always, the classification of the planning system as "not now fully implemented" was a human decision -- in this case, a decision of the Chief Provisioner. His stated reason was that, given Peerless' very tight cash position, he did not have enough maneuvering room to exploit the LP recommendations, even if he could rely on them -- and the fact that the very important yield coefficients were in their fifth re-work was evidence enough that he could not rely on the LP.

There were several contributing factors of which two should be cited:

First, the long turn-around, high error rate, and inability to get good predictions of primal production (all of which we emphasize, were improving rapidly with time) had allowed the provisioners to avoid confronting the question of just how much help the system could be as a planning aid. They were therefore uncommitted.

Second, parallel operation of two systems is a meaningless exercise when the users have never really had enough time to keep the old system running smoothly. This was very nearly the case at Peerless. The additional time required to run the new system in parallel was a far more burdensome cost than the additional money.

Indeed, the only way that all the problems could have been solved would have been for the provisioners to take responsibility for the accuracy of data input and the smooth operation of the support system. However, there is a clear tendency for people to prefer responsibility for an overall (human-generated) plan to responsibility for the numbers on which a (machine-generated) plan is based. Some of the reasons are abvious. First, human plans have the characteristic that the consequences of errors tend to be proportional to the magnitude of mistakes, while a machine-generated plan has the potential for a very small error (in input data) to produce profound errors in the plan. Second, in this particular complex planning scheme, it is hard to predict what effect on the plan will be caused by a relatively minor decision about prices, bounds, and the like. It may be that this planning system gave the provisioners <u>too</u> <u>much</u> responsibility.

Shortly after the planning system was suspended, the provisioners evolved a scheme which has some of the potential of the LP system and many fewer problems. Starting with each primal, manual calculations are made of the potential profit for each possible way of allocating that primal to production. These profit figures are then used in mak-

ing allocation decisions. Such a scheme, while it does not take account of interactions and is therefore surely suboptimal, will be, we hope, at least livable, and certainly better than what existed before the LP-based planning system was initiated.

In Conclusion

This paper provides documentation of the steps and pitfalls in the design of a system to make LP a useful technique for managers charged with day-to-day production scheduling decisions. The "ideal" system is offered as a model of what such a system can be. As important, the actual system, while not now in use, demonstrates that such a system can be constructed even when severe resource limitation exists.

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APPENDIX

Sample System Artifacts

1. Sample Dump of the B-Section of the LP Master File

```
CL0525 B 1  0415    -1.       0926     .8031   1051
SB A 35-UP OTHER GR SK HAM  BS    27.001       .

CL0526 B 0  0421    -1.       0701     0.1      0702
CL0526 B 0  0706     0.1      0707     0.1      0708
CL0526 B 0  1002     0.0278   1050     0.086    1051
CL0526 B 1  1059     0.0018   1060     0.0071   1502
SB A  2-25-DWN C CAN GRSKHM BS   132.089       .

CL0527 B 1  0422    -1.       0926      .7294   1051
SB A 2 25-UP OTHER GRSKDHAM BS    24.855       .

CL0529 B 0  0401    -1.       0701     1.       1001
CL0529 B 1  1052     0.131    1053     0.042    1054
SB A 8-12 C CAN GR SK HAM   LL      .         .08642-

CL0530 B 0  0402    -1.       0701      .1600   0702
CL0530 B 0  1050     0.066    1051     0.089    1052
CL0530 B 1  1060     0.0071   1502 99999.
SB A 12-14 C CAN GR SK HAM  LL      .         .03193-

CL0531 B 0  0403    -1.       0703     0.54     0704
CL0531 B 0  1051     0.089    1052     0.131    1053
CL0531 B 1  1502 99999.
SB A 14-16S C CAN GR SK HAM LL      .         .03555-

CL0532 B 0  0405    -1.       0704     0.22     0705
CL0532 B 0  1050     0.066    1051     0.089    1052
CL0532 B 1  1060     0.0071   1502 99999.
SB A 16-18S C CAN GR SK HAM BS   531.362       .

CL0533 B 0  0407    -1.       0706     0.66     0707
CL0533 B 0  1051     0.089    1052     0.131    1053
CL0533 B 1  1502 99999.
SB A 18-20S C CAN GR SK HAM LL      .         .00856-

CL0534 B 0  0409    -1.       0707     0.43     0708
CL0534 B 0  1050     0.066    1051     0.089    1052
CL0534 B 1  1060     0.0071   1502 99999.
SB A 20-22S C CAN GR SK HAM BS   541.004       .

CL0535 B 0  0411    -1.       0709      .7700   0710
CL0535 B 0  1051     0.089    1052     0.131    1053
CL0535 B 1  1502 99999.
SB A 22-24 C CAN GR SK HAM  BS    74.280       .

CL0536 B 0  0401    -1.       0723     0.1      1001
CL0536 B 0  1052     0.1478   1053     0.0464   1054
CL0536 B 1  1502 99999.
SB A 8-12 HT CAN GR SK HAM  LL      .         .41492-

CL0537 B 0  0402    -1.       0723     0.25     0724
CL0537 B 0  1002     0.0287   1050     0.066    1051
CL0537 B 1  1059     0.0016   1060     0.0064   1064
SB A 12-14 HT CAN GR SK HAM BS    67.364       .

CL0538 B 0  0403    -1.       0726     0.2      0727
```

```
   .0798    1052        .1121    1502 99999.       3301        .667
     .01000-  CL0522      LL        .02494   CL0352      LL

   .100     0703        0.1      0704       0.1       0705       0.1
  0.1       0709        0.1      0710       0.1       1001       0.0026
  0.139     1052        0.132    1053       0.06      1054       0.1005
99999.
     .07219-  CL0323      UL      INFINITY          NONE

   .1621    1052        .1025    1502 99999.       3301        .667
     .34452-  CL0366      LL      INFINITY          NONE

  0.0026    1002        0.0378   1050       0.066     1051       0.089
  0.0412    1059        0.0018   1060       0.0071    1502 99999.

  0.61      0703        0.23     1001       0.0026    1002       0.0278
  0.131     1053        0.042    1054       0.0412    1059       0.0018

  0.46      1001        0.0026   1002       0.0278    1050       0.066
  0.042     1054        0.0412   1059       0.0018    1060       0.0071

  0.56      0706        0.22     1001       0.0026    1002       0.0278
  0.131     1053        0.042    1054       0.0412    1059       0.0018

     .00066-  CL0742      LL        .00183   CL0352      LL

  0.34      1001        0.0026   1002       0.0278    1050       0.066
  0.042     1054        0.0412   1059       0.0018    1060       0.0071

  0.46      0709        0.11     1001       0.0026    1002       0.0278
  0.131     1053        0.042    1054       0.0412    1059       0.0018

     .01138-  CL0311      UL        .01084   CL0312      LL

  0.23      1001        0.0026   1002       0.0278    1050       0.066
  0.042     1054        0.0412   1059       0.0018    1060       0.0071

     .00550-  CL0360      LL        .00423   CL0313      LL

  0.0023    1002        0.0287   1050       0.066     1051       0.089
   .0514    1059        0.0016   1060       0.0064    1064        .0290

  0.15      0725        0.35     0726       0.25      1001       0.0023
  0.089     1052        0.1478   1053       0.0464    1054        .0514
   .0290    1502 99999.
     .00401-  CL1951      UL        .00137   CL0352      LL

  0.28      0728        0.3      0729       0.22      1001       0.0023
```

Sample Listing of Change Cards Submitted to "Update Coefficients"

```
CL8246RW2251    1.
CL8246RW8860   -1.
CL8247RW1500  -99.99
CL8247RW8047    1.
CL8247RW8860   -1.
CL8248RW1500   -0.0728
CL8248RW8048    1.
CL8248RW8860   -1.
CL8248RW1501   25.
CL8249RW1500   -0.1324
CL8249RW8049    1.
CL8249RW8860   -1.
CL8249RW1501   24.
CL8250RW1500  -99.99
CL8250RW8050    1.
CL8250RW8860   -1.
CL8252RW1500  -99.99
CL8252RW8052    1.
CL8252RW8860   -1.
CL8254RW1500  -99.99
CL8254RW8054    1.
CL8254RW8860   -1.
CL8256RW1500  -99.99
CL8256RW6002    1.
CL8256RW8860   -1.
CL8257RW1500  -99.99
CL8257RW6003    1.
CL8258RW1500  -99.99
CL8258RW6058    1.
CL8258RW8860   -1.
CL8259RW1500  -99.99
CL8259RW6059    1.
CL8259RW8860   -1.
CL8260RW1500   -0.32
CL8260RW8060    1.
CL8260RW8860   -1.
CL8260RW1501    1.
CL8261RW1500  -99.99
CL8261RW8860   -1.
CL8265RW1500   -0.37
CL8265RW8061    1.
CL8265RW8065    1.
CL8265RW8860   -1.
CL8265RW1501   45.
```

Sample Output of the "Monitor Changes" Routine

(Note: this sample taken prior to installation of
the "Monitor Price" feature.)

```
                    COEFFICIENT CHANGE LIST                  10-20-67
 COL          ROW                     NEW                    OLD
0063         1500                  -.1665                -.1693
0063         1503                      NONE                .0088
0063         6020                   .0093                 .0100
0064         1500                  -.1637                -.1652
0064         1503                      NONE                .0083
0064         6020                   .0093                 .0110
0065         1500                  -.1637                -.1652
0065         1503                      NONE                .0083
0065         6020                   .0093                 .0110
0066         1500                  -.1637                -.1652
0066         1503                      NONE                .0083
0066         6020                   .0093                 .0110
0067         1500                  -.1637                -.1652
0067         1503                      NONE                .0083
0067         6020                   .0093                 .0110
0068         1500                  -.1637                -.1652
0068         1503                      NONE                .0083
0068         6020                   .0093                 .0110
0069         1500                  -.1637                -.1652
0069         1503                      NONE                .0083
0069         6020                   .0093                 .0110
0070         1500                  -.1718                -.1702
0070         1503                      NONE                .0105
0070         6020                   .0109                 .0110
0071         1500                  -.1718                -.1702
0071         1503                      NONE                .0105
0071         6020                   .0109                 .0110
0072         1500                  -.1718                -.1702
0072         1503                      NONE                .0105
0072         6020                   .0109                 .0110
0073         1500                  -.1718                -.1702
0073         1503                      NONE                .0105
0073         6020                   .0109                 .0110
0074         1500                  -.1718                -.1702
```

Sample Model by Row Listing

```
4600 4218           .2656
4600 4250           .2821
4600 4251           .2821
4600 4600         -1.

4601 4218           .0271
4601 4250           .0288
4601 4251           .0288
4601 4601         -1.

4602 4218           .0881
4602 4250           .0936
4602 4251           .0936
4602 4252           .1240
4602 4602         -1.

4603 4250           .0620
4603 4251           .0620
4603 4603         -1.

4604 4252           .3282
4604 4604         -1.

4605 4252           .0813
4605 4605         -1.

4606 4252           .1216
4606 4606         -1.

4607 4351           .05845
4607 4607         -1.

4608 4360           .05143
4608 4608         -1.
```

UARCO BUSINESS FORMS - WATSEKA, ILL.
F1424

Sample MPS Control Program

```
CONTROL PROGRAM COMPILER

0001                    PROGRAM
0002                    INITIALZ
0057                    XFREQINV = 50
0058                    XINVERT = 1
0059                    MVADR(XDONFS,INFEAS)
0060                    MVADR(XDOUNB,MERTES)
0061                    MOVE(XPBNAME,"PBFILE")
0062                    MOVE(XOLDNAME,'PBFILE')
0063                    MOVE(XDATA,"NEWLP")
0064                    REVISE('SUMMARY')
0065                    SETUP("BOUND","ZZZZZZZZ","MAX")
0066                    MOVE(XOBJ,'RW1500')
0067                    MOVE(XRHS,"ZZZZ0001")
0068                    MOVE(XDATA,'BASIS')
0069          *         BASIS INSERT BLCCK (PRESENT IF OLD BASIS)
0070                    INSERT
0071                    GOTO(DOIT)
0072          *         END BASIS INSERT BLOCK
0073                    CRASH
0074          DOIT      PRIMAL
0075                    SOLUTION
0076                    PUNCH('LIST','VALUE')
0077                    RANGE
0078                    EXIT
0079          INFEAS    TRACE
0080          MERTES    STATUS
0081                    SOLUTION
0082                    PUNCH ('LIST','VALUE')
0083                    EXIT
0084                    PEND
```

Portion of Sample Iteration Log

```
                       EXECUTOR.

        ITER     NUMBER    VECTOR    VECTOR    REDUCED     FUNCTION
---------------------------------------------------------------------
       NUMBER    NONOPT     OUT        IN        COST        VALUE

         117               1363      1360     .05646-     2215.11
---------------------------------------------------------------------
         118               1516      1252     .00004-     2215.33
    M    119       35      1728      1663     .03923-     2217.28
    M    120       37      1252      1207     .01636-     2217.50
---------------------------------------------------------------------
         121               1727      1544     .00235-     2217.50
    M    122       11      1485      1485     .00001      2217.93
         123               1207       876     .00001-     2218.13
---------------------------------------------------------------------
         124                782      1711     .00775-     2218.16
         125               1656      1652     .00313-     2218.17
    M    126       10      1714      1210     .00426-     2218.19
---------------------------------------------------------------------
    M    127        6      1186      1186     .00000      2218.42
         128               1185      1185     .00000      2218.65
         129               1412      1494     .00000-     2218.78
---------------------------------------------------------------------
         130               1573      1574     .01032-     2218.80
         131                906       746     .00000-     2218.81
    M    132        3      1680      1681     .00041-     2218.81
---------------------------------------------------------------------
         133                746       759     .00000-     2218.82
         134               1652      1656     .00110-     2218.82
    M    135        5       759       771     .00364-     2218.84
---------------------------------------------------------------------
         136               1650      1651     .00041-     2218.84
      OPTIMAL  SOLUTION
---------------------------------------------------------------------
```

7. Portion of Sample MPS Output (Solution Section)

```
EXECUTOR.

NUMBER  .COLUMN.   AT   ...ACTIVITY...   ..INPUT COST..   ..LOWER LIMIT

 1222   CL2706     ES      40.00000            .                 .
 1223   CL2707     LL     400.00000          .25400         400.00000
 1224   CL2708     LL      40.00000          .27880          40.00000
 1225   CL2709     LL      60.00000          .29000          60.00000
 1226   CL2720     ES     569.89414            .                 .
 1227   CL2721     ES     617.06586            .                 .
 1228   CL2722     LL          .               .                 .
 1229   CL2723     ES     231.16000            .                 .
 1230   CL2724     LL          .               .                 .
 1231   CL2725     LL          .               .                 .
 1232   CL2726     ES     133.95600            .                 .
 1233   CL2727     LL          .               .                 .
 1234   CL2728     LL          .               .                 .
 1235   CL2729     LL          .               .                 .
 1236   CL2730     ES      35.12573            .                 .
 1237   CL2731     ES     143.48227            .                 .
 1238   CL2732     ES      87.32000            .                 .
 1239   CL2733     LL          .               .                 .
 1240   CL2734     LL          .               .                 .
 1241   CL2735     ES     137.34000            .                 .
 1242   CL2736     LL          .               .                 .
 1243   CL2737     LL          .               .                 .
 1244   CL2738     ES      66.32400            .                 .
 1245   CL2739     ES     132.64600            .                 .
 1246   CL2740     LL          .               .                 .
 1247   CL2741     LL          .               .                 .
 1248   CL2742     ES      44.21600            .                 .
 1249   CL2743     ES     523.92000            .                 .
 1250   CL2744     LL          .               .                 .
 1251   CL2750     UL      40.00000          .68000          20.00000
 1252   CL2751     UL      80.00000          .56000          40.00000
 1253   CL2752     UL      80.00000          .63000          40.00000
 1254   CL2753     EQ          .               .                 .
 1255   CL2754     UL    1200.00000          .53000         600.00000
 1256   CL2755     UL     200.00000          .58000         100.00000
 1257   CL2756     UL     120.00000          .53000          60.00000
 1258   CL2757     UL     160.00000          .52000          80.00000
 1259   CL2758     UL      80.00000          .48000          40.00000
 1260   CL2759     UL     120.00000          .53000          60.00000
 1261   CL2760     UL      60.00000          .47000          20.00000
 1262   CL2761     UL     120.00000          .46000          60.00000
 1263   CL2762     EQ      40.00000          .46000          40.00000
 1264   CL2763     EQ     480.00000          .41000         480.00000
 1265   CL2764     EQ     400.00000          .36000         400.00000
 1266   CL2850     ES     198.23463          .06750              .
 1267   CL2851     ES      63.16647          .27000              .
 1268   CL2852     ES      32.01310          .01950              .
 1269   CL2853     ES     241.51800          .37000              .
 1270   CL2854     LL          .             .15000              .
 1271   CL3000     ES      72.61469            .                 .
 1272   CL3001     ES    1157.46598            .                 .
```

```
..UPPER LIMIT.  .REDUCED COST.

  99999.00000          .
    600.00000          .02116-
    120.00000          .00433-
    120.00000          .06127-
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
     40.00000          .15581
     80.00000          .10847
     80.00000          .08077
       .               .46691-
   1200.00000          .09804
    200.00000          .09906
    120.00000          .08710
    160.00000          .10386
     80.00000          .04571
    120.00000          .15766
     60.00000          .10072
    120.00000          .10538
     40.00000          .11243
    480.00000          .04239
    400.00000          .00366
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .
  99999.00000          .01141-
  99999.00000          .
  99999.00000          .
```

8. Portion of Sample MPS Output (Ranges Section)

```
            EXECUTOR.

UMBER  .COLUMN.  AT   ...ACTIVITY...   ..INPUT COST..  ..LOWER LIMIT
                                                       ..UPPER LIMIT

 1214  CL2698    LL          .                .               .
                                                       99998.94830

 1216  CL2700    LL       39.99994          .46000         19.99997
                                                          39.99995

 1217  CL2701    LL          .              .29000            .
                                                          39.99999

 1218  CL2702    LL      199.99983          .33340        199.99983
                                                         399.99981

 1219  CL2703    LL     1199.99901          .33340       1199.99901
                                                        1599.99877

 1220  CL2704    LL      199.99983          .33340        199.99983
                                                         399.99981

 1221  CL2705    LL          .                .               .
                                                       99998.94830

 1223  CL2707    LL      399.99982          .25400        399.99982
                                                         599.99981

 1224  CL2708    LL       39.99999          .27880         39.99999
                                                         119.99998

 1225  CL2709    LL       59.99994          .29000         59.99994
                                                         119.99993

 1228  CL2722    LL          .                .               .
                                                       99998.94830

 1230  CL2724    LL          .                .               .
                                                       99998.94830

 1231  CL2725    LL          .                .               .
                                                       99998.94830

 1233  CL2727    LL          .                .               .
                                                       99998.94830

 1234  CL2728    LL          .                .               .
                                                       99998.94830

 1235  CL2729    LL          .                .               .
                                                       99998.94830

 1239  CL2733    LL          .                .               .
                                                       99998.94830
```

```
LOWER ACTIVITY   ...UNIT COST..   ..UPPER COST..  LIMITING   AT
UPPER ACTIVITY   ...UNIT COST..   ..LOWER COST..  PROCESS.   AT

     817.06519-        .            INFINITY-     CL2721     LL
         .             .                .         CL2659     LL

      34.58343      .13563-          .32437       CL2251     LL
     123.49858      .13563          INFINITY      CL2251     UL

         .          .06463          INFINITY-     CL2650     LL
      19.70951      .06463-          .35463       CL2600     LL

     458.41723-     .00400          INFINITY-     CL2256     LL
     780.10356      .00400-          .33740       CL2720     LL

     541.58247      .00400          INFINITY-     CL2256     LL
    2204.46788      .00400-          .33740       CL2256     UL

     164.24483      .00400          INFINITY-     CL2730     LL
     346.05260      .00400-          .33740       CL2731     LL

      19.78978-        .            INFINITY-     CL2602     LL
      39.99997         .                .         CL2706     LL

     448.80744-     .02116          INFINITY-     CL2657     LL
     496.76113      .02116-          .27516       CL2603     LL

         .          .00433          INFINITY-     CL2706     LL
      59.78978      .00433-          .28313       CL2602     LL

      55.20400      .06127          INFINITY-     CL2251     LL
     133.93223      .06127-          .35127       CL2251     UL

      35.12570-        .            INFINITY-     CL2730     LL
     143.48219         .                .         CL2731     LL

     569.89365-        .            INFINITY-     CL2720     LL
     231.15988         .                .         CL2723     LL

      35.12570-        .            INFINITY-     CL2730     LL
     143.48219         .                .         CL2731     LL

     569.89365-        .            INFINITY-     CL2720     LL
     133.95591         .                .         CL2726     LL

      35.12570-        .            INFINITY-     CL2730     LL
     133.95591         .                .         CL2726     LL

     817.06519-        .            INFINITY-     CL2721     LL
      35.12570         .                .         CL2730     LL

     569.89365-        .            INFINITY-     CL2720     LL
      87.31994         .                .         CL2732     LL
```

9. Sample Output of "Update B-Solution" and "Report"

L.P. Col. No.	Activity Type	Description	Activity At	Recommended Activity	Reduced Cost
0301	SB B	8-12 HAMS (A PRICE)	LL	.	.00500-
0302	SB B	8-12 HAMS (B PRICE)	LL	.	.02000-
0303	SB B	12-14 HAMS (A PRICE)	LL	.	.00500-
0304	SB B	12-14 HAMS (B PRICE)	LL	.	.01500-
0305	SB B	14-16 HAMS (A PRICE)	LL	.	.00641-
0306	SB B	14-16 HAMS (B PRICE)	LL	.	.01641-
0307	SB B	16-18 HAMS (A PRICE)	LL	.	.00970-
0308	SB B	16-18 HAMS (B PRICE)	LL	.	.02470-
0309	SB B	18-20 HAMS (A PRICE)	LL	.	.00970-
0310	SB B	18-20 HAMS (B PRICE)	LL	.	.02470-
0311	SB B	20-22 HAMS (A PRICE)	UL	207.000	.00512
0312	SB B	20-22 HAMS (B PRICE)	LL	.	.00488-
0313	SB B	22-24 HAMS (A PRICE)	LL	.	.00870-
0314	SB B	22-24 HAMS (B PRICE)	LL	.	.01470-
0315	SB B	24-26 HAMS (A PRICE)	LL	.	.00970-
0316	SB B	24-26 HAMS (B PRICE)	LL	.	.01970-
0317	SB B	26-30 HAMS (A PRICE)	LL	.	.00970-
0318	SB B	26-30 HAMS (B PRICE)	LL	.	.02470-
0319	SB B	30-35 HAMS (A PRICE)	LL	.	.00500-
0320	SB B	30-35 HAMS (B PRICE)	LL	.	.01000-
0321	SB B	35-UP HAMS (A PRICE)	LL	.	.00500-
0322	SB B	35-UP HAMS (B PRICE)	LL	.	.01000-
0323	SB B	25-DOWN 2 CJ HAMS	EQ	30.600	.01279
0350	SB S	8-12 GR SK HAM	BS	47.255	.
0351	SB S	12-14 GR SK HAM	BS	248.715	.
0352	SB S	14-16 GR SK HAM SKR	BS	115.003	.
0353	SB S	14-16 GR SK HAM FLTR	BS	383.819	.
0354	SB S	16-18 GR SK HAM SKR	LL	.	.
0355	SB S	16-18 GR SK HAM FLTR	BS	60.021	.
0356	SB S	18-20 GR SK HAM SKR	BS	89.864	.
0357	SB S	18-20 GR SK HAM FLTR	LL	.	.
0358	SB S	20-22 GR SK HAM SKR	LL	.	.01674-
0359	SB S	20-22 GR SK HAM FLTR	LL	.	.00700-
0360	SB S	22-24 GR SK HAM	BS	208.451	.
0361	SB S	24-26 GR SK HAM	BS	265.750	.
0362	SB S	26-30 GR SK HAM	BS	36.162	.
0363	SB S	30-35 GR SK HAM	LL	.	.00470-
0364	SB S	35-UP GR SK HAM	LL	.	.00470-
0365	SB S	2 25-DOWN GR SK HAMS	LL	.	.01749-
0366	SB S	2 25-UP GR SK HAMS	LL	.	.04012-
0401	SB I	8-12 HAMS	LL	.	.00470-
0402	SB I	12-14 HAMS	LL	.	.00470-

Greatest Cost Limit	Limiting Activity	At	Least Cost Limit	Limiting Activity	At
.47500	CL0450	UL	.48000	CL0301	LL
.44500	CL0451	UL	.45000	CL0303	LL
.42500	CL0466	LL	.42500	CL0405	LL
.38799	CL0507	LL	.44637	CL0305	LL
.40000	CL0354	LL	.40065	CL0777	LL
.39500	CL0357	LL	.39705	CL0514	LL
.37800	CL0411	LL	.38242	CL0514	LL
.37000	CL0412	LL	.37800	CL0672	LL
.35500	CL0413	LL	.35970	CL0458	LL

10. Sample Output of "Report Solution Changes"

```
0054 B  H LVE WGT HOGS 280-300G3 BS    181.027         .

0055 A  H LVE WGT HOGS 280-300G4 BS    139.463         .
0055 B  H LVE WGT HOGS 280-300G4 BS    266.512         .

0056 A  H LVE WGT HOGS 280-300G5 BS    106.919         .
0056 B  H LVE WGT HOGS 280-300G5 BS    283.129         .

0057 A  H LVE WGT HOGS 280-300G6 BS    374.529         .
0057 B  H LVE WGT HOGS 280-300G6 BS    864.124         .

0058 A  H LVE WGT HOGS 300-320G1 BS       .            .
0058 B  H LVE WGT HOGS 300-320G1 BS      4.804         .

0059 A  H LVE WGT HOGS 300-320G2 BS      3.744         .
0059 B  H LVE WGT HOGS 300-320G2 BS      5.836         .

0060 A  H LVE WGT HOGS 300-320G3 BS     22.737         .
0060 B  H LVE WGT HOGS 300-320G3 BS     55.301         .

0061 A  H LVE WGT HOGS 300-320G4 BS     25.272         .
0061 B  H LVE WGT HOGS 300-320G4 BS     63.879         .

0062 A  H LVE WGT HOGS 300-320G5 BS     30.441         .
0062 B  H LVE WGT HOGS 300-320G5 BS     89.705         .

0063 A  H LVE WGT HOGS 300-320G6 BS    133.055         .
0063 B  H LVE WGT HOGS 300-320G6 BS    386.663         .

0064 A  H LVE WGT HOGS 320-340G1 BS      1.324         .
0064 B  H LVE WGT HOGS 320-340G1 BS      1.293         .

0065 A  H LVE WGT HOGS 320-340G2 BS      2.764         .
0065 B  H LVE WGT HOGS 320-340G2 BS      2.541         .

0066 A  H LVE WGT HOGS 320-340G3 BS      4.017         .
0066 B  H LVE WGT HOGS 320-340G3 BS      6.267         .

0067 A  H LVE WGT HOGS 320-340G4 BS      9.532         .
0067 B  H LVE WGT HOGS 320-340G4 BS     23.808         .

0068 A  H LVE WGT HOGS 320-340G5 BS      8.107         .
0068 B  H LVE WGT HOGS 320-340G5 BS     26.457         .

0069 A  H LVE WGT HOGS 320-340G6 BS     37.728         .
0069 B  H LVE WGT HOGS 320-340G6 BS    108.262         .

0070 A  H LVE WGT PKRS 300DOWNG1 BS     71.611         .
0070 B  H LVE WGT PKRS 300DOWNG1 BS     78.001         .

0071 A  H LVE WGT PKRS 300DOWNG2 BS     99.331         .
0071 B  H LVE WGT PKRS 300DOWNG2 BS     70.054         .

0072 A  H LVE WGT PKRS 300DOWNG3 BS     46.713         .
0072 B  H LVE WGT PKRS 300DOWNG3 BS     56.394         .

0073 A  H LVE WGT PKRS 300DOWNG4 BS     12.484         .
```

10. Sample Output of "Report Solution Changes"

```
     5.19751-   CL0001     UL    INFINITY        NONE

     8.21026-   CL0002     UL    INFINITY        NONE
     3.58365-   CL0001     UL    INFINITY        NONE

    10.65811-   CL0002     UL    INFINITY        NONE
     3.38308-   CL0001     UL    INFINITY        NONE

     3.16277-   CL0002     UL    INFINITY        NONE
     1.22014-   CL0001     UL    INFINITY        NONE

    INFINITY-      NONE          INFINITY        NONE
   189.72678-   CL0001     UL    INFINITY        NONE

   299.73680-   CL0002     UL    INFINITY        NONE
   156.21537-   CL0001     UL    INFINITY        NONE

    49.49412-   CL0002     UL    INFINITY        NONE
    16.63221-   CL0001     UL    INFINITY        NONE

    44.54730-   CL0002     UL    INFINITY        NONE
    14.42058-   CL0001     UL    INFINITY        NONE

    37.01056-   CL0002     UL    INFINITY        NONE
    10.31561-   CL0001     UL    INFINITY        NONE

     8.59597-   CL0002     UL    INFINITY        NONE
     2.51769-   CL0001     UL    INFINITY        NONE

   846.77575-   CL0002     UL    INFINITY        NONE
   704.26055-   CL0001     UL    INFINITY        NONE

   405.83184-   CL0002     UL    INFINITY        NONE
   358.61285-   CL0001     UL    INFINITY        NONE

   279.33320-   CL0002     UL    INFINITY        NONE
   145.48059-   CL0001     UL    INFINITY        NONE

   117.81976-   CL0002     UL    INFINITY        NONE
    38.41946-   CL0001     UL    INFINITY        NONE

   138.50884-   CL0002     UL    INFINITY        NONE
    34.58938-   CL0001     UL    INFINITY        NONE

    29.89206-   CL0002     UL    INFINITY        NONE
     8.57631-   CL0001     UL    INFINITY        NONE

    15.83404-   CL0002     UL    INFINITY        NONE
    11.83854-   CL0001     UL    INFINITY        NONE

    11.46323-   CL0002     UL    INFINITY        NONE
    13.16308-   CL0001     UL    INFINITY        NONE

    24.18177-   CL0002     UL    INFINITY        NONE
    16.31228-   CL0001     UL    INFINITY        NONE

    90.00837-   CL0002     UL    INFINITY        NONE
```

11. Sample Output of "Monitor Inconsistencies"

```
0306     .46     B 14-16 HAMS (B PRICE)      INCONSISTENT
0366     .0      S  2 25-UP GR SK HAMS       INCONSISTENT
0660     .0      P 14-16 SMOSKLS WA FC HM    INCONSISTENT
3613    0.0      P FRESH PICNIC CHUNKS       INCONSISTENT
4100    0.       I 11-18 REG LN              INCONSISTENT
8015  -99.99                                 INCONSISTENT
8017  -99.99                                 INCONSISTENT
8020  -99.99                                 INCONSISTENT
8050  -99.99                                 INCONSISTENT
8059  -99.99                                 INCONSISTENT
8060  -99.99                                 INCONSISTENT
8061  -99.99                                 INCONSISTENT
8065  -99.99                                 INCONSISTENT
8121    0.       I 20% PK TRIM (21)          INCONSISTENT
8122    0.       I PICNIC TRIM (22)          INCONSISTENT
8140    0.       I 40% LEAN BF (40)          INCONSISTENT
8142    0.       I 85% BF CHO BRIS (42)      INCONSISTENT
8145    0.       I 60% LEAN BEEF (45)        INCONSISTENT
8152    0.       I 70% LEAN BF (52)          INCONSISTENT
8158    0.       I 20% PK TRIM (58)          INCONSISTENT
8167    0.       I 80% LEAN BF (67)          INCONSISTENT
8266     .4221   O PIC CHUNKS (66)           INCONSISTENT

     0022 INCONSISTENT          NO DESCRIPTION
```

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