XLAYER: AN EXPERT SYSTEM PROVIDING MANAGEMENT ADVICE TO COMMERCIAL LAYER MANAGERS

Ed Schmisseur and John Pankratz

Abstract

XLAYER, an expert/knowledge-based microcomputer program, was designed and developed to diagnose layer management problems and recommend expert remedial management advice. The program also provokes management action by calculating the economic loss attributed to major management problems. It analyzes data generated by a commercially marketed layer performance financial microcomputer program and has demonstrated the ability to emulate poultry management experts in the diagnoses of 80 individual layer management problems. The program provides scarce expert poultry management advice to poultry layer managers regardless of size and scale of operation.

Key words: expert system, knowledge-based system, rule-based, economic loss, layer management.

Expert or knowledge-based computer programs are becoming an important operations and management component of many Fortune 500 companies (Simons; Herrod) and are being actively explored to assist smaller businesses (Harmon et al.). They are beginning to emerge as a field of research, development, and use in commercial agriculture (McKinion and Lemmon; Michalski et al.; Boulanger; Roach et al.; Fermanian et al.; Spahr and Puckett; Levins and Varner; Oltjen et al.). They also represent the next logical step in the progression of computer-supported information and decision-aid systems for farm managers first initiated by agricultural researchers in the early 1950s. (Schmisseur and Doluschitz).

Expert or knowledge-based system programs contain domain-specific knowledge and use complex inferential reasoning to reach conclusions human experts would reach if faced with a comparable problem (Hart; Weiss and Kulikowski). The basic knowledge contained in these programs consists of rules, facts, relationships, reasons, and heuristics obtained from human experts who can solve problems in a particular domain of expertise. Expert systems embody techniques for solving problems, manipulating stored knowledge, coping with uncertain information, and explaining how an inference is proceeding or a conclusion has been reached (Simons).

Expert or knowledge-based system program developments are a new area of applied poultry science research. The results of one effort to apply expert system technology to poultry layer management are reported here.

PROBLEM-SOLVING FOUNDATIONS

The practical and empirically verifiable diagnostic rules of poultry layer management as practiced by a cooperating poultry management consulting firm[1] served as the problem-solving paradigm used in the XLAYER program. These domain-dependent methods were developed by consulting firms and have proven useful over a period of years through practical consulting experience. Collectively, these diagnostic rules implicitly seek to maximize layer flock profitability by identifying problems which impact production performance, costs, and returns. They utilize problem-solving techniques and data manipulations which explicitly and rigorously critique these separate but interrelated areas of layer management.

[1] The management expertise contained in the XLAYER program represents that of Mel Gehman, President and Founder of Heritage PMS, Inc., RD #3 Box 458-B, Annville, Pennsylvania 17003.

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The general problem-solving approach embodied in the XLAYER program is relatively straightforward. It attempts confirmation of all management problems contained in the knowledge base by matching a list of management problem symptoms with indicators of substandard flock performance. When a critical number of matches occurs, a management problem is confirmed and a management recommendation is issued. The search for management problems begins with the evaluation of production decisions followed by decisions about egg marketing, and then production costs.

The diagnostic rules, general problem-solving approach, and search strategy embodied in the XLAYER program were solicited from the cooperating consultants. A series of interviews with these experts

1) identified important management problems impacting layer flock profitability;
2) dictated the data and the heuristics needed to diagnose these problems;
3) established the analytical or step-by-step procedure followed to determine problems; and
4) ascertained what management recommendation would be issued.

After each interview, new insights about the diagnostic process were encoded in the XLAYER program and then tested using test case data. In subsequent interviews, previously discovered problem-solving rules were confirmed, new problem-solving capabilities were added, and the depth of the program's diagnostic capabilities was increased.

DATA REQUIREMENTS

The XLAYER program was developed to analyze weekly layer flock performance data generated by a commercially-marketed poultry management microcomputer program, Layer Performance.[2] This integration was important since the consulting firm developed Layer Performance to collect and calculate data useful in their diagnoses of layer management problems. Furthermore, many of XLAYER's data needs could be obtained directly from data files produced by Layer Performance rather than through additional keyboard entries.

The major types of data produced by Layer Performance and utilized by the XLAYER program are illustrated in Figure 1. The Layer Performance program produces a report which provides weekly data on three major areas of poultry management—flock performance, financial performance, and egg gradeout. Flock performance data contain livability, egg production, and nutrition information such as mortality, body weight, house temperature, egg case weight, shell thickness, metabolizable energy, and protein, and the content of specific amino acids in the layer ration. Financial performance indicators report itemized income and expense categories and net profit. Egg gradeout data show egg size and grade, quality, quantity, and price information.

The XLAYER program uses approximately 100 different data observations generated by the Layer Performance program. These data, automatically stored in a file called "Record," represent both actual layer performance and equivalent performance potentials or standards. Performance potentials or standards are based on standards published by commercial genetic companies and breeder farms. They reflect the different layer strains, age of birds, molting phase, and environmental conditions.

Other data required by the XLAYER program, but not produced by Layer Performance, include information on pullet flock history, layer house equipment, marketing arrangements and prices, and criteria by which flock performance are compared to performance standards. Pullet history information includes pullet weights, feed consumption, uniformity and shank index information at selected weeks of rearing, and general pullet rearing conditions. This information is manually entered and permanently stored in a file called "Flock Profile" when a pullet flock starts production.

Information about layer house equipment includes the type of feeding, egg gathering, and manure handling system in the layer house. These data, also manually entered, are permanently stored in a file called "Housing/Equipment Profile."

Information about marketing and prices includes egg selling/processing arrangements, egg prices by egg grade or case weight, and feed ingredient prices. These data are specified in a file called "Price Profile." Price information is manually updated weekly.

The various criteria by which flock performance are compared to flock performance standards are contained in a file called "Evaluative Criteria." These criteria were obtained from the cooperating consulting firm. They are based on experience in analyzing flock performance records.

[2]Layer Performance is a registered trademark of Heritage PMS, Inc., RD #3 Box 458-B, Annville, Pennsylvania 17003.

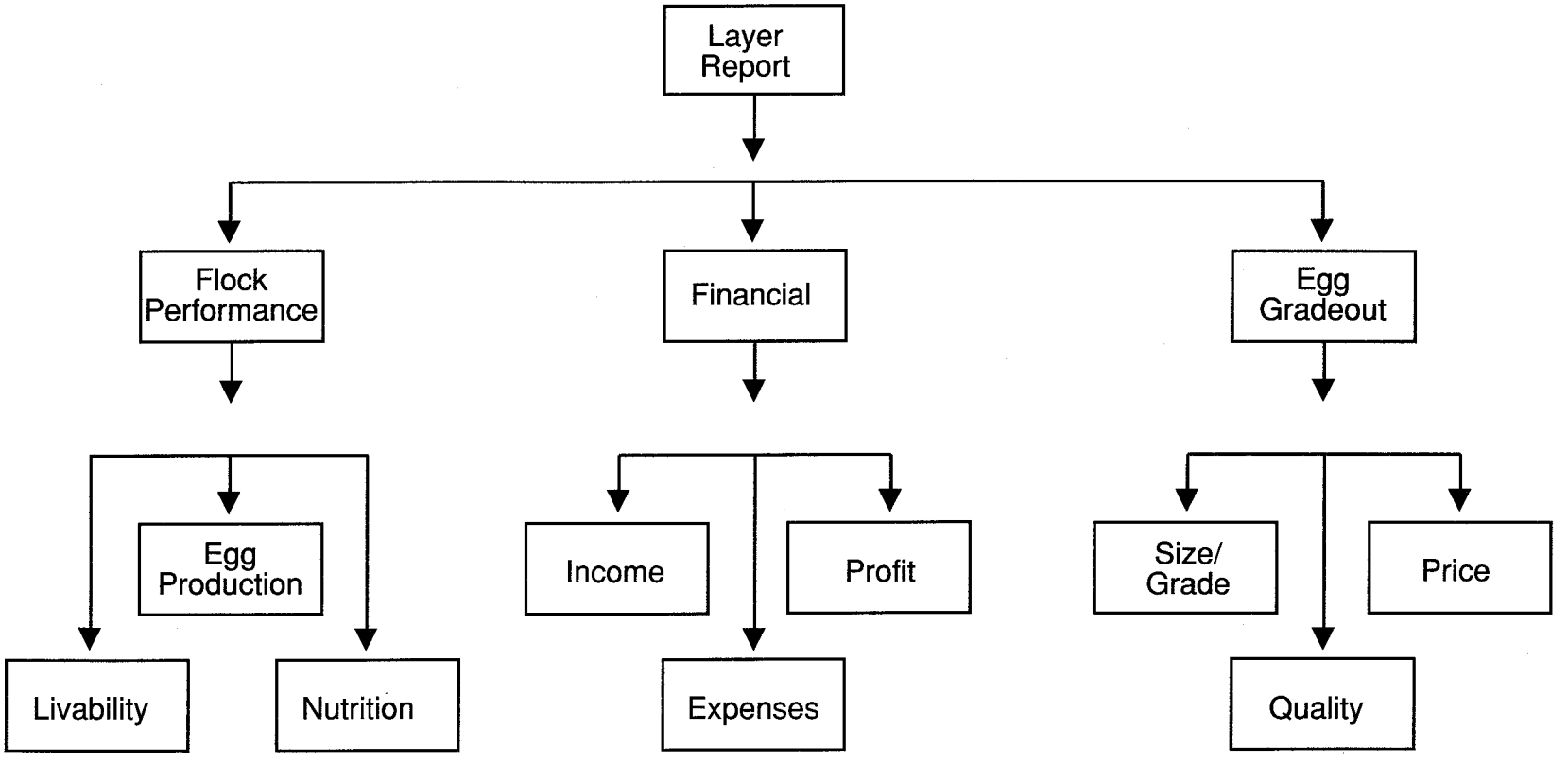

Figure 1. Heritage's Layer Performance Report.

PROGRAM OVERVIEW

The XLAYER program:

1) identifies major management problems judged to be impacting layer flock profitability;

2) calculates associated economic losses attributed to major management problems; and

3) issues specific management recommendations designed to eliminate the management problem. It is written using a commercially-marketed expert development and delivery shell microcomputer program, M.1.[3] The XLAYER program' s code was written in the "PROLOG"-like production rule language contained in the M.1 program. The shell program requires an IBM-PC compatible microcomputer equipped with a graphics card and a minimum of 320K RAM.

The XLAYER program's relationship to its data needs and users is illustrated in Figure 2. Users execute and communicate with the XLAYER program by interacting with M.1. The M.1 program automatically calls the XLAYER program and immediately begins the consultation. During consultation, the XLAYER program automatically seeks relevant flock performance, performance standards, and other needed data. Should data not be found, the natural language user interface of M.1 queries the user. Users then must respond. A response of "unknown" is acceptable as the XLAYER program has the ability to infer management problems based on other known information. At each query point, users can ask the XLAYER program to explain its reasons for the query. Also, at the end of the consultation, users can query the program to explain how it arrived at its conclusions.

After the XLAYER program has completed its analysis, an "Executive Management Report" is compiled. This report includes a brief description of each management problem, its associated economic loss to provoke management action and facilitate quick partial budgeting of the decision recommendation, and specific management recommendations. If no management problems exist, the XLAYER program generates a brief report indicating this finding.

DIAGNOSTIC FRAMEWORK

A generalization of XLAYER's diagnostic framework is presented in Figures 3 through 5. These diagnostics are contained in some 400 individual production rules. Diagnostics pertain to egg production, egg blend price, variable production costs, and fixed costs. The diagnostic framework, or fault tree, illustrates the complexity of the inference process. It also shows the path of impact of management decisions made in each specific area of production.

Management decisions about layer nutrition

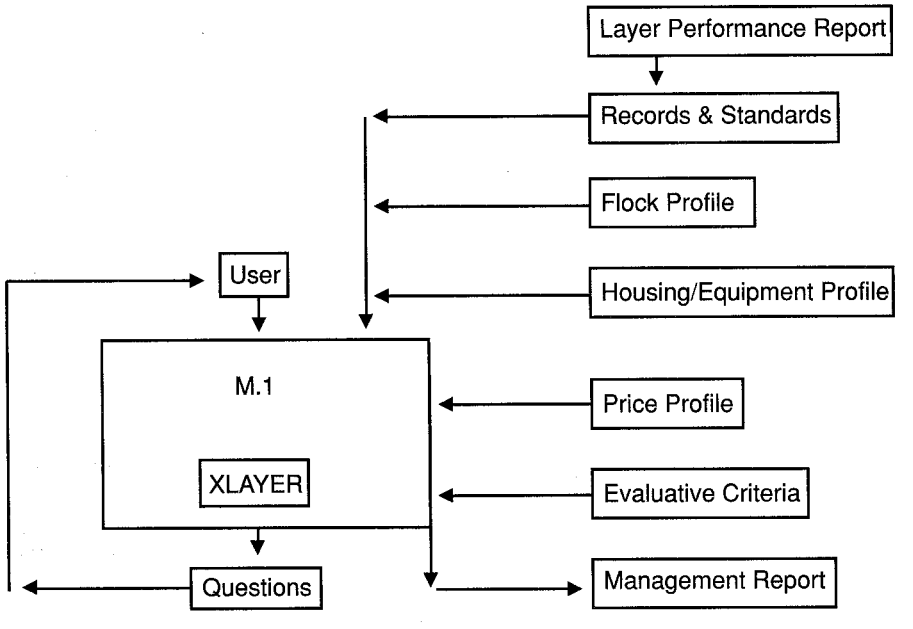

Figure 2. XLAYER's Relationship to Users and Data.

[3] M.1 is a registered trademark of TEKNOWLEDGE, Inc., P.O. Box 10119, Palo Alto, California 94303.

depict one of the complex inferences within the XLAYER program. Nutritional decisions impact egg production directly and also indirectly through feed consumption (Figure 3). But, nutrition decisions also indirectly impact egg blend price through both small eggs and egg quality (Figure 4) and indirectly impact variable production cost through feed costs (Figure 5). Specifically, egg quality is directly affected by shell quality, which in turn is impacted by nutrition decisions, and feed cost is directly affected by feed consumption, which in turn is impacted by nutrition. Similar complex inferences exist for management decisions affecting environmental conditions in the layer house, disease, pullet quality, and stress.

The complexity of the diagnostics contained in the XLAYER program is more easily seen in its diagnostic rules. For example, the primary rule confirming a methionine supplementation problem exhibits a complex inference. This rule and others presented also provide insights into the basic analytical process or problem-solving approach employed in the XLAYER program. The rule, taken directly from the XLAYER code, is:

```
if ((low_feed_consumption and low_production)
    or (low_feed_consumption and small_egg_sizes
      is unknown)
    and methionine_per_hen_day = MPHD
    and goal_methionine_per_hen_day = GMPHD
    and upper_wide_bounds = UWB
    and lower_wide_bounds = LWB
    and MPHD > GMPHD * UWB
    or MPHD < GMPHD * LWB)
    or (small_egg_sizes
    and methionine_per_hen_day = MPHD
    and goal_methionine_per_hen_day = GMPHD
    and upper_moderate_bounds = UMB
    and lower_moderate_bounds = LMB
    and MPHD > GMPHD * UMB
    or MPHD < GMPHD * LMB)
    then methionine.
```

The rule's interpretation is:

1) if low feed consumption and low production exists and the methionine level fed per hen day exceeds either an upper or lower bound,

2) or small egg sizes exists without either low feed consumption or low production and the methionine level fed per hen day exceeds either a narrower upper or lower bound,

then a methionine supplementation problem is confirmed. It shows that a methionine supplementation problem can manifest itself in several performance indicators.

When a methionine problem is confirmed, another XLAYER rule is invoked which actually issues the management alert and prescribes a remedy. This rule is:

```
if methionine and display ( ['Verify suspected
    methionine imbalance in the layer ration.
    Methionine intake should be within 20 per-
    cent of your flock's potential intake. If con-
    firmed reformulate the ration's protein and
    methionine content.'] )
    then problem.
```

However, before the primary rule can be confirmed, either low feed consumption and low production or small egg sizes must also be confirmed from other production rules contained in the XLAYER program.

The low feed consumption, low production, and small egg sizes diagnostic rules are relatively simple. The low feed consumption rule is:

```
if feed_per_hen_day = FPHD
    and goal_feed_per_hen_day = GFPHD
    and critical_feed_per_hen_day = CFPHD
    and FPHD < GFPHD * CFPHD
    then low_feed_consumption.
```

This rule confirms low feed consumption when the amount of feed consumed per hen day is less than the goal or standard for feed consumption per hen day adjusted downward by coefficient of tolerance for feed consumption.

The low production rule is:

```
if eggs_per_hen_housed = EPHH
    and goal_eggs_per_hen_housed = GEPHH
    and critical_eggs_per_hen_housed = CEPHH
    and EPHH < GEPHH * CEPHH
    and egg_blend_price = EBP
    and starting_number_hens = SNH
    and (((GEPHH - EPHH) * SNH)/12) * EBP =
    PRODL
    and display( ['
        Economic losses attributed to low produc-
        tion are: ',tab(6), $(PRODL)] )
    then low_production.
```

It confirms low production when egg production per hen housed is less than the standard for production adjusted downward by a coefficient of tolerance for egg production, and it calculates the associated economic loss. This loss is based on the difference between the egg production standard and actual egg production per hen housed adjusted by the total number of hens housed.

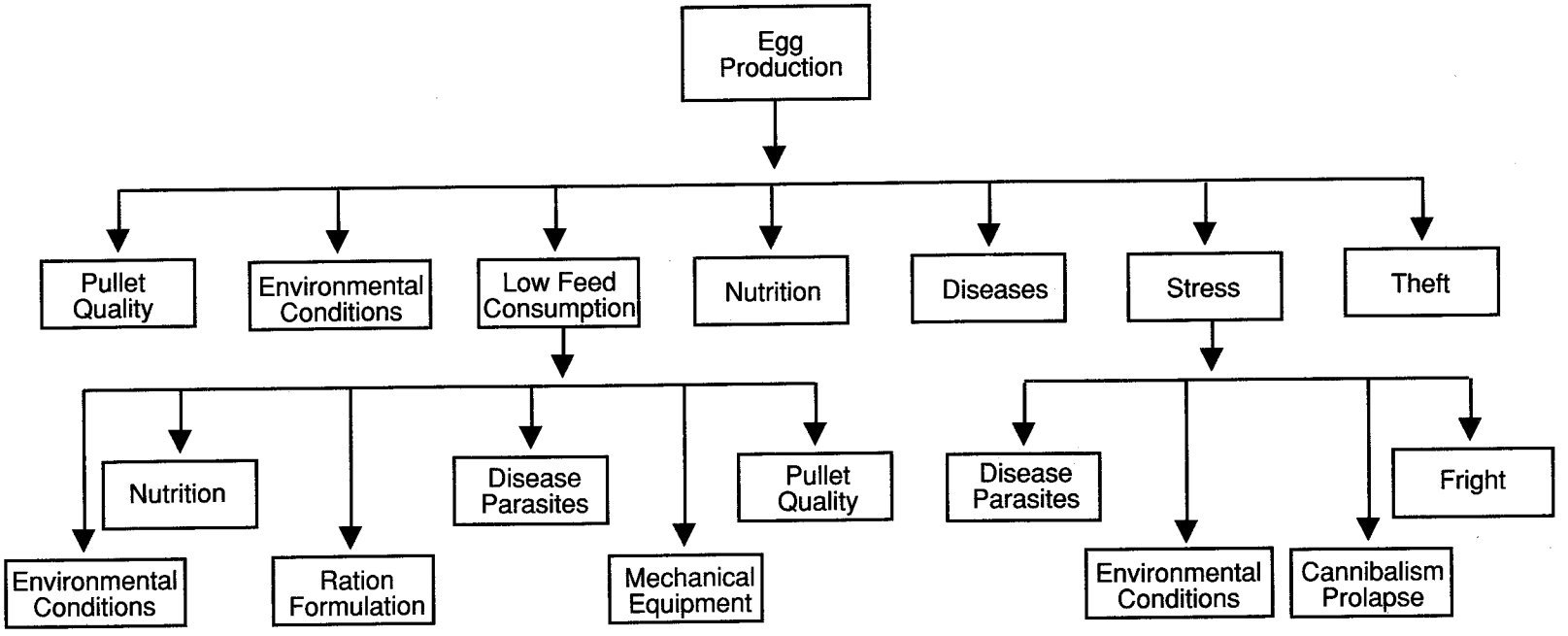

Figure 3. Egg Production Diagnostic Framework of XLAYER.

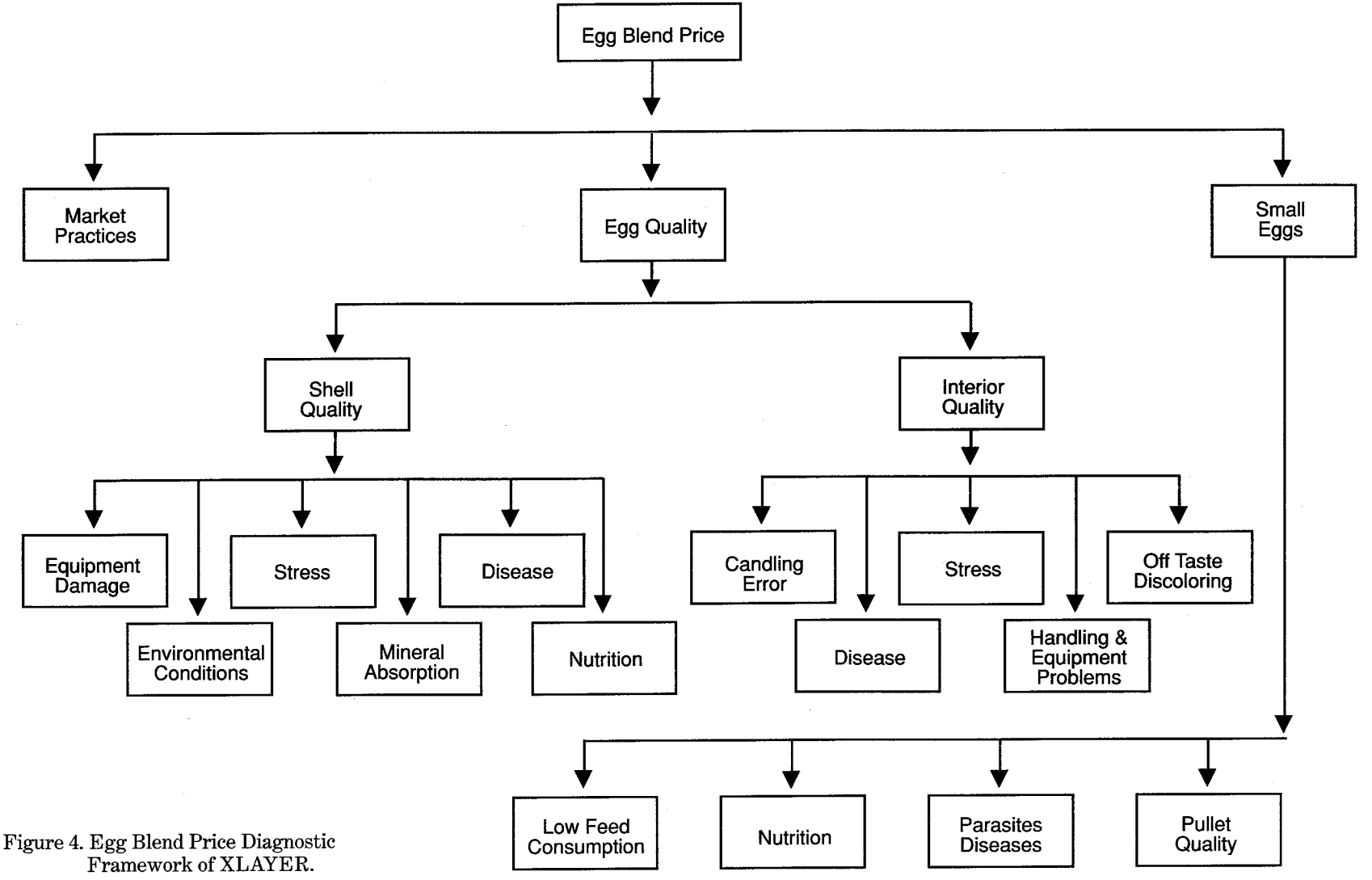

Figure 4. Egg Blend Price Diagnostic Framework of XLAYER.

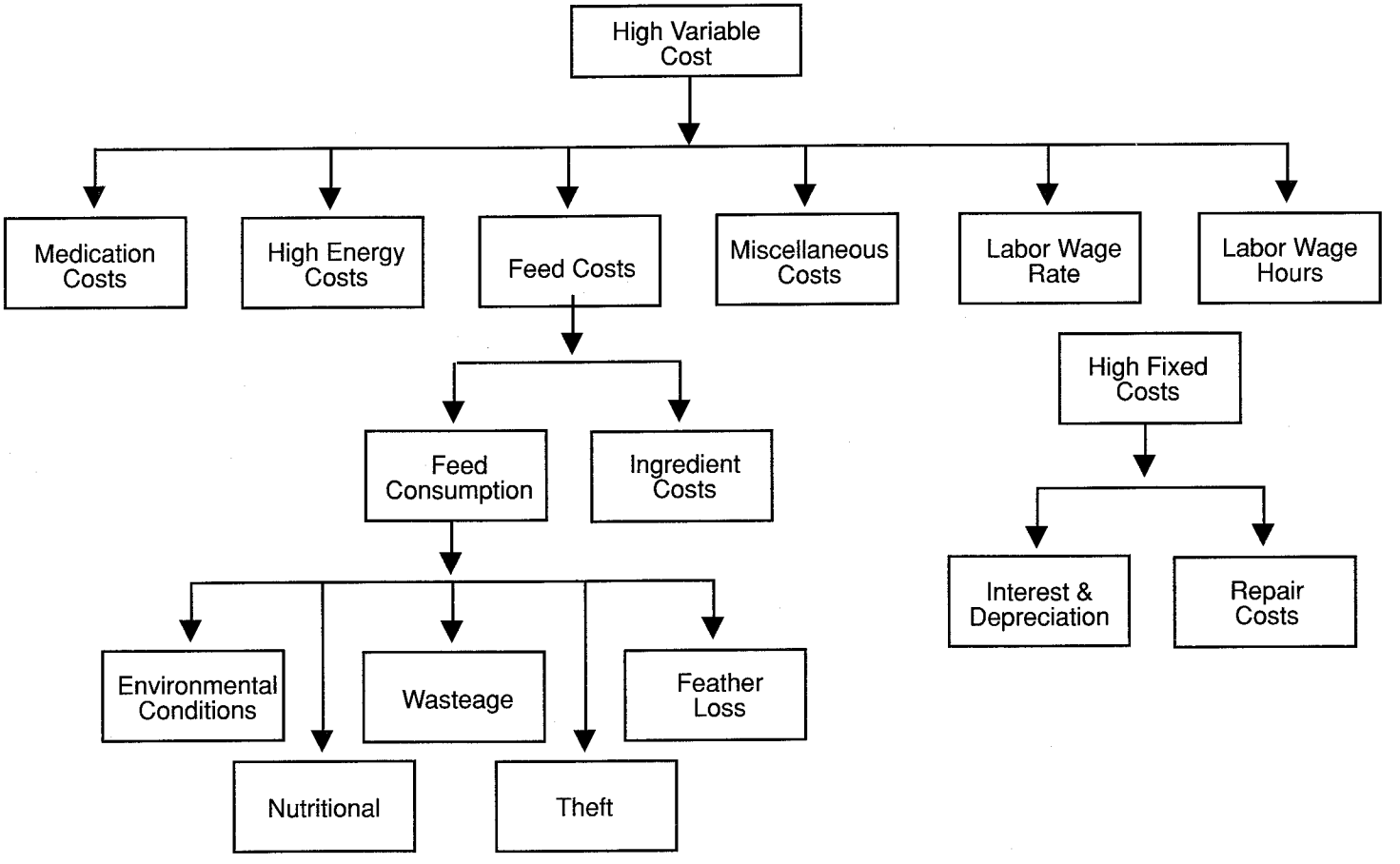

Figure 5. Variable and Fixed Cost Diagnostic Framework of XLAYER.

The small egg sizes rule is:

```
if case_weight = CW
   and goal_case_weight = GCW
   and critical_case_weight = CCW
   and CW < GCW * CCW
   and average_blend_price = ABP
   and dozen_eggs_graded = DEG
   and potential_blend_price = PBP
   and (PBP - ABP) * DEG = SMALLEGGS
   and display( ['
       Economic loss attributed to small egg sizes
       is approximately,',tab(4), $(SMALL
       EGGS),' per week.'] )
   then small_egg_sizes.
```

This rule confirms small egg sizes when egg case weight is less than a case weight standard adjusted downward by a tolerance level for egg case weight. It also calculates the associated economic loss due to small egg sizes based on the difference between the egg blend price received and the potential egg blend price multiplied by the number of eggs graded.

Another type of diagnostic rule contained in the XLAYER program reflects a complex inference requiring the user to respond to a query about current production conditions. A simple example of this type of rule is:

```
if (low_feed_consumption and low_production)
   or (low_feed_consumption and
      small_egg_sizes)
   and grain_change = yes
   then change_grain.
```

As this rule is being confirmed and the preconditions of either low feed consumption and low production or low feed consumption and small egg sizes exist, the user is automatically queried about possible recent changes in the type of grain used in the layer ration. The query involves two separate rule statements

```
question(grain_change) ='
   Have you significantly changed the type
   of grain used in your layer ration?'.
legalvals(grain_change) = [yes,no].
```

The first of these two query rules issues a prespecified question to the user, while the second provides acceptable answers and error checking capability to the query.

If the user responds to the questions by answering yes, another XLAYER rule is invoked which states the management problem and offers a remedy. This rule is:

```
if change_grain and display( ['
   A major change in the grain ration is
   suspected to be causing production prob-
   lems. Reformulate your ration and phase
   in new grains gradually even if the cost
   per pound is higher. Gradually move to
   the lower cost grain substitute.'] )
   then problem.
```

Notedly absent from the diagnostic framework are interrelationships between such factors as nutrition, disease, and stress. Although these interrelationships are theoretically possible, the cooperating consultants did not require analyzing these type of interrelationships in their consulting work and did not include them in the XLAYER program. They argued in today's skillfully managed commercial poultry flocks, management problems attributed to these type of interrelationships are rare.

PROGRAM OUTPUTS

The XLAYER program possesses the ability to diagnose multiple management problems and recommend management actions for more than 80 individual layer production management problems. This capability is exhibited in a management report displayed on screen and/or printed. The report identifies management problems, their associated economic loss, and specific management recommendations. An example management report appears in Figure 6. Specific management problems and recommendations related to housing and equipment management, nutrition, diseases, economics, marketing practices, and general management practices are contained in the program.

Approximately 37 percent of the XLAYER program's diagnostics are about layer nutrition. Nutritional diagnostics include such things as excessive or restrictive metabolizable energy, calcium, and sodium supplementation, methionine, methionine-cystine, lysine, threonine, and trytophane amino acid imbalance, improper vitamin and/or trace mineral mix supplementation, and poor egg shell quality induced by improper ration formulation.

Some 23 percent of the XLAYER program's diagnostics directly address general management practices. Improperly trained egg candlers, a poorly managed poultry waste system, cage overcrowding or under-utilization, sudden changes in layer house environment, excessive egg handling time, and egg or feed theft represent some of the type of general management problems considered by the XLAYER program.

Housing/equipment diagnostics account for about 18 percent of the XLAYER program's management expertise. The XLAYER program identifies problems like improperly ad-

justed or operating mechanical egg gathering and feeder equipment, high or low layer house temperature, low or high water consumption due to malfunctioning waterers or poor well water quality, limited lighting, and inadequate ventilation.

Economic diagnostics, representing 14 percent of the XLAYER program's capability, address traditional economic performance problems. These include such things as high repair and maintenance, pullet rearing, labor, interest, and energy costs.

Disease and marketing problems represent the remaining diagnostic powers of the program. High broker fees, inappropriate class weight sales contract, respiratory diseases, parasites, infectious coryza, fowl cholera, and MG disease are some of the disease and marketing diagnostics addressed by the XLAYER program.

PROGRAM LIMITATIONS

The XLAYER program has the potential to be a useful management tool, yet it has limitations. Major limitations relate to the program's knowledge base. XLAYER's knowledge base is static since the program does not possess the ability to learn from experience. As a result, XLAYER's knowledge base must be continually updated as new diagnostic techniques are developed and possibly new genetic bird strains are introduced. The magnitude of this limitation is unknown. It may be mitigated because new knowledge can be added to expert system programs much more easily than modifying code in algorithmic programs.

XLAYER's knowledge base is also limited to the diagnostic knowledge of the cooperating consultants. No measure of their poultry management diagnostic skills has been made. The magnitude of this limitation is also unknown.

PROGRAM TESTING/VALIDATION

The XLAYER program has been subject to controlled testing with numerous test case data. During initial case testing, the XLAYER program's diagnostic capabilities were further enhanced, and its depth of knowledge was increased. More than 300 individual cases, representing a flock's complete weekly data set, were subjected to analysis by the XLAYER program. These cases, although carefully constructed, confirmed that the program could successfully diagnose each, as well as various practical combinations, of the more than 80 layer management problems included in the XLAYER program.

Currently, it is being intensively field tested with flock data from both the East and West coasts. In these tests, weekly flock performance data are being analyzed by the XLAYER program and its diagnostics are compared to those independently developed by the poultry management experts being emulated by the XLAYER program. In these limited field tests with some 122,000 hens in various flock sizes, representing approximately 70 flock weeks of production data, the XLAYER program has exhibited the promising ability to perform on a level consistent with that of its counterpart poultry management experts. That is, in approximately 90 percent of the weekly tests, the XLAYER program's diagnostics were identical to those independently prescribed by the poultry management experts.

Additional field testing and more intensive validation with more participating flocks is continuing. Field testing is scheduled to be completed by the summer of 1990.

PROGRAM AVAILABILITY

The XLAYER program will be made available to poultry managers by the cooperating consulting firm after extensive field testing is

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Economic losses attributed to low production are: $425 per week.

Verify suspected high metabolizable energy level in layer ration. If confirmed, reformulate ration to reduce metabolizable energy level to your flock's standard recommended in the Layer Performance Financial Report.

Also note a methionine-cystine imbalance in the layer ration. Methionine-cystine should be within 20 percent of your flock's potential intake. If confirmed, reformulate the ration's protein content and methionine-cystine supplementation.

Water intake appears high.

Figure 6. XLAYER's Management Report: An Example.

completed in the summer of 1990. The cost of the program has not been established. Program code, excluding Layer Performance and M.1, can be obtained by contacting the authors of this article.

CONCLUSIONS

The present level of performance of the XLAYER program suggests that expert system programs have potential applied application in poultry layer management. Furthermore, it has been demonstrated that an expert system program can be linked to a standalone agricultural, computerized decision-support program and can automatically and routinely access information generated by this program to diagnose management problems and provide insightful management advice. The level of performance of the XLAYER program indicates that it can substitute for scarce and relatively expensive human, poultry layer management expertise. Its successful adoption and widespread use should increase the production efficiency of layer operations and improve producer profits.

The XLAYER program also has shown that it can provide valuable management information in a readily useable form to a range of flock sizes. Relative to economies of size issues, this expert system program appears to be size neutral. That is, it equally benefits different sizes of operation. If any unequal benefit should occur, it is hypothesized benefits favor smaller operations because of the economies associated with making available scarce and expensive human expertise in the more economical form of an expert system microcomputer program.

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