OADEX: AN ADVISORY EXPERT SYSTEM FOR STRUCTURE APPRAISAL AND DESIGN OF INDUSTRIAL ORGANIZATIONS

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ABSTRACT

In today's business world, it is important for managers to assess the effectiveness of their working organization structure. It is equally important, if necessary, to reform and redesign the organization structure to meet the dynamic change in market.

This paper presents a framework of an advisory expert system for Organizations' Structure Appraisal and Design (OADEX). It is designed in a way to combine both theory and practices. A prototype is built by using a production rule-based expert system shell. This work demonstrated that the application of such an approach to industrial organizations is feasible through the use of expert systems.

Keywords: Expert Systems, Knowledge-based systems, Organization Design, Organization Appraisal, Organization structure

INTRODUCTION

Managers manage all the necessary resources to accomplish organization goals. The resources are not only the obvious ones like people, material and facilities, but the design of the organization and the work environment too.

Organization structure is necessary to provide a framework within which organizations can work. By showing the dominant and subordinate roles, it indicates who has what authority and where responsibility and reporting channels are located within the organization. It also demonstrates the way the work tasks are specialized and the corresponding division of labor [1].

Most organization structures' reflect how the powerful decision-makers in organizations feel they can best accomplish their purpose. The structure shows the relationships they want between the leaders of the different parts of an organization. The normally assumed objectives of best structure to get work done or to be most effective are - surprisingly to many people in organizations - often clearly not followed. Some time the purpose of the powerful leader is different to the organization's and detracts from it. While there are some opportunities for checks and balances in the usual organization structure, they are not usually activated until a major problem occurs and then it is too late.

Therefore, it is vital for practicing managers from time to time to assess the effectiveness of their working structure. Also, it is more important to reform the organization structure as appropriate to meet the dynamic environment.

Practicing managers who are experts in the field of organization design are scarce, very much in demand, and expensive. Expertise is also being lost through personnel changes due to job transfer or retirement; and when available, it is laboriously transferred to other humans, a very slow and expensive process. For these reasons, Oadex is proposed as an intelligent advisory expert system that can enhance the capabilities of the less experienced managers. The development of artificial expertise despite being relatively expensive;

once developed, it is easy to disseminate and can be operated at a low cost. In general, expert systems are less vulnerable to errors than human experts, who may be distracted by conflicting demands or make different decisions in identical situations because of emotion or stress. The possibility of combining various forms of expertise leads to the formulation of a shared knowledge base that can be studied for consistency and reliability, making the use of expert systems appropriate.

The work presented in this paper introduces a framework of an advisory expert system for Organizations' Structure Appraisal and Design. Oadex encapsulates the practical experience with one of the common organization theories "contingency theory" in one system. Interviews and questionnaire were used to collect the relevant pieces of information and knowledge. A prototype is built based on specialized knowledge using a rule-based expert system shell.

SYSTEM OVERVIEW

The system is designed to work in practical industrial environment in which usually three elements are involved: the end-user, the organization being assessed and Oadex. Figure 1 shows interaction between each element, information transferred and required, for the functioning of Oadex.

Through the end-user, the necessary data about the organization under consideration (internal and external environments) is fed to Oadex for analysis and evaluation tasks. The analysis result that is a recommended solution scheme, in turn, triggers the configuration of the organization structure and the guideline for the key position associated with the recommended structure. The system output is in the form of graphical displays and can be printed.

Like any expert system, Oadex comprises three basic components: the knowledge-base(s), the inference engine and the user interface. The strength of Oadex laying in its knowledge bases. The use of Oadex as an advisory system is limited to the manufacturing organizations, especially those working in a commodity business. That is the manufacturing firms are working basically with a raw material that is considered a commodity. In the following section the details of building the system knowledge bases are presented.

SYSTEM DOMAIN OF KNOWLEDGE

The Contingency Approach

The current state of organization theory is the result of an evolutionary process. Theories have been introduced, evaluated, and refined over time. The organization theory has passed through four schools of thoughts, the Classical School, the Human-relations School, the Contingency School and the System School [2].

The contingency theory has been chosen as a core principle around which Oadex was built. This approach provides excellent analytical and diagnostic tool to systematically analyze organizations problems and needs [3, 4].

Contingency theory concentrates on organization strategy [7, 8], technology [9, 10], environmental uncertainty [11,12], size of the organization [10, 13]. These are the major contingency variables that determine what the right structure for an organization should be [5, 6]. Two other factors has been considered in the contingency framework. These are the industry type [10, 11] and the strategic key driving forces (organization capabilities) [7]. They may not affect the organizations structure directly like the contingency variable, however they affect the contingency variables themselves and hence indirectly the structure. Figure 2 depicts the framework of the contingency variable on which Oadex is based.

Knowledge Acquisition

In order to inter-relate the contingency variable with practice, the system knowledge base must include practical expertise. This is done through the knowledge acquisition tasks which has been conducted with an organization design

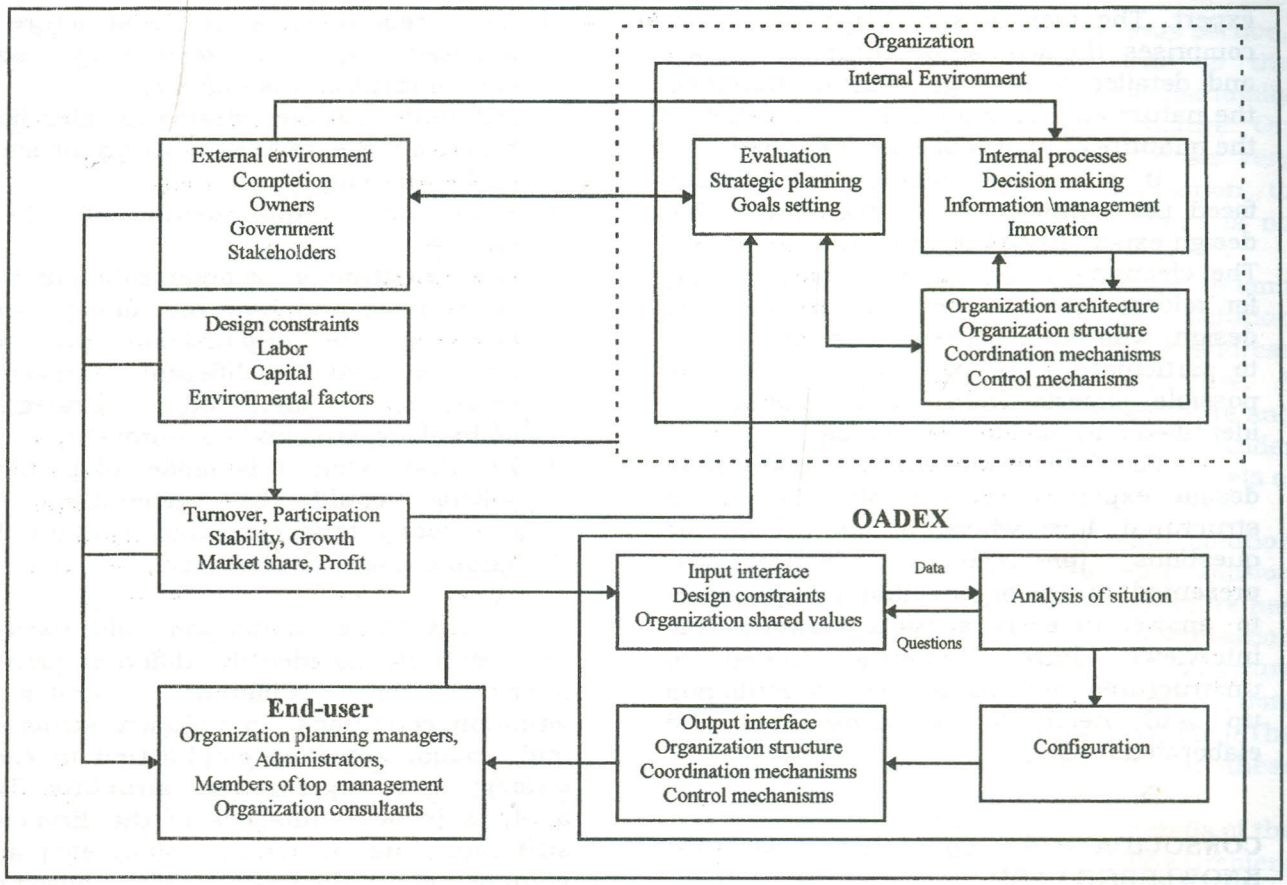


Figure 1 System architecture

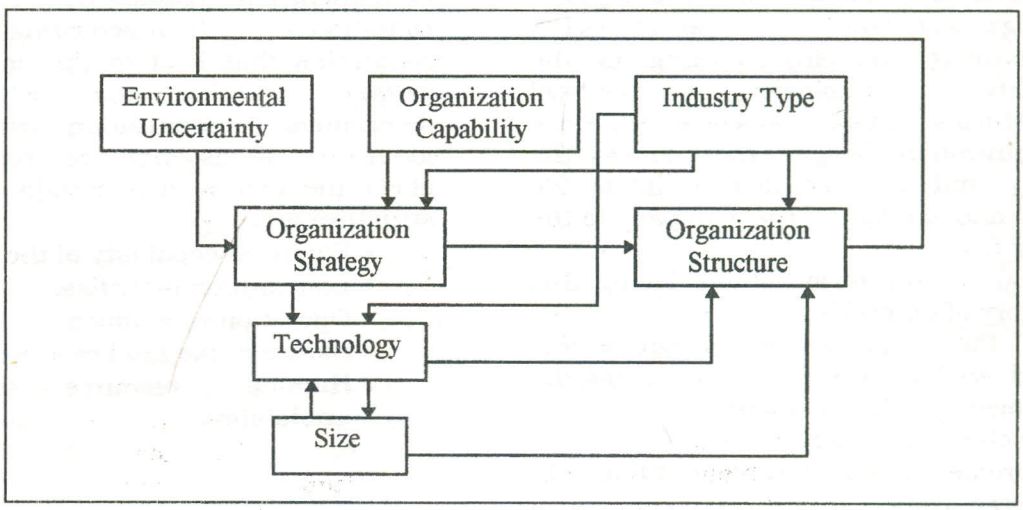


Figure 2 Framework of the adopted contingency approach

expert. The task of knowledge acquisition comprises the acquisition of the preliminary and detailed knowledge. During this task, the nature and an approximate evaluation of the quantity of knowledge are identified.

It is worthy to mention the difficulty faced the author to elect the organization design expert since the choices were limited. The election process began by the searching for a local expert, in the field of organization design, who has good experience and willing to participate. This step generated a list of possible experts. Then, certain criteria were identified and the choice is made.

The interviews with the organization design expert have basically followed a structured line where a list of specific questions (prepared in advance) was presented to the organization design expert to answer in every session. However, the interviews have frequently shifted to unstructured ones as new issues would pop up and need to be investigated and elaborated further.

CONSOLIDATION OF THE SYSTEM KNOWLEDGE BASE

Case Study

The amount of information and knowledge gathered in each interview session was immense and in order to consolidate the findings from the acquired knowledge case study has been utilized. A manufacturing company working in the commodity business, Food-Oil manufacturing company was selected. Since the organization design expert knows the company and is able to consolidate the findings and configure the company to the following features:

1. Typical problems/situations facing this category of enterprises.
2. How the organization design expert would analyze these problems using the contingency theory framework and the value chain approach.
3. Requirements that have to be fulfilled in the organization structures of companies working in this industry.
4. Other requirements in the structure as imposed by the technology, size, environment of this industry.
5. Different feasible strategies identified based on the results of the analysis of each situation.
6 Structural requirements of these strategies.
7. The structure of the organization and its subsystems and how the fit is realized between the organization proposed structure and the different contingency variables (identified strategies, technology, size, and environment).
8. To what extent this model of problem solving could be generalized (in commodity business), and what are the variances and similarities?

The value chains were also used in the analysis to identify: different driving forces for different strategies, situation/conditions in industry structure and, major activities emphasized in each strategy and organization structure. The analysis involved analysis of the firm cost structure (raw material, labor, etc.) and identification of the value activities based on the value they add to the final product.

Characterizing Factors

From the example of a Food-Oil manufacturing company, a series of conditions (characterizing factors) constrains that lead to the indication of a certain situation that which finally determines organization structure is identified. In essence the conditions that affect the choice of a certain organization structure are:

- Financial capability of the firm.
- Distribution activities.
- Operation economics.
- Nature of the final product.
- Human resource capabilities/ availability.

THE TRANSFORMATION TO ORGANIZATION STRUCTURE KNOWLEDGE-BASE

Logic behind the Conditions

This section presents the logic behind the conditions i.e. the constraints and potentials of the characterizing factors:

1. Financial capability of the firm (low-medium-low medium-high): this is both a constraints and potential. If finance is short then the company should stick to certain strategies rather than others. If finance is available then the company can have, for example, its own distribution channel, expand its lines (expand by forward/backward integration, etc.).
2. Distribution activities: similar to financial capability, distribution can be both a potential and constraint. In the sense recognized in Oadex knowledge-base it is a potential to gain competitive advantage if properly installed and managed
3. Operation economics: as Oadex knowledge base addressing potential profitable activities, it is also addressing non-economical/profitable ones. In this respect, the economics of the operation of the firm takes place, e.g. the costs of raw material and the processing may be just at the margin of the final product price.
4. Nature of the final product: if the final product is a commodity and in a way constraining the company profit margins then differentiating the product by some means can be a way to locate new more economic/and profitable activities.
5. Human resource capabilities/ availability: a few of the human resource capabilities are crucial to working in certain activities. For example, hedging capabilities are important to success of procurement in commodity markets. Similarly, marketing capabilities may also be crucial to the management and operation of distribution channels or sophisticated processing systems.

Knowledge Articulation

As discussed in the previous section, the characterizing factors lead to the indication of a certain situation that finally determines an organization structure. On one hand, the characterizing factors very much differ from one organization to another. On the other hand, there is no right or wrong organization structure.

Therefore, it was necessary to limit and narrow down the choices. Solution Scheme (SS) was the term used to address the suggested organization structure. A solution scheme describes the feature and characteristic of the organization under investigation. This was done in two levels of details.

At one level, seven main solution schemes were identified. To each solution scheme a main organization structure has been worked out with the organization design expert. At that level, each structure has the essential departments (production, finance, procurement, marketing, etc.). The level and line of authority of these departments were also determined.

At the second level, the details of the Production, Finance and Procurement departments are configured. The Production Department has four different configurations, the Finance Department has two different configurations and the Procurement Department has two different configurations. The formation of an organization structure at both levels is determined in the acquired knowledge.

As an outcome to the process of gaining a knowledge base for organization structure, a line of thought has to be constructed. Flow charts, tables and matrices were developed to articulate the knowledge together decision trees. Decision trees were then audited by the organization design expert where recommendation for changes take place. Figure 3 shows the solution schemes decision tree.

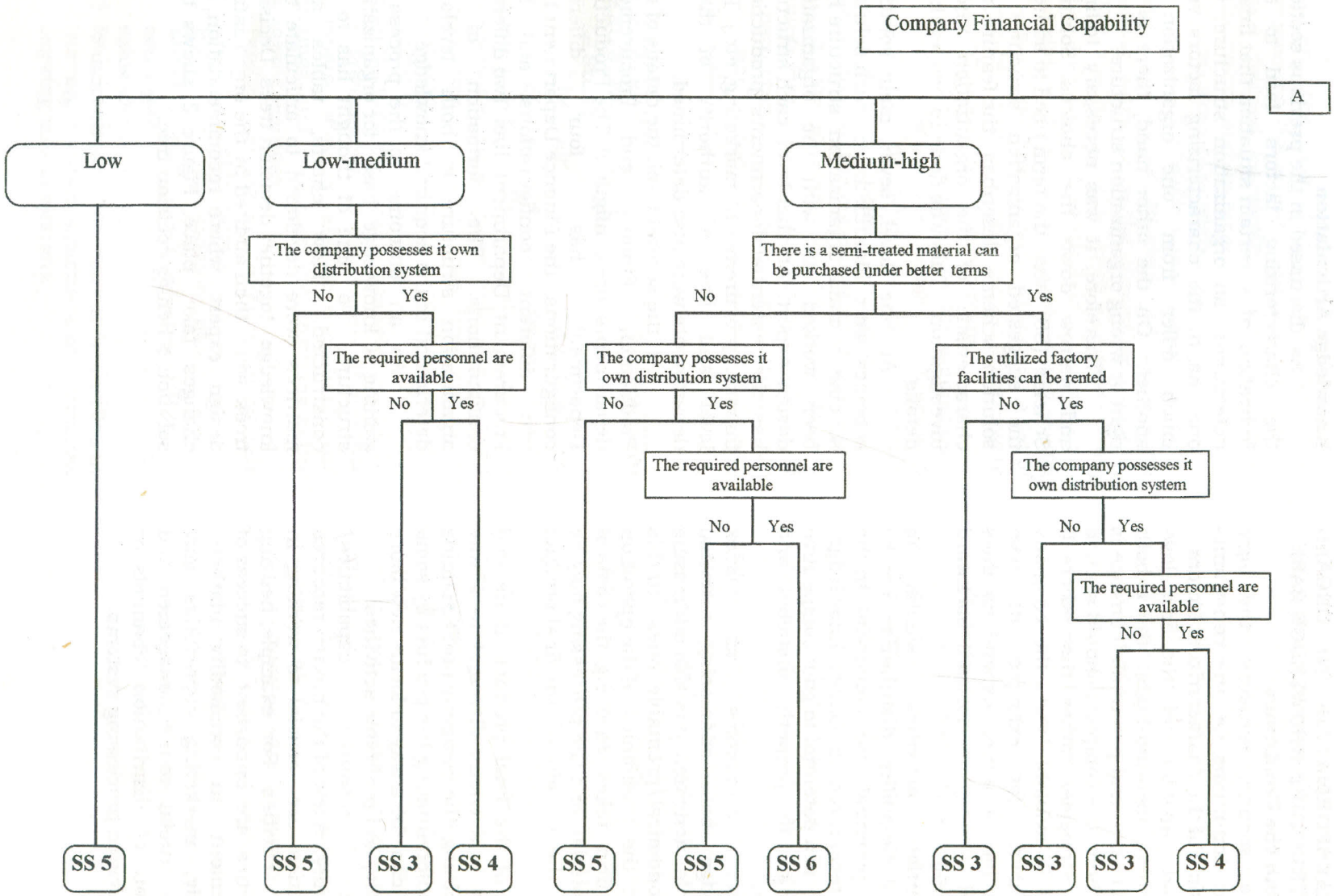


Figure 3 Solution schemes decision tree

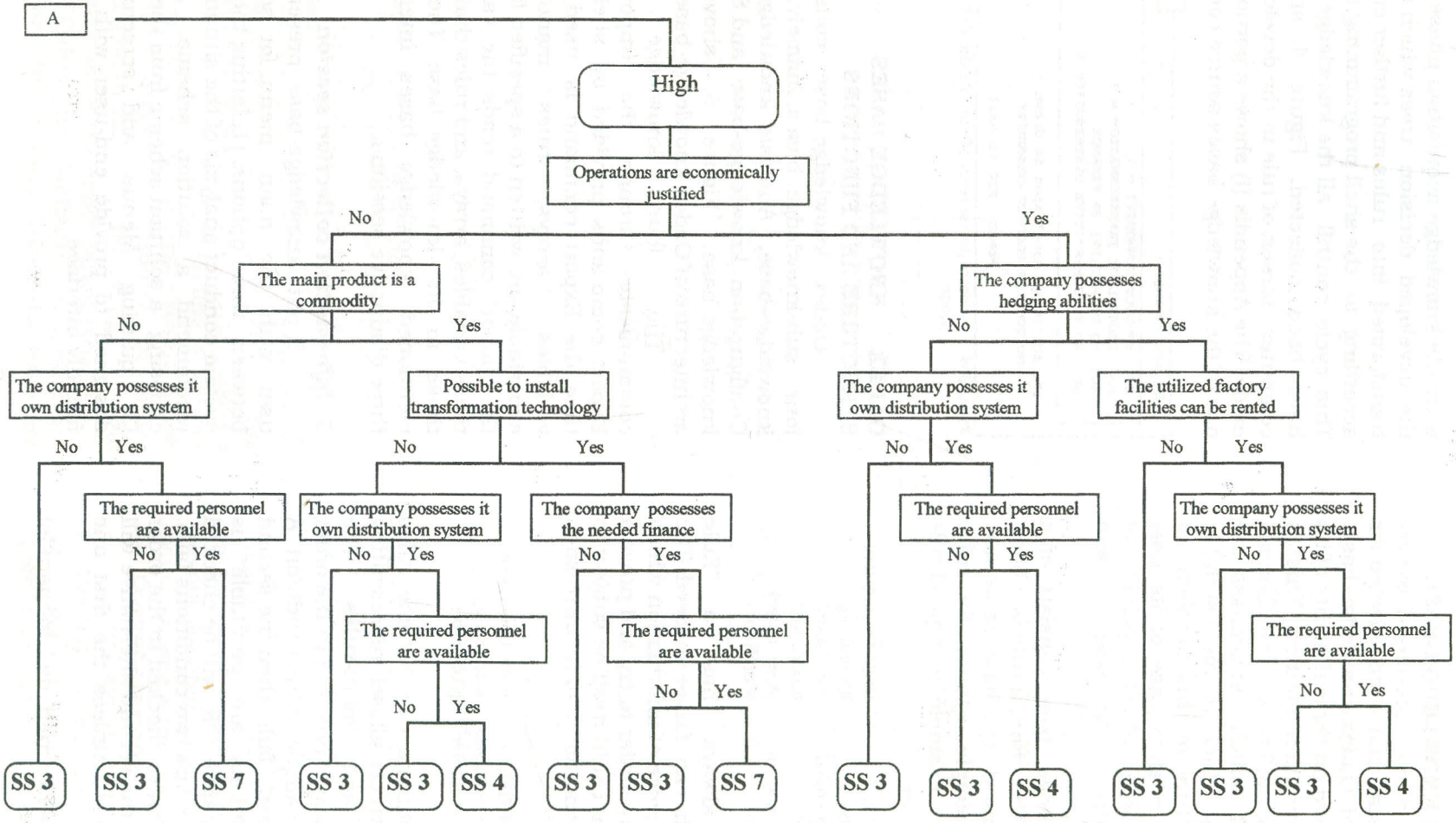


Figure 3 Solution schemes decision tree (*Cont'd*)

BUILDING OADEX KNOWLEDGE-BASE

A medium sized, rule-based expert system shell 'Crystal' has been selected for the development of Oadex knowledge-base. It was chosen based on the suitability of its knowledge representation method. This in addition to its inference mechanism reasoning method which encompass the backward chaining which is most suitable for the design nature of this problem. In addition to the relative ease of its use, moderately low cost, and its capability of interfacing with databases and spreadsheets.

The knowledge base consists of a number of rules. Therefore, a rule is a basic element in the knowledge base structure. Crystal uses a simple syntax for rules representation. For example a typical rule structure is as follows:

```
SCHEME ALLOCATION              {Rule Conclusion}
IF  Finance ability low        {Condition}
AND Economically justified     {Condition}
AND Go to scheme 4             {Condition}
OR  Finance ability medium     {Alternative}
AND Go to scheme 5             {Condition}
```

A rule always has a "Rule Conclusion" which can fail or succeed. The "Condition" is the piece of information which crystal will use in order to try and prove a rule. The condition could itself be subject to whole series of conditions of its own, such as:

```
ECONOMICALLY JUSTIFIED         {Rule Conclusion}
IF NOT A commodity business    {Condition}
AND Operations are profitable  {Condition}
```

Thus, conditions can become rules and vice versa, which allows representing complex rules and meta-rules. The conditions are always checked in the order they appear. For example, if the condition "A commodity business" fails, then the second condition "Operations are profitable" is ignored. The alternative, OR will be checked if either of the previous two conditions fails. Alternatives are always checked in the order they appear, thus the second alternative will never be considered unless the first one fails.

This phase carried out in parallel with the knowledge acquisition phase, using the developed decision trees which is then transformed into rules and further encoded according to the shell programming syntax. This cycle conttill all the knowledge pieces have been collected. Figure 4. shows a computer screen of rule in the development mode. The Appendix (I) shows a portion from one of the knowledge bases source code.

```
By confirming:-                                          Why

 If   PRODUCT COMMODITY = 1                              (Yes)
 and  TECHNOLOGY TRANSFORMATION = 1                      ( - )
 and  GO TO ABILITY TO FINANCE                           ( - )
 or   GO TO COMPETITIVE DISTRIBUTION 5                   ( - )

The following conclusion is drawn:-
    GO TO MAIN PRODUCT COMMODITY

                Press  ESC to exit
```

Figure 4 A computer screen of rule in the development mode

OADEX KNOWLEDGE-BASES - THE STRUCTURE AND FUNCTIONS

Oadex knowledge-base consists of four sub-knowledge bases, namely: Input knowledge-base, Analysis knowledge-base, Configuration knowledge-base and Scheme knowledge-base. Figure 5. shows the architecture of Oadex knowledge-bases.

The four knowledge bases communicate through the Import and Export commands provided by shell. Each time the Export command is used, all the variables, arrays, rules marked as exportable are written to a specified file, and the Import command reads the values of these variables, arrays, and rules that match those in its knowledge base. The above mentioned knowledge bases interact in three distinctive sessions:

1. Information collection session

Input knowledge-base presents the user with the main menu for selection between three options: (1) letting the expert system conduct analysis of the situation and recommend a solution scheme, and (2) choosing a solution scheme from the list, or (3) quitting. Menus, and screens were designed to provide end-user with a user friendly interface.

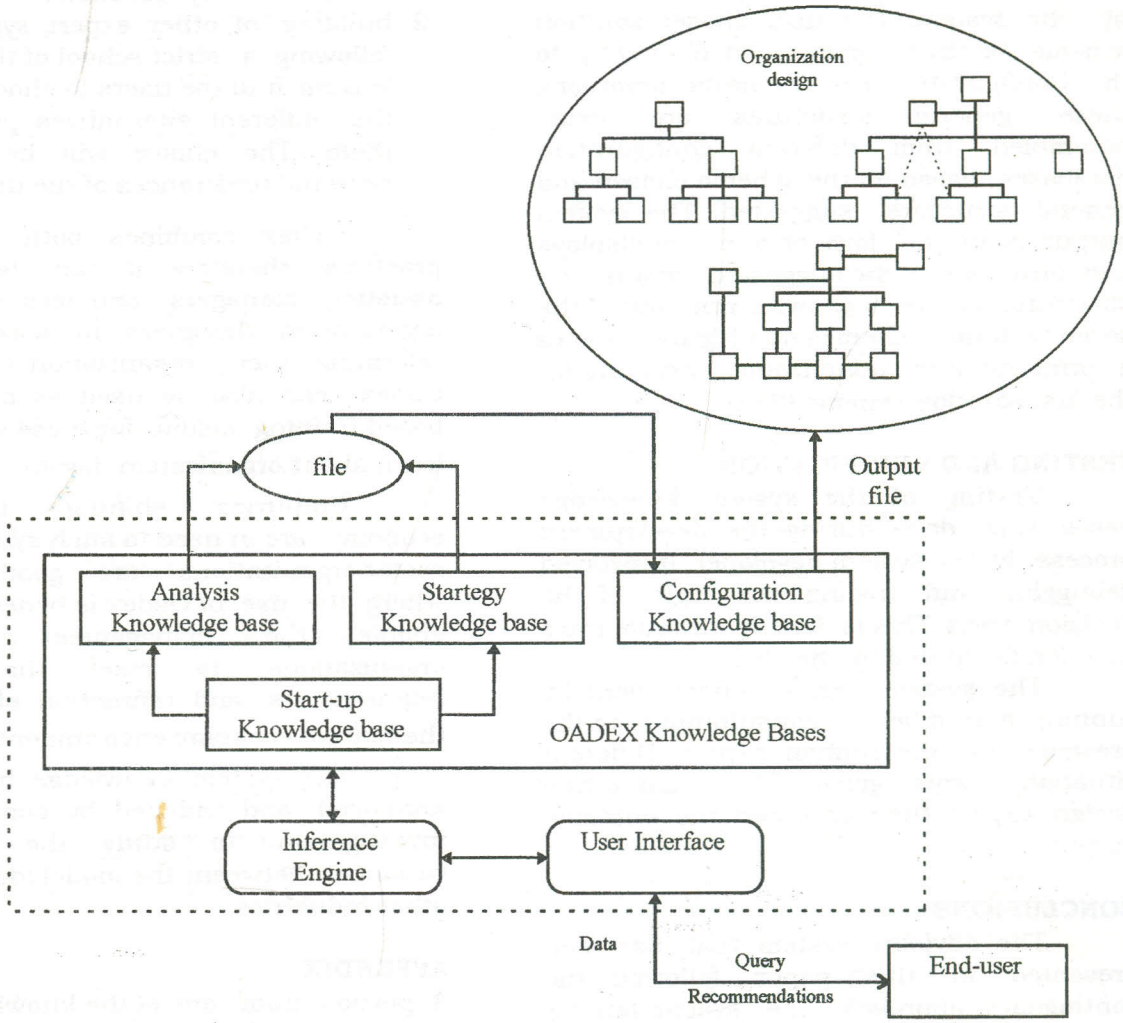


Figure 5 The architecture of Oadex knowledge-bases

2. *Decision-making session*

Oadex analyze the situation of the given organization through the Analysis knowledge-base using the hypothesis generation and verification; i.e. the problem-solving procedure as recommended by the organization design expert. The analysis would result on recommending a certain solution scheme (intermediary result) which in turn trigger a number of other recommendations including the configuration of the organization structure.

Either the Configuration knowledge-base or the Strategy knowledge-base are used during the output task. The Configuration knowledge base performs two functions. The primary one involves a configuration task which involves using initial data; intermediary result of the Analysis knowledge-base, to identify a way to fit some set of components together. The second function is holding the user interface which presents the results to the user.

3. *Output session*

Strategy knowledge base is activated in the case the end-user chooses to override the system Analysis and Configuration knowledge-bases of a certain structure and

select one of the solution schemes provided by the system. The user chosen-solution scheme is thus communicated directly to the 'Configuration' KB. The units comprising these general structures are being assembled from different configuration databases based on the scheme chosen and general structure suggested. The system output is in the form of graphical displays and print out of the suggested organization structure. Figure 6 shows a print out of the seven solution schemes and Figure 7 shows a print out of the organization structure for the first solution scheme (SS1).

TESTING AND VERIFICATION

Testing of the system knowledge bases was done during the development process by the system developer. It involved debugging and tracing the logic of the decision tress. This is done by the rule trace function facilitated by the shell.

The system verification was done by running a number of consultations in the presence of the human expert. Different situations were given. The organization design expert then assessed the obtained output.

CONCLUSIONS

The advisory system that has been presented in this paper followed the contingency approach. The system builder (the author) and the organization design expert have clearly embedded this line of thought in the developed expert system. This has been achieved by adopting the idea 'organization structure follow scheme' which formed the core of the knowledge analysis as discussed earlier.

However, the contingency approach is not the only approach towards organization design. Building of the system has thus intentionally skipped the other approaches, which may be considered unavoidable weakness. Since it is not in any way feasible to combine approaches or subjective opinion in one expert system. The future remedy to this weakness is either by:

1. reconciliation of different approaches to organization design, which does not seem to be very probable.
2. building of other expert systems each following a strict school of thought and leaving it to the users to choose between the different alternatives presented to them. The choice will be based on personal preferences of the user.

Oadex combines both theory and practices, therefore it can be useful in assisting managers and less experienced organization designers in assessing and reforming their organization's structures. Oadex can also be used as a computer-based training media for those who need to learn about organization design.

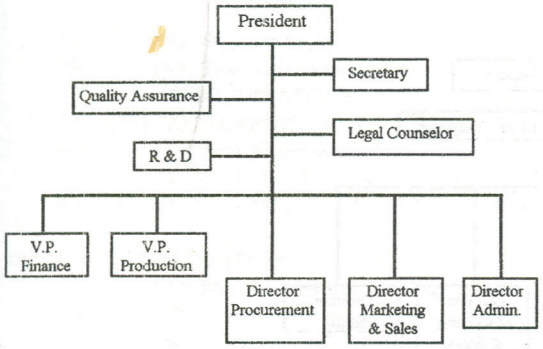
Countries shifting to market economy, are in need to such system. Public sector organizations are good example, where the use of Oadex is beneficial. It will enable the management of these organizations to meet the dynamic requirements and refunction efficiently in the market economy environment.

The system knowledge base can be enhanced and widened by conducting an investigation to study the extent of variances between the model identified and other industries.

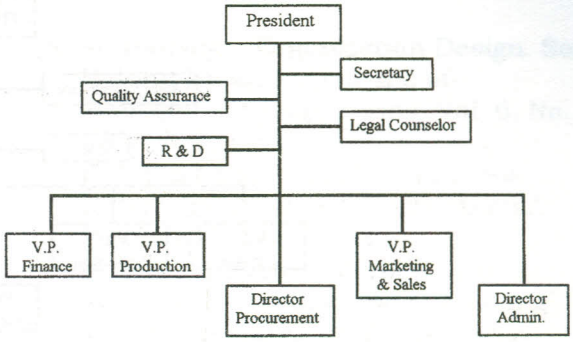
APPENDIX

A portion from one of the knowledge bases source code

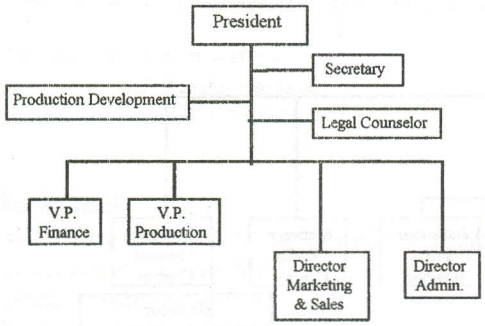
```
[14] GO TO MAIN PRODUCT COMMODITY
IF      DO: Menu Question          product_commodity
        AND DO: Test Expression
                  PRODUCT_COMMODITY = 1
        AND  DO: Menu Question technology_transformation
        AND DO: Test Expression
                  TECHNOLOGY_TRANSFORMATION = 1
        AND [1] GO TO ABILITY TO FINANCE
        OR  [5]  GO TO COMPETITIVE DISTRIBUTION 5

[15]    GO TO RENTING OPERATION
IF              DO: Menu Question semi_treated
        AND     DO: Test Expression
                  SEMI_TREATED = 1
        AND     DO: Display Form
        AND     DO: Restart Rule
        OR      DO: Test Expression
                  SEMI_TREATED = 2
        AND     DO: Display Form
```



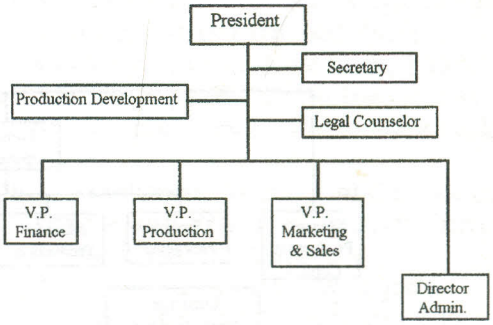
(a) Solution Scheme 1



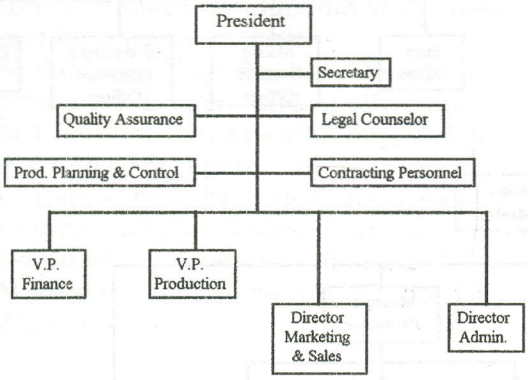
(b) Solution Scheme 2



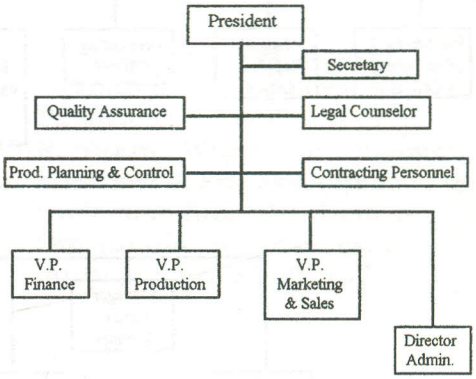
(c) Solution Scheme 3



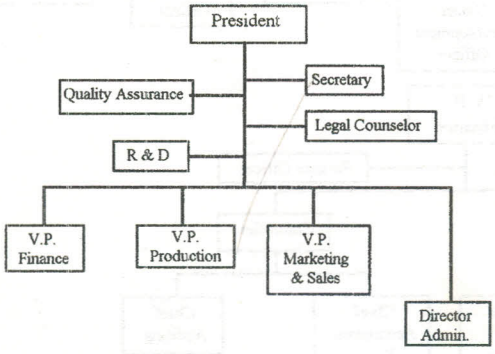
(d) Solution Scheme 4



(e) Solution Scheme 5



(f) Solution Scheme 6



(g) Solution Scheme 7

Figure 6 A printout of the seven solution schemes

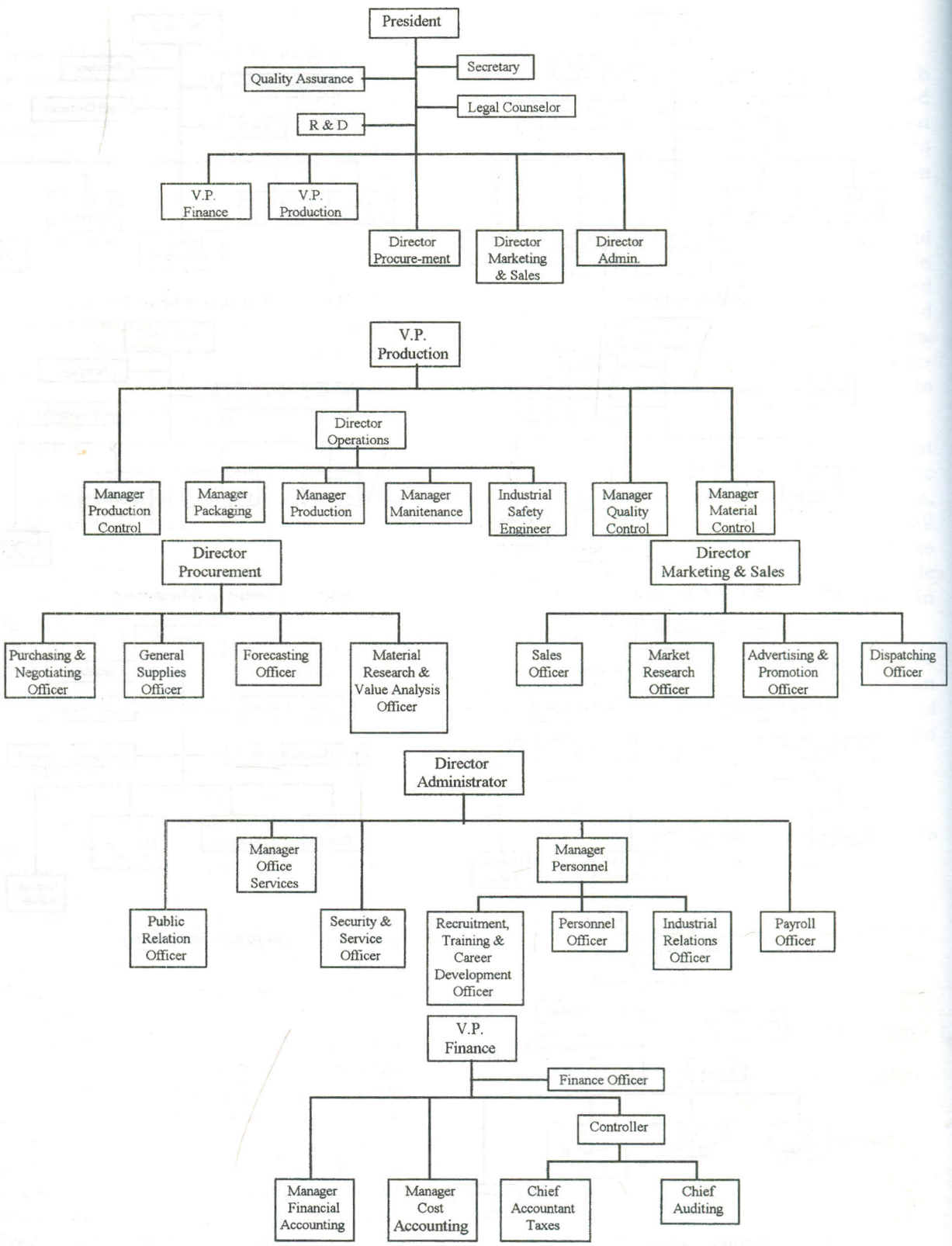


Figure 7 A printout of the organization structure for the first solution scheme (SSI)

```
        AND     DO: Restart Rule
        OR      DO: Test Expression
                  SEMI_TREATED = 3
        AND [16] GO TO RENTING UTILITIES
        OR      DO: Test Expression
                  SEMI_TREATED = 4
        AND [5] GO TO COMPETITIVE DISTRIBUTION 5

[16] GO TO RENTING UTILITIES
IF              DO: Menu Question renting_facility
        AND     DO: Test Expression
                  RENTING_FACILITY = 2
        AND [3] GO TO COMPETITIVE DISTRIB3
        OR  [4] GO TO COMPETITIVE DISTRIBUTION 4

[17] GO TO SOLUTION SCHEME 3
IF              DO: Assign Variable
                  solution scheme:= 3
```

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