

# Student-Developed Decision Support Systems as a Learning Aid in Industry Sector Analysis Projects

Michel Mitri

*Decision Support Systems (DSS) technology provides a structure and model that can be used as a pedagogical tool for guiding students while they conduct research projects. This article describes a DSS technique called Candidate Evaluation and its implementation in a DSS authoring tool called Candidate Evaluation Editor (CEVED) and a consultation environment called Candidate Evaluator (CEVAL). The software is used by students in various business courses to augment research in which they identify key components of a sector in the information technology industry and then evaluate companies and their products in that industry sector. CEVED provides a mechanism for creating a knowledge-based expert system and gives students exposure to multi-attribute utility models. CEVAL allows students to apply the model and knowledge base in evaluating real-world companies and products. This is a viable alternative to the traditional term-paper assignments normally given as research projects.*

## Introduction

Decision support systems (DSS) and expert systems (ES) technologies are commonly used for creating computer-aided instruction (CAI) programs. Such software, often called “courseware,” typically includes lesson content, questions, and branching logic designed to meet the needs of an individual student. A sufficiently sophisticated courseware program analyzes the student’s responses to questions and other activities and responds appropriately according to the branching logic programmed by the courseware developer. Often, artificial intelligence and DSS techniques are used to enhance the presentation and diagnostic capabilities of a CAI system. The use and effectiveness of such systems have been studied and reported in the literature (Alavi, 1994; Hofmeister, 1991; Kwok & Ma 1999; Sallis & Jones, 2002).

I have used this approach to develop DSS software for CAI purposes in business courses, primarily related to international marketing (Mitri, 1995; Mitri, Karimalis, Cannon, & Yaprak, 2000) and information systems management (Mitri, 1999), as well as for student and curriculum assessment purposes (Mitri, 2001). The DSS technique I created is called Candidate Evaluation (CE) and is

implemented in two software products, a DSS authoring tool called CEVED, and a DSS inference engine and end-user interface called CEVAL (Mitri, 1991). It has been applied to various learning modes including cognitive, objective, and constructive modes (Mitri, 2002).

## Description of Candidate Evaluation Method

Candidate Evaluation (CE) is a DSS methodology that uses multi-attribute utility models combined with rule-based reasoning to help users evaluate and select from among candidates based on a set of evaluation criteria established by an expert in a particular domain. In this respect, CE combines DSS and expert system approaches. Multi-attribute utility models typically are implemented using a weighted algebraic formulation to obtain scores which measure the “utility” or “goodness” of a candidate being evaluated. This provides a quantitative framework for decision-making, a

*Michel Mitri is Associate Professor, Information Technology and Management Science Program, James Madison University, Harrisonburg, Virginia.*

common technique in DSS. Rule-based expert systems use IF-THEN rules to test for conditions and to produce actions or conclusions based on the truth or falsity of these conditions. These provide a logical, qualitative component to decision making. Thus, the CE method uses both quantitative and qualitative reasoning in its decision processes.

The CE model is implemented via two software tools, an authoring tool called CEVED (Candidate Evaluation Editor) and a run-time end-user consultation program called CEVAL (Candidate Evaluator).<sup>\*</sup> As described below, students are assigned an industry sector to research, use CEVED to build a CE model related to that sector, and then use CEVAL to run that model against candidate companies or products in their chosen industry sector.

The major components of CE include: evaluation criteria, contextual questions, evaluative questions, interpretation fragments, plan types and plans, and hypertext tutorials. The next section of the paper describes these components.

### *Evaluation Criteria*

The central focus of a CE model is a hierarchy of abstracted candidate features, called evaluation criteria, which serve as the baseline for evaluating the candidate. Each criterion is made up of the following attributes: a name, a link to its parent criterion, thus implementing a tree structure; a list of qualitative ratings such as “excellent” or “poor” and corresponding threshold scores, which are the minimum quantitative scores for each of the ratings; a weight implementing the coefficients of the weighted linear model; and a descriptive explanation message that describes the purpose of the criterion.

Criteria are related to each other in a parent-child relationship via the parent attribute, producing a tree-structured hierarchy. A parent criterion’s overall score is based on a linear weighted sum of the scores of its children criteria.

### *Contextual Questions*

These are multiple-choice questions designed to establish the weights of importance of various criteria based on the context. These allow for the dynamic

alteration of the underlying weighted linear model’s coefficient values for the evaluation criteria. The contextual questions contain the following attributes: the criteria affected by the question; the question’s text, a list of multiple-choice answers with corresponding weight-adjustment values specifying the direction and degree to which the chosen answer will change each associated criterion’s weight, and an optional explanation message. During a consultation, users’ answers for contextual questions will determine the final weights for each criterion.

### *Evaluative Questions*

The CE model also includes multiple-choice evaluative questions that will be presented to the end user during a consultation. Questions are grouped into question sets. Each question set is associated with a lowest-level criterion, or leaf node in the evaluation criterion hierarchy.

An evaluative question contains: the question text, an importance weight or coefficient for the question-set’s linear model, a list of multiple-choice answers and their corresponding scores that implement the variables of the linear model, and an explanation message similar in function to those for criteria, but at a finer-grained level. In addition, the evaluative question can be linked to one or more hypertext topics (see Figure 3).

During a consultation, the overall score of a question set is a linear-weighted sum of the questions’ weights and their scores based on user answers. This score provides the rating for the question set, or leaf-node criterion, and is propagated upward to contribute to the scores of the criterion’s ancestors in the criterion hierarchy.

### *Interpretation Fragments*

Another important component of the CE model is a set of interpretation fragments that are linked to and triggered by combinations of criterion ratings or the answers to evaluative questions. An interpretation fragment includes: a heading or title, a body of explanatory text, and a set of presentation conditions each consisting of one or more criterion-rating pairs and relational operators that constrain the

circumstances under which the interpretation text may appear.

Interpretation fragments bring the explanatory power of expert systems technology to the overall multi-attribute utility model embedded in the CE method. Their rule-like IF-THEN structure provides a logical component that facilitates additional reasoning power in the system. During a consultation a final interpretation of the evaluation results will be composed of the set of all interpretation fragments whose conditions were met.

### *Plan Types and Plans*

Plans are decision alternatives. Each plan type is composed of several plans. A plan is composed of a description of the plan and a series of factors that support the plan and factors that refute the plan. Supporting factors are those conditions that would argue in favor of adopting the plan together with the degree or strength of support. Refuting factors are those conditions that would argue against adopting the plan together with the degree or strength of the refutation.

During a CEVAL consultation plans will be scored based on the accumulation of support and refutation weights, then ranked according to the appropriateness of the plan for the given candidate. Thus, for each plan type, there will be a ranked order of plans from most appropriate to least appropriate.

### *Hypertext Tutorials*

The CE architecture allows for the creation of hypertext topics that form a glossary of terms or phrases relevant to a particular CE model. In this way, developers of CE models can incorporate detailed explanations and online help features.

## **The Assignment**

Students of an information resource management course use the CE model to conduct industry sector analyses of technology-related industries. They use CEVED to create a DSS related to their research topic and then use CEVAL to evaluate candidates, usually real-world products or companies that they are researching. A team of students is assigned a

particular sector in the technology industry and is required to research, analyze, and produce a term paper and DSS pertaining to that sector. Industry sectors have included e-commerce software tools, web development environments, semiconductors, search engines, RAID drives, network operating systems, and IT security systems, just to name a few. This project facilitates many learning objectives, including the development and use of computerized decision models, the development of research and analysis skills, oral and written communication skill development, and evaluation and synthesis. With this project, students work toward the type of higher-order skill attainment espoused by Bloom (1956).

The required topics to cover in the sector analysis, and to discuss in the term paper, include the following:

1. A description of the components of the type of product being analyzed.
2. Definitions of all abbreviations and acronyms.
3. A detailed description of the major products that can be found in the marketplace for this segment of the IT industry.
4. The major companies that manufacture, assemble, and distribute this type of IT product, described in terms of their size, relative share of the market, etc.
5. A description of the performance criteria for the type of product being analyzed, that is, how one judges the quality of the product. These performance criteria will make up the CEVAL evaluation criteria and evaluative questions that students construct for their decision support system.
6. A comparison of the relative strengths and weaknesses of the products and their manufacturers, in terms of the performance criteria. Students use CEVAL to do an analysis of each of at least three products or companies in their industry sector and discuss these results in the paper.
7. A historical perspective showing the progress of improvement in the products described in terms of the performance criteria.

8. A description of anticipated future trends in this industry, again in terms of the performance criteria.

Based on this sector analysis, students develop and implement a DSS using the CEVED software. Specifically, they develop the following components in their model:

1. A hierarchy of evaluation criteria that comprise the technical and the business factors. For this, students will need to research the industry to identify the relevant technical and business-related performance criteria in that industry.
2. For each evaluation criterion there should be at least three ratings, such as excellent, adequate, or poor.
3. For each evaluation criterion, there should be an explanation describing what it means and why it is an important consideration.
4. For each rating of each evaluation criterion, there should be an interpretation fragment that gives a paragraph of text explaining the rating and its implications.
5. For the lowest-level evaluation criteria in the hierarchy, there must be a few multiple-choice evaluative questions that will serve as user input for establishing the scores and ratings of the evaluation criteria.
6. Students also need to create hypertext tutorial topics to serve as a glossary of technical terms relevant to their industry sector.
7. Students may choose to create plans or context questions as refinements to their models. Most students do not use these features; primarily they use evaluation criteria, evaluative questions, interpretation fragments, and hypertext tutorials.

Once they have developed this DSS, students use CEVAL to evaluate companies and their products or services with respect to the criteria they had established in the model. They must select at least three vendors or manufacturers in their assigned industry sector. Students then use the CEVAL software to evaluate the vendors' performance. As the students answer the multiple-choice questions, they are required to include

comments on the screen CEVAL provides to justify the answers. These comments will include the students' reasons for giving a particular answer or references to literature that they read. In this way, the instructor can verify that the student is giving answers based on serious thought instead of simply making guesses or giving random answers.

Finally, the term paper should also include the following descriptions with regard to the DSS:

1. A description of CEVED and CEVAL, and how they work.
2. A description of the evaluation criteria that were defined.
3. Figures of the CEVED evaluation criteria hierarchy and figures of various sample screens from the CEVAL run of the module.
4. A narrative description of the model.
5. Descriptions of the candidates that were run through the system.
6. Comparison of the results from the system versus what the students would have expected.

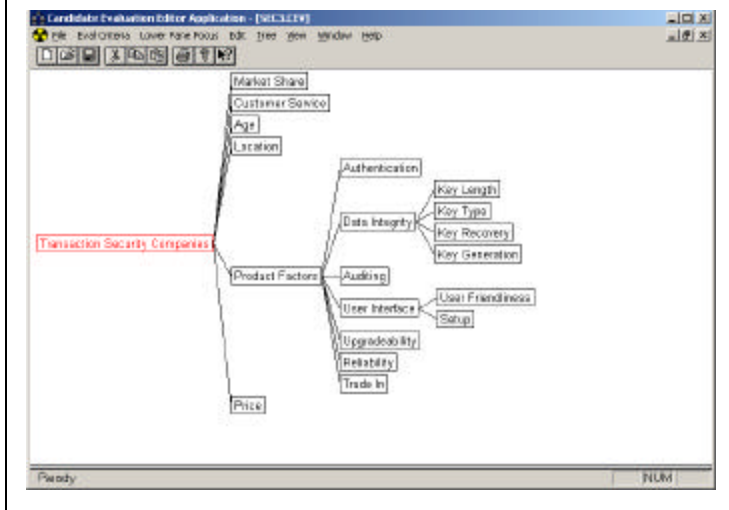
### **An Example Student Candidate Evaluation Model: Evaluation of IT Security Services**

The DSS described here was developed by a team of students in an IT management course. This team used the CEVED program to develop a CE model for evaluating information security service tools. The criteria they established were based on their research in the IT security industry and were divided into company characteristics and product characteristics. Figure 1 shows a CEVED screen containing the evaluation hierarchy for the IT Security model.

The students incorporated in each criterion the important properties, such as weight, ratings and threshold scores, and explanation. Figure 2 shows the dialog that allows them to enter these properties.

Students also created evaluative questions for each of the lowest level criteria, the leaf nodes in the hierarchy. Figure 3 shows a sample evaluative question created by the students who developed the IT Security model. Here, the students wrote the text of the question and answers. In addition, the students identified the weight of importance that this

**Figure 1: A CEVED screen showing the hierarchy of evaluation criteria for evaluating IT Security tools and companies**



**Figure 2: A CEVED dialog that allows CE authors to create and edit evaluation criteria. Attributes include name, weight, ratings and threshold scores, and explanations**

**Figure 3: A CEVED dialog that allows CE author to create/edit an evaluative question**

question exerts with respect to its evaluation criterion, the scores that are assigned for each answer that the end user may give, an explanation, and links to hypertext topics that are relevant to the question. Notice that the explanation box provides a means for students to enter knowledge they have gained regarding a specific component of the model. Thus the knowledge that students obtained as a result of their research is incorporated in the model in qualitative as well as quantitative representations. In a sense, these verbal fragments are analogous to writing a term paper, only in a highly structured framework.

After constructing the hierarchy of evaluation criteria and the evaluative questions, the students created interpretation fragments and tied these to conditions related to the ratings for criteria. During a CEVAL consultation, these fragments are triggered in a rule-based fashion based on the truth value of the conditions. For example, see the interpretation fragment generated in the CEVED screen of Figure 4.

This interpretation fragment is triggered in CEVAL if the candidate rates as “bad” in the Key Recovery criterion. This causes the paragraph of the explanation to become part of the overall verbal report. The verbal report is composed of all the paragraphs whose conditions have been met. In the assignment, students were required to produce a paragraph for each possible rating of each criterion. In the IT security model there are 20 evaluation criteria, and the students made 3 ratings for each criterion, so they constructed a total of 60 interpretation fragments.

Finally, students created several hypertext topics that formed a glossary of terms relevant to the model in question. For the IT security model, these included mostly security-related terms and their definitions.

Construction of this model adds a unique dimension to the typical research project by imposing a model-based structure and forcing students to consider the topics they read about in terms of this structure. A corollary benefit is that this model can then be used by future

students to learn about the important criteria for selecting IT security tools; thus, future students can benefit from the work of past students.

## Using CEVAL to Evaluate the IT Security Companies

After developing the CE model, the students used the model to evaluate and compare three IT security products. This comparison was done via CEVAL. This program, which serves as the inference engine of the CE algorithm, allows the user to answer the evaluative questions, then scores and rates the candidates being evaluated, in this case the candidate IT security companies, and provides interpretations and side-by-side comparisons of the evaluation results.

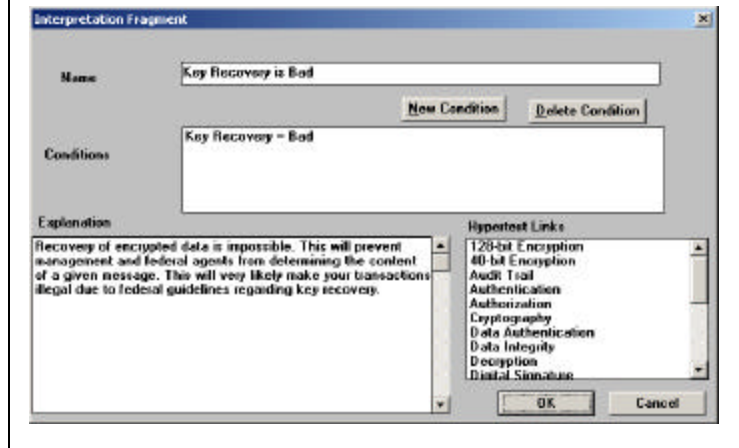
For their research project the students evaluated three IT security products, all high-end tools used by major corporations. The students created candidate files using CEVAL for each of these companies, and then proceeded to use the CEVAL program to answer the multiple-choice evaluative questions. A typical screen in CEVAL looks like Figure 5.

The screen includes a list of all the questions. As the user scrolls from one question to the next, the full question text appears at the bottom of the screen, and the choices become available for the user. The user also has the ability to enter comments for each answer given. Students were required to include these comments to justify the answers they gave, which showed the instructor that research was conducted to arrive at a reasonable answer.

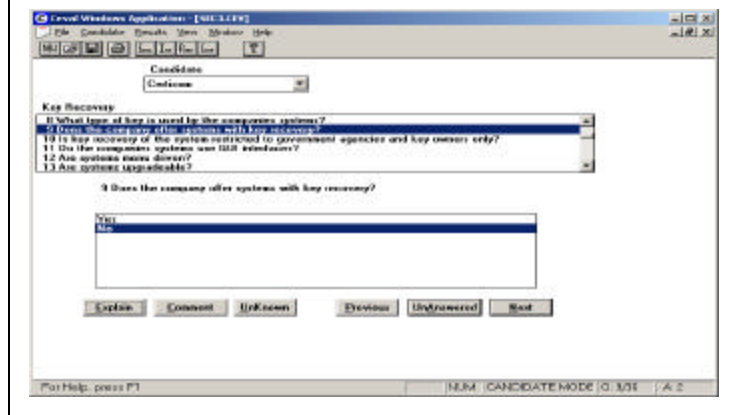
Since the students created an expert system, they also created explanations for each of the questions that an end user could query. In addition to the question's explanations, the hypertext links provide access to related topics, as shown in Figure 6.

As the question-and-answer process proceeded, the students were able to view the results of the evaluation, including the

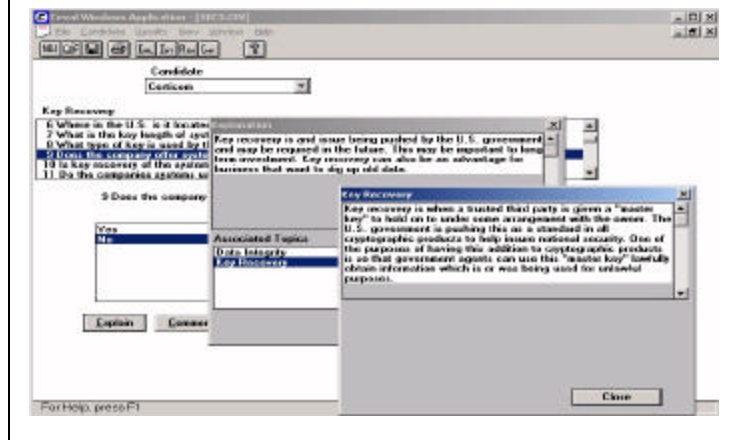
**Figure 4: A CEVED dialog that allows a CE author to create and edit interpretation fragments**



**Figure 5: A CEVAL screen that shows the list of evaluative questions, the answer choices of a selected question, and a pop-up window for user comments related to the selected question**



**Figure 6: A CEVAL screen showing the explanation and associated hypertext topics for a selected evaluative question**



quantitative scores and ratings. Figure 7 shows the scores and ratings for one of the companies after the evaluation. Here, the students were able to see the score and rating for the candidate on each of the evaluation criteria. Furthermore, the student could see the questions that related to the selected evaluation criterion and see what changes would occur to the scores when he or she changed the answer.

In addition to viewing evaluation results, students could see the interpretation. Recall that interpretation fragments are paragraphs of text that will be displayed if their conditions are met. The full set of interpretation fragments that meet their conditions is called an interpretation, which is essentially a text report that describes the evaluation result and its implications. Figure 8 shows an interpretation in the IT security model. The interpretation screen shows the list of interpretation fragments whose conditions have been met in the top box and shows the full description for a selected interpretation fragment in the bottom box.

The students were also able to see a side-by-side comparison of the candidate IT security products and companies using the CEVAL program. CEVAL's comparison option presents a grid of the scores and/or ratings for each of the criteria, as shown in Figure 9. Students could also choose to see a graphical display of these comparisons via CEVAL's bar-chart option.

The students used the evaluation results in their final report to help them rank their preferences for IT security tools based on the criteria they had established while developing the DSS. Their final report included descriptions of their CE model, references to the academic and industry literature related to IT security tools, and a description of the results of running CEVAL to evaluate and compare the candidate companies.

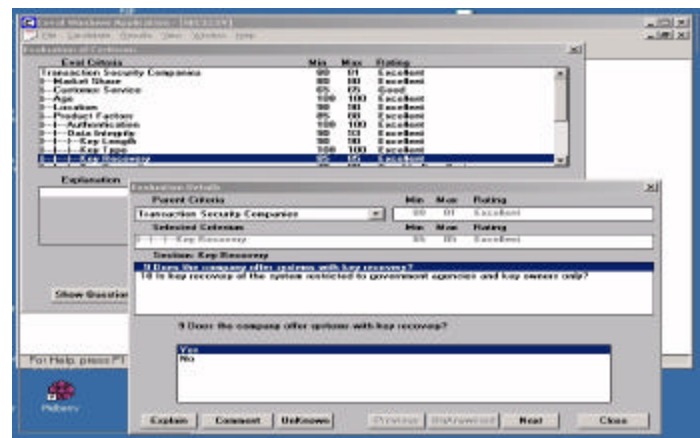
### Conclusions and Future Directions

This article described a DSS system based on the Candidate Evaluation (CE) model, a multi-

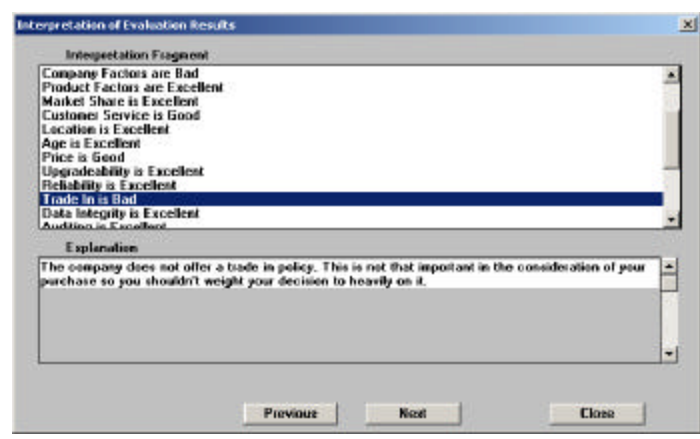
attribute decision model I developed. This DSS system, implemented in the software tools Candidate Evaluation Editor (CEVED) and Candidate Evaluator (CEVAL), was used by students in various business courses to augment research projects in which students study an industry sector, develop a DSS for evaluating companies or products in that industry, and then use the DSS to evaluate and compare these companies or products.

Although I have not conducted formal studies to assess the usefulness of this approach to teaching,

**Figure 7: A CEVAL screen showing the evaluation (scores and ratings) for each evaluation criterion, with a popup dialog showing the questions related to the selected criterion**



**Figure 8: A CEVAL screen showing the list of interpretation fragments whose conditions were met in an evaluation, and the full text of the selected fragment**



**Figure 9: A CEVAL screen showing side-by-side comparisons of the candidates**

Evaluation Criteria	Certicom	Security	F-Secure
Transaction Security Companies	Excellent	Excellent	Excellent
Market Share	Excellent	Good	Good
Customer Service	Good	Excellent	Excellent
Age	Excellent	Excellent	Good
Location	Excellent	Excellent	Excellent
Product Factors	Excellent	Excellent	Excellent
Authentication	Excellent	Excellent	Excellent
Data Integrity	Excellent	Excellent	Excellent
Key Length	Excellent	Excellent	Excellent
Key Type	Excellent	Excellent	Excellent

the anecdotal evidence (based on feedback from students and based on evaluating the students' performance on their projects) has been positive. Students seem to consider this method to be a refreshing change of pace compared to the traditional term-paper assignments they normally receive. Also, the structure imposed by the CE model appears to help focus the students in their studies, providing a framework that guides their search for information and their written presentations. The CE model exposes students to multi-attribute utility models and to rule-based systems. Finally, this gives students practical experience in designing, implementing, and using decision support systems in realistic business domains.

I am currently working to develop an Internet version of CEVAL that can be run via a web browser and that uses models stored in a database on the web server. When complete, this will provide access to various CE models to a wider audience.

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\*Note: CEVED and CEVAL are computer programs that were developed by the author. In their current state they are stand-alone executable files, which run with the assistance of some .DLL library files. The author is currently working on developing Web-based versions of this software. Readers who are interested in obtaining copies of CEVED and CEVAL, along with sample CE models, can contact the author at [mitrimx@jmu.edu](mailto:mitrimx@jmu.edu). The author is also happy to provide a copy of the assignment, associated lecture notes, and previous students' project solutions.

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