Chapter 10:
An application for admission in public school systems *

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Abstract: *An application of expert systems for admission procedures in public school systems is presented in this chapter. The specific problem under consideration is selection of applicants for public nursery schools. The selection is supported by an expert system which evaluates, classifies and ranks applications. The main emphasis is on explanation of the underlying knowledge and solutions, suggested by the system. The system has been developed using DECMAK, an expert system shell for multi-attribute decision making. This chapter presents: the background of the selection problem, a brief overview of the DECMAK shell, description of the expert system and its development, practical results, and the impact of normativity to the results.*

1 Introduction

The objectives of this chapter are to present the results of applying an expert system to a multi-attribute decision making process in a public school system which evaluates, classifies and ranks options to accept students, and to qualitatively assess the sensitivity of the results to changes in the administrative normativity.

The specific problem under consideration, common in excess demand public service agencies, is to select 300 out of 600 applicants for a nursery school in a closely populated young family neighborhood in Ljubljana, Yugoslavia.

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Considering that 300 rejected families would not be happy with the decision, and particularly since this problem was being confronted by other school districts too, the school authorities established a pilot project at this particular school with the aim to develop a methodology for selecting applicants. To this effect a task force team was established consisting of 13 experts from diverse disciplines.

The expert team encountered formidable problems facing the Acceptance Committee, among them their own heterogeneous composition and the different levels of knowledge that each member possessed about the specific problem. Another problem was that the existing procedure for selection was not very helpful in decision making and required data not available in the application forms. Furthermore, there was a high degree of unreliable and in some cases missing information in these forms.

Given the challenges posed by the situation the expert team included two consultants which led the development of a computer-based decision support system. The consultants used an expert system shell DECMAK which is a system of computer programs intended to help the decision-maker cope with multi-attribute decisions (Bohanec & Rajkovič 1987). The theory which underlines this system is based on a new approach to multi-attribute decision making, which combines the traditional (numerical and analytical-oriented) methods with artificial intelligence, mainly expert systems and techniques of machine learning.

The results of the two years of development and testing indicate the following:

a A simple survey of parents of accepted and rejected children shows that they accepted the decisions made with the help of the expert system.

b The work of the Acceptance Committee in nursery schools has been considerably reduced and they feel relieved of the burden of personal explanations by the explanatory power of the methodology.

The results of this application seem sensitive to the following norms:

a The norms guiding the selection and structure of the expert team;

b The norms defining the role of the expert team leader and the system consultants;

c The norms establishing the relationship among the public school authorities, the Acceptance Committee and the expert team.

d The norms establishing the approval process of the decision making criteria (the semantic tree) and the decision rules.

2 Background

Recent socio-economic trends in the Socialist Federative Republic of Yugoslavia indicate that most young families' income is generated by both parents. In Ljubljana, capital of the northern republic of Slovenia where unemployment is almost negligible (below 1%) and with a burgeoning of new housing developments populated by young families, the demand for children's admission in nursery schools outstrips supply, notwithstanding the fast growth rate of new schools.

This general problem was exemplified in a particular Ljubljana district where there were approximately 600 applicants for 300 spaces to be considered by the Acceptance Committee in the local nursery school each year. This expert team found formidable obstacles, some of them inherent in the group approach to multi- attribute decision making. Among these problems the following ones can be highlighted:

a Knowledge heterogeneity: The Acceptance Committee consisted of people with different backgrounds and with varied perceptions about the child-family context. The result was a complex array of approaches to solve the problem and few parameters to serve as the basis for consensus.

b Lack of unifying evaluation methodology: The methodology used by the Committee was borne out of expediency and as such the criteria chosen kept changing as a function of time and of the subjective whims of the members. As a consequence the results were inconsistent.

c Inadequate information: Because the methodology was never unambiguously stated and accepted the data requirements were also loosely specified. Therefore the gathered data did not provide adequate information to help decision-makers.

Facing such powerful obstacles it was not surprising that the Acceptance Committee members felt frustrated and had a general feeling of guilt for not performing fairly in the decision process and not providing the school authorities with a clear answer to the question asked by at least 300 parents: Why was my child not accepted?

To solve the problem a project was initiated to design, develop, test and implement a methodology to support the Committee and consequently the school authorities in their acceptance procedures utilizing a computer-based decision support system.

The project called for establishment of an expert task force team consisting of 13 members including two decision theory experts, one of them selected as chairman of the group and both given the technical responsibility of the project.

The team faced a ranking and selection problem with multiple criteria and a lack of accurate and reliable information to make the pertinent decisions.

To develop the decision support system they recommended the use of an expert system shell named DECMAK that would enable to arrive at a selection methodology which would aggregate qualitative assessments for each criterion and would provide answers whose inner logic would be transparent for the clients.

3 Expert system shell - DECMAK

The main tool used in developing the decision support system to rank nursery school applications was DECMAK (Bohanec & Rajkovič 1987). This is an expert system shell specialized for multi- attribute decision problems, i.e. problems where several alternatives (also called options) are to be ranked according to their quality. The quality depends on a particular set of attributes.

DECMAK is an expert system shell. Its main purpose is to help the user to build a problem-specific knowledge base. The system offers a number of tools for this purpose (Bohanec & Rajkovič 1987). The knowledge base is then utilized in solving the problem, i.e. ranking alternatives.

The structure of the knowledge base closely corresponds to the common multi-attribute decision making schema (Keeney & Raiffa 1976) consisting of two major elements:

1. Attributes structured in the form of a semantic tree, and
2. Decision rules that define the quality of alternatives as a function of the given attributes.

The process of building an expert system using DECMAK has two phases: first, the knowledge about a particular decision problem (i.e. attributes and decision rules) is acquired from the decision-maker(s) and encoded into a knowledge base, and second, the knowledge base is utilized to evaluate and rank options.

Decision rules are entered into the knowledge base in the If-Then form, for example:

IF Social conditions of the family are problematic,
AND Health conditions of the family allow acceptance of a child,
THEN a priority acceptance of the child is recommended.

Such rules are accomplished by a mixed-initiative dialogue between the user and DECMAK (Bohanec & Rajkovič 1988). Mainly, DECMAK suggests conditional parts of rules to be assessed, and the decision-maker just gives their 'THEN' values which are immediately checked for consistency by DECMAK. For verification and justification of the knowledge, DECMAK is also able to translate the rule representation into other representations such as decision trees, aggregate rules and graphics that show the same knowledge from different viewpoints and at different levels of detail.

In the evaluation and ranking stage, the explanation and analysis of the results are specially emphasized. To this effect, DECMAK incorporates the following capabilities (Bohanec & Rajkovič 1987):

- An interactive evaluator for what-if analysis;
- Automatic explanation of the evaluation process;

- Selective explanation of advantages and disadvantages of each alternative;
- Selective comparison of alternatives;
- Sensitivity analysis;
- Option generation.

The DECMAK system has been successfully applied in about thirty practical decision making situations such as:

- Evaluation of computer systems for an enterprise;
- Selection of computer hardware and/or software for schools;
- Evaluation of production control and data base management software;
- Trading partner selection;
- Feasibility evaluation of a project;
- Selection of applicants for a given job;
- Performance evaluation of public enterprises.

4 Development of the expert system

The development of the expert system to rank nursery school applications was divided into two stages:

a building the knowledge base, and

b evaluating and ranking of the alternatives.

The first stage included two activities: assessing and structuring attributes into the form of a semantic tree, and definition of decision rules for classifying alternatives as a function of the attributes. The second stage was a practical test of the system. The knowledge base was utilized to rank the applications according to their acceptance priority.

4.1 Building the knowledge base

4.1.1 Structuring the attributes

The decision-making problem domain is represented in the form of a semantic tree which consists of the most relevant attributes that could describe the conditions of the child's family. There are three main categories of attributes:

1. Occupation of parents and characteristics of the nursery,

2. Family structure and financial standing, and
3. Social and health status of the family.

These categories are represented by internal nodes in the tree. They are aggregates of eight elementary attributes or tree 'leaves'. For instance, the category "Family structure and financial standing" is an aggregate of

a Form of the family,

b Number of children,

c Housing conditions, and

d Financial standing of the family.

The complete structure of the tree is shown in table 1 where the root (least indented line labeled U) represents the final evaluation of the application. The internal nodes of the tree are labeled A, B, C and D, and the leaves are represented by K1 to K8. The application for each child can then be described in terms of the values of each of the eight elementary attributes which were obtained from the application forms.

Table 1: Tree structure of the attributes

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(U)           FINAL EVALUATION VALUE OF THE APPLICATION
   (A)          OCCUPATION OF PARENTS AND CHILD'S NURSERY
      (K1)         Parents' occupation
      (K2)         Child's nursery
   (B)          FAMILY STRUCTURE AND FINANCIAL STANDING
       (D)         FAMILY STRUCTURE
          (K3)        Form of the family
          (K4)        Number of children
       (K5)        Housing conditions
       (K6)        Financial standing of the family
   (C)          SOCIAL AND HEALTH PICTURE OF THE FAMILY
       (K7)        Social conditions
       (K8)        Health conditions
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The specific value of each attribute belongs to a previously defined discrete set of values. For example, the attribute "Social conditions" can take one of the following three descriptive values:

(1) Non-problematic

(2) Slightly problematic: When education ability of parents is low (unequal, inconsistent education, exaggerated pretentiousness or indulgence, neurotic reactions of parents), or there are improper relations in family (easier forms of parental personality disturbances, privileged or ignored children, conflicts in the family), and

Table 2: Attribute values

(U) FINAL EVALUATION VALUE OF THE APPLICATION:
- (1) acceptance is not recommended,
- (2) acceptance is recommended,
- (3) acceptance is very much recommended,
- (4) priority acceptance is recommended,
- (5) special priority acceptance is recommended.

(A) OCCUPATION OF PARENTS AND CHILD'S NURSERY:
- (1) convenient,
- (2) less convenient,
- (3) inconvenient,
- (4) critical.

(K1) Parents' occupation:
- (1) usual,
- (2) pretentious,
- (3) of great pretension.

(K2) Child's nursery:
- (1) proper,
- (2) less proper,
- (3) improper,
- (4) critical,
- (5) very critical.

(B) FAMILY STRUCTURE AND FINANCIAL STANDING:
- (1) convenient,
- (2) inconvenient,
- (3) critical.

(D) FAMILY STRUCTURE:
- (1) less critical,
- (2) critical,
- (3) very critical.

(K3) Form of the family:
- (1) complete family,
- (2) completed family,
- (3) incomplete family,
- (4) foster family.

(K4) Number of children:
number of preschool and school-age children.

(K5) Housing conditions:
- (1) convenient,
- (2) less convenient,
- (3) critical.

(K6) Financial standing of the family:
- (1) convenient,
- (2) inconvenient.

(C) SOCIAL AND HEALTH PICTURE OF THE FAMILY:
- (1) acceptance is not recommended,
- (2) acceptance is recommended,
- (3) priority acceptance is recommended.

(K7) Social conditions:
- (1) non-problematic,
- (2) slightly problematic,
- (3) problematic.

(K8) Health conditions:
- (1) acceptance is not recommended,
- (2) acceptance is recommended,
- (3) priority acceptance is recommended.

(3) Problematic: When there exist improper educational ability of parents, improper relations in the family, social and antisocial forms of restraint behavior of parents or other members of the family.

A summary of the values for the remaining attributes is given in table 2.

The values for each of the elementary attributes (tree leaves) were obtained from the child's parents and, in particular cases, from professional institutions such as the Centre for Social Affairs. An application form was carefully designed in order to obtain:

- relevant data containing a complete picture of the child's family status, and
- data which could be:
  - expressed with the leaf-attribute values,
  - obtained with a certain reliability,
  - verified and examined.

The appropriateness of the attributes and application forms was tested in practice, critically analyzed and changed. For instance, the initial design of the tree was complex. It consisted of about 30 attributes. The tree was later reduced to the form shown in table 1. Some attributes were omitted because they either had relatively small influence to the final evaluation results or could not reach the required reliability levels.

4.1.2 Decision rules

Data from the application forms provided individual attribute values for the leaves of the tree (table 1). Each application could then be described with coded values. For instance, the coded value for "Child One" was represented as follows:

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'Child One': 2 3 1 1 3 1 2 2
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were the codes drawn from table 2 signify:

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(leaf K1) Parents' occupation:             pretentious (2)
(leaf K2) Child's nursery:                 improper (3)
(leaf K3) Form of the family:              complete family (1)
(leaf K4) Number of children:              (1)
(leaf K5) Housing conditions:              critical (3)
(leaf K6) Financial standing of the family: convenient (1)
(leaf K7) Social conditions:               slightly problematic (2)
(leaf K8) Health conditions:               acceptance is recommended (2)
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A numerical coding of descriptive values was chosen in order to simplify data manipulation due to the large number of applications.

Probably the most crucial task to build the knowledge base was to identify and define a mapping of partial leaf values into the final evaluation value. The expert team proposed aggregation of lower-level values utilizing decision rules.

An example of such rules for the social and health picture of the family (attribute C in table 2) is the following: ‘priority acceptance’ is recommended (value 3) regardless of the value of social conditions (K7) if health conditions (K8) say that priority acceptance is recommended (value 3). On the other hand, ‘acceptance’ is recommended (value 2) if health conditions (K8) are recommended (value 2), even if social conditions (K7) are slightly problematic (value 2).

Table 3 shows the complete set of rules for the social and health picture of the family. In the whole knowledge base, there are five such tables, one for each aggregate attribute (node) in the tree. Each table can be considered as a one-level aggregation function.

According to these rules the applications are finally classified into 5 classes. To refine the ranking within a class an aggregation formula was used, tested and proved quite useful in practice.

Table 3: Decision rules

Social conditions (K7)	Health conditions (K8)	Social and health picture of the family (C)
	Acceptance is not recommended (1)	Acceptance is not recommended (1)
<= Slightly problematic (2)	Acceptance is recommended (2)	Acceptance is recommended (2)
	A priority acceptance is recommended (3)	A priority acceptance is recommended (3)
Problematic (3)	Acceptance is recommended (2)	A priority acceptance is recommended (3)

The formula was the weighted average of the values of the attributes:

$$F = \sum_{X \in A} w(X)x$$

where:

F	- evaluation value
A	- set of all attributes, i.e. leaves and aggregate attributes
X	- an attribute
$w(X)$	- weight of attribute X
x	- value of attribute X.

Weights were chosen such that the evaluation value F would lie in the interval from 1 to 5. As rules also classify applications into 5 classes, a comparison of both kinds of evaluation results was made possible.

The values of the attributes, denoted x in the formula, represent numerical codes of descriptive values. These results were not influenced by the number of values of a certain attribute, but only by its importance. In this particular case, lower-level attributes had lower weights.

The knowledge base, consisting of a set of tables of decision rules and the formula, was proposed by the expert team, but the Acceptance Committee could change it according to their own judgment. However, they could not change the semantic tree (tables 1 and 2) or the application form as they were the common basis (dictionary, language) for the comparison of data and results.

4.2 Evaluation and ranking of applications

After the nursery school collected the applications and examined the data and the subsequent Acceptance Committee's review of these data as well as of the knowledge base, the evaluation was performed using DECMAK. The result was presented as a list of children's names arranged according to priorities as depicted in table 4. The codes correspond to table 2 and the evaluation classes are shown near the evaluation results which were obtained by the formula for intra-class ranking.

Table 4: Applications, ranked according to the acceptance priority

Name	Evaluation attributes (leave values)								Evaluation result (formula)	Priority class (rules)
	K1	K2	K3	K4	K5	K6	K7	K8		
1.Child One	1	4	1	4	3	2	3	2	(4.48)	5
2.Child Two	2	3	3	2	3	2	3	1	(4.46)	5
3.Child Three	1	3	3	3	1	2	2	2	(4.08)	4
4.Child Four	2	3	3	1	3	2	2	1	(3.81)	4
....										
27.Child Twenty-seven	2	3	1	1	3	1	2	1	(3.11)	4
....										
38.Child Thirty-eight	2	3	1	1	1	1	1	1	(2.61)	4
39.Child Thirty-nine	2	3	1	1	1	1	1	1	(2.61)	4
40.Child Forty	1	3	1	3	1	1	1	1	(3.11)	3
41.Child Forty-one	2	1	3	1	2	1	1	1	(2.95)	3
....										

If we compare the applications 27 and 40 in table 4 we can see that the formula evaluation result is equal in both cases (3.11). Yet we must not equalize them or even compare because they belong to different priority classes (4 and 3, respectively).

As a first approximation, the Acceptance Committee could have cut-off the list at the point where the number of applications corresponded to the number of free places in the nursery school. But in practice, there were marginal cases around the cut-off line which required some further consideration.

In spite of the two level approach (rules and the formula) some applications obtained equal or only slightly different final evaluation values (e.g. applications numbered 38 and 39 in table 4). The reason is that the data did not allow to make further differentiation among such applications. In those cases the Acceptance Committee decided to give additional treatment to these applications. Nevertheless, the work of the Acceptance Committee was reduced from several days to approximately one day.

This process allowed to explain the evaluation results to the parents since once they were acquainted with the list (table 4) they could compare their children's positions with the others on the basis of real data which influenced the priority. The decision rules, for which the Acceptance Committee was responsible, were also easily explained.

5 Results

The expert team implemented and tested the expert-system-based methodology with the involvement of school authorities and of the members of the Acceptance Committee. The school authorities adopted the approach and endorsed it to higher authorities in the city of Ljubljana and the Republic of Slovenia. They are presently considering the application of the methodology developed for the pilot project, on a larger scale.

At the beginning of the project some members of the Acceptance Committee thought that the system was an additional burden for them that would require more work and learning a new, unproven technology. But later on they almost unanimously agreed that possessing an explicit methodology and the reduction of the dependence on subjective valuations simplified their work, reduced the time of deliberations and allowed them to explain without ambiguities the results to the school authorities. Consequently, it was also easy for the authorities to explain the results to the parents of the applicants.

Nursery schools and other professionals involved in the problem have immediately adopted the approach. The amount of work became smaller and consistency of decisions higher. As a consequence, the number of conflict situations between parents and nursery schools decreased.

The critical evaluation of the system results indicated the following:

a The children that needed nursery the most were accepted. This was proved by an analysis of accepted and rejected children, based on questioning some chosen families (Rajkovič et al. 1985). This was also shown by the fact that the complaints on the Acceptance Committee decisions were rare.

b The data available in the decision making process gives school authorities the possibility to organize children in an optimal manner for their educational requirements.

c The work of the Acceptance Committee has been shortened from 4 to 5 days to 1 to 2 days. Considering that the Committee is composed of 10 to 15 members this implies a considerable savings of time.

d Legal security of people has increased since it became easy to give reasons for individual applications being accepted or rejected. The proposal of a new regulation on accepting children to nursery schools is based on methods used in our work.

6 Sensitivity of the results to normativity

For this admissions system to be implemented on a larger scale than the pilot project it is clear that certain norms must be defined. The design of these norms should take into consideration the sensitivity of the results to their characteristics. The experience of the pilot project indicates that the following norms appear to affect the outputs of the system:

a Norms guiding the selection and structure of the expert team.

b Norms defining the role of the expert team leader and the system consultants.

c Norms that establish the relationship among the public school authorities, the Acceptance Committee and the expert team.

d Norms establishing the approval process of the decision making criteria (semantic tree) and the decision rules.

6.1 Selection and structure of the expert team

Perhaps the most important decision to be taken by school authorities is the definition of who will constitute the expert team. In the pilot study the fact that one member of the Acceptance Committee was an expert on decision theory and was eventually made chairman of the expert group contributed greatly to the success of the project.

Diversity of the backgrounds of the expert team had a dual effect: positive since it enriched the knowledge sources but also negative since it was difficult to achieve consensus. It also appears that the number should be reduced from the 13 used in the pilot study to 5 or 7.

6.2 The role of the expert team leader and system consultants

The expert team leader in this case was acknowledged as an authority in decision theory and that facilitated his work. Since the project has important technical inputs, it appears that the chairman should have the capability to be a 'knowledge engineer' to transfer the expertise of the group to the knowledge base of the expert system. If this is not possible this role could be played by a specialized expert system's consultant.

6.3 Relationships

The relationship among authorities, Acceptance Committee and the expert team must be clearly defined: The expert provides the methodological support, the Acceptance Committee recommends and the authorities decide. It became very important in the pilot study that any overlaps should be avoided, particularly the expert team should avoid at all costs the 'temptation' to decide on behalf of the authorities.

On the other hand, the Acceptance Committee is a heterogeneous group of nonprofessionals gathered together for a short time. Consequently, there should be a person (decision moderator) who acts as an 'interface' between the expert system and the members of the Committee, thus allowing the members to concentrate on essential elements of decision making, e.g. on rules and critical cases.

6.4 Approval of the semantic tree and decision rules

The building of the expert system knowledge base requires that the semantic tree is clearly defined. Since the methodology is based on the application of the semantic tree, its structure will determine the outcome. It is therefore very important for the decision-makers to approve the form of the tree and its logical implications.

The same thing can be said about the decision rules that permit the aggregation of attributes. They should be clearly explained to the decision-makers and their approval should be obtained before proceeding with the project. In the pilot project particular care was placed in this procedure and it can be said that it was instrumental in the successful final acceptance of the system by the school authorities.

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