An Expert System for Metal Resources Exploration and Mining Feasibility Evaluation

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Abstract: The development process of Metal Resources Technical and Economic Evaluation Expert System (MRTEES) is introduced in the aspects of requirements analysis, design of the expert system, main functions of the expert system and features of the expert system. The system is based on C/B/S mixed mode and uses ASP.NET technology with .Net Framework being chosen as the development platform and metal resources database providing data support at the bottom layer. The system is an auxiliary management system for metal resources technical and economic evaluation and has the basic functions of auxiliary decision analysis, metal resources database management, data management and comprehensive query. Technical and economic evaluation model can be set up by users independently according to at which stage a project is, mainly including exploration stage, development stage and production stage, and according to the mining methods, for example underground mining, surface mining and in-situ leaching mining. Then, the technical and economic evaluation parameters can be generated. By inputting the value of each parameter in a simple and convenient way, the evaluation results can be directly calculated out and shown in the form of diagrams among others, and feasibility evaluation report can also be automatically generated, making the technical and economic evaluation process accurate and efficient. As the system can achieve the functions of scenario analysis, sensitivity analysis, shareholder's returns analysis, horizontal comparison of different projects, it can improve the ability of project senior decision makers for rapid response to the rival and meet the demand of pricing negotiations.

Keywords: metal resources database, exploration and mining, feasibility evaluation, expert system, C/B/S mixed mode

1. Introduction

With the arrival of a new round of industrialization upsurge in both developing and developed countries, growth of demand for metal resources is entering a new stage. Population involved in the new industrialized countries is about four times that of all previous industrialized countries, implying resource consumption increases dramatically both in speed and in quantity. It is a must to seize the strategic opportunity of developing and utilizing metal resources around the world to lay abundant resource base for national industrialization. Objectively speaking, global configuration of metal resources is an inevitable trend. Presently, many issues, for example, resources exploration, mining, merge of mining companies, metal trades, mining financing, etc., generally show the feature of globalization. For the reality that competition for metal resources is becoming fiercer, industry standards of mineral resources will undoubtedly be improved. Occupying large scale mineral resources with high grade and developing them with low cost is the base for the survival of mining companies and metal resources merchants. With the growing demand of global investment in mineral resources exploration, which is at the upstream of the industry chain, geological exploration industry is promising. Globally building market relationships for mineral resources exploration companies is key to their

sustainable development. Developing large and super-large deposit with low cost is also an important approach to enhancing core competence of a country or an enterprise. Mining companies around the world are rushing to purchase mineral resources globally. However, in different countries, economic, financial and tax systems for mineral resources vary greatly, and mining and processing techniques, technical parameters and equipment selection also change a lot. Thus, pro-phase research work is necessary for feasibility evaluation of mineral resources projects and it can be time wasting if taken in the traditional way. It is necessary to accelerate the process considering the complex and rapidly changing international situation.

Expert system is a useful tool for applying domain expert's knowledge and experience to help solve problems efficiently in the domain and has been widely used in almost all areas especially in business and manufacturing industry (Gong et al 2014). Expert system can act as either substitute or assistance of human experts with its abilities of interpretation, predication, diagnosis, design, planning, monitoring, control, debugging, instruction, repair, decision making, consultation and so on. Researchers from different domains have made efforts on developing expert systems (Castellanos et al 2011, Dymova et al 2010, Ebersbach and Peng 2008, Ertl and Christ 2007, Iqbal et al 2007, Kim et al 2015, Koutsantonis and Panayiotopoulos 2011, Marlow et

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al 2015, Piltan et al 2012, Polat and Guenes 2007, Ruiz-Mezcua et al 2011, Subelj et al 2011, Wan et al 2012, Wen 2010, Wen 2008, Zarandi and Ahmadvpour 2009). Applications of expert system show its efficiency and much more work should be done for its further development and application. To meet the demand of efficiently and accurately achieving investment feasibility evaluation of metal resources projects, Metal Resources Technical and Economic Evaluation Expert System (MRTEES) is developed. This paper aims to introduce the development process of the expert system in the aspects of requirements analysis, design of the expert system, main functions of the expert system and features of the expert system.

2. Requirement Analysis

2.1 Standardization of financial valuation model

There exists much difference in the links of cost occurring with regard to different mining and processing methods. Thus, many financial valuation models, namely for example, investment estimation models and cost models, should be established respectively for different projects to achieve standardization of the valuation process. The models should meet the demand of accurate financial valuation for different type of projects that are classified according to at which stage a project is, mainly including exploration stage, development stage and production stage, and according to the mining methods, for example underground mining, surface mining and in-situ leaching mining.

2.2 Multiple technical and economic evaluation methods for metal mine

Metal resources technical and economic evaluation methods should be selected and organized systematically. The methods should meet the demand of achieving appropriate technical and economic evaluation for different type of projects by considering the evaluation purposes and characteristics of the evaluation parameters.

2.3 Database for metal resources evaluation

The database should include the basic two parts. One is the existing data about metal resources evaluation for obtaining the related evaluation parameters that can be used for setting up evaluation models and providing the basis for comparison when a new project is to be evaluated. The other is the supporting information, such as laws and regulations, cultural information, which is actually the accumulation of project data and experience.

3. System Design

3.1 System deployment

System deployment is mainly composed of the client side and the server side. Logical architecture of the system is shown in Figure 1. At the server side, data related to metal resources projects and other auxiliary information are stored with Data Base Management System (DBMS). At the client side, users can access to the server by using the browser.

Figure 1. Logical architecture of MRTEES.

3.2 System overall structure

The system adopts both B/S mode and C/S mode for data access, thus is based on C/B/S mixed mode. B/S mode is mainly used for comprehensive query of information and C/S mode for processing table data and outputting report forms. ASP.NET technology is also used by the system and specific functional modules are developed on the .Net Framework platform. Metal resources database provides data support for the system at the bottom layer. The technologies guarantee universality, flexibility and maintainability of the system.

3.3 System functional structure

MRTEES is an auxiliary system for enterprise management by assisting decision analysis and supporting

project management. A project model can be set up by the importing function of the system or by using the default models in the system. Then technical and economic evaluation of the model can be carried out by determining the related evaluation parameters and choosing proper evaluation methods. Data related to metal resources can be stored in the database. Users can be assigned different access permissions to the database for performing operations like query and download. The system mainly has the functions of decision-making analysis, metal resources database management, data management and comprehensive query as shown in Figure 2.

For the module project model setting, the following items are set. 1) Definition and interpretation of basic evaluation parameters, fine items and annual parameters; 2)

Rules for judging data abnormal; 3) Logical relationships for incidence query based on key words of parameters or other items.

For the module project evaluation management, evaluation methods are gathered for selection in decision

making analysis. The methods include relative valuation method, PE (price-earnings ratio) method and DCF (Discounted Cash Flow) method among other methods.

Figure 2. Functional structure of MRTEES.

4. Introduction to Main Functions

4.1 Decision making analysis

Decision making analysis should be conducted based on a complete project model i.e. a series of interrelated computation sheets. To improve the modeling efficiency, MRTEES can be used for achieving standardization of the modeling process. A project model can be easily set up by controlling the parameter inputting interface as well as with the data positioning setting within the related computation sheets. The input parameters should be tested before they are used for calculation so as to guarantee accuracy of the input data, which can be achieved through the function module of abnormal data analysis. The function module of incidence query allows knowing about the value and other information of a parameter according to its initial setting in the default models or other project models. The basic process for project model evaluation is shown in Figure 3. It should be noted that incidence query can associate with not only metal resources database but also other databases in the system.

A variety of charts can be generated for a set of data. Taking uranium project for example. Figures 4 and 5 are respectively stacked chart and line chart for the results of

sensitivity analysis with DCF method and can be used for analyzing the influence of different sensitivity factors on shareholder’s IRR (Internal Rate of Return). In Figure 4, the horizontal axis represents the accumulated effect of each factor with each change rate and the vertical axis lists each factor. Length of the stacked strip represents sensitivity of each factor for its influence on shareholder’s IRR. In Figure 5, the horizontal axis represents the change scale of each factor and the vertical axis represents the change rate of shareholder’s IRR under the influence of each factor. Slope of each line represents the impact weight of the corresponding factor. According to the charts, sensitivity declines as the following sequence: uranium price, uranium (332) resources quantity, infrastructure investment, unit mining cost and soda price.

Figure 6 is a bubble chart that shows NPV (Net Present Value), shareholder’s IRR and total output of different uranium resources projects. There are five projects namely pro.1, pro.2, pro.3, pro.4, pro.5 respectively. The horizontal axis represents NPV in the unit of one hundred million, the vertical axis represents shareholder’s IRR, the size of each bubble represents the total output of the corresponding project which is written on each bubble in number. The

chart is for horizontal comparison of different projects. The most suitable project is determined according to whether it can best satisfy the present situation of a company. For example, though pro.4 has the least IRR, it has the biggest

total output. Considering the fact that uranium is scarce and price fluctuation of the metal is obvious, pro.4 is the most suitable one for a company whose profit situation is good.

Figure 3. Basic process for project model evaluation.

Figure 4. Sensitivity analysis results shown in stacked chart for uranium project with DCF method.

Figure 5. Sensitivity analysis results shown in line chart for uranium project with DCF method.

Figure 6. Project evaluation results shown in bubble chart for horizontal comparison.

4.2 Metal resources database management

Accuracy of the decision-making analysis results relies on truthfulness and timely updating of the technical parameters, economic parameters and cost parameters. Metal resources database is to provide data support for MRTEEEES. It includes four databases namely enterprise and case database, technical database, economic database and cost database. Again, taking uranium resources database for example, and Table 1 lists the main sub-databases of the four databases. Data in the sub-databases are stored in the form of tables. A user can perform operations like adding data, modifying data or deleting data for data in each cell within the user's permission scope. Such data as price of metals, interest rate and exchange rate change frequently and need to be updated timely.

4.3 Data management

Data management mainly includes project data management and supporting data management. Project data management is related to a project's due diligence, project approval application, feasibility report, pre-feasibility study

report, feasibility study report, preliminary design report. Supporting data management is about corresponding laws and regulations, research report, social and cultural information, etc.

Table 1. Uranium resources database and sub-database.

Enterprise and case database	Technical database	Economic database	Cost database
country or district data	hydrometallurgical mill database	uranium price database	database of raw and auxiliary materials for mining
enterprise database	uranium-ore deposit database	exchange rate database	database of raw and auxiliary materials for hydrometallurgy
trade case database		interest rate database	database of equipment for underground mining
		tax profile of each country	database of equipment for surface mining
		database of country related to tax agreement	database of equipment for hydrometallurgy
		tax database of key country	database of general drawing for transportation equipments
		economic database of each country from World Bank	
		database of macro situation of Canada	
		database of macro situation of China	

4.4 Project comprehensive query

Project comprehensive query means searching for the information of parameters or indexes of different project model. The system allows comprehensive query for abundant contents, for example, basic parameters of project, hydrometallurgy cost details of exploration project, comprehensive estimation of geological exploration, investment estimation of mine construction, cost estimation of other engineering construction, cost estimation, wage estimation and main indexes of project.

There are two methods of querying. One is classification query by selecting the corresponding items under each category. The other is filtering query by using key words directly.

4.5 System management

System management includes the following issues: 1) Defining modules and classes of the system; 2) Recording logs of logging and operation; 3) Personalized setting for interface skin and shortcut menu; 4) User management. For user management, firstly user roles are defined and corresponding role permissions are set. Then, a user role is directly assigned to a user and the user can perform operations on the system within the role's permissions. Both user role setting and user role assignment setting are self-defined, making the user role levels unlimited.

5. System Features

(1) MRTEES is designed for business operations of mine

enterprises. It is an auxiliary management system for technical and economic evaluation for it can provide decision making analysis and support project management. It mainly aims to provide the standardized modeling and evaluation process for enterprises characterized by having multiple mine categories, multi-stage projects, multiple mining methods and evaluation methods. It can perform project technical and economic evaluation and feasibility evaluation, including investment estimates, financial analysis, economic cost-benefit analysis, risk analysis and so on.

(2) The project modeling process is made standardized. A model is set up by controlling the parameters inputting interface and setting the data positioning. The system can achieve automatic calculation, which saves the cumbersome work for constructing forms when establishing a new model.

(3) Through metal resources database management, a large number data can be collected and updated timely. As a result, the parameters are increasingly completed, which guarantees accuracy of the evaluation and analysis results. Enterprise and case data management, project data management and auxiliary data management make possible coding, accumulating and sharing of existing information.

(4) The system is established based on C/B/S mixed mode and uses ASP.NET technology. The system makes full use of the Intranet and also the Internet and the business office area is expanded. By using Web Office, the system is fully compatible with spreadsheet and other kinds of document formats. It can automatically generate feasibility evaluation report, which largely reduces the complicated paperwork and thus improves work efficiency.

6. Conclusions and Discussion

MRTEES achieves the functions of decision making analysis, metal resources database management, data management, comprehensive query and so on. The standardized evaluation process helps horizontal comparison of all kinds of metal resources projects. Owing to completeness of the database, especially technical database, economic database and cost database, the feasibility evaluation results is more accurate and the investment risk can be largely reduced. By expanding the database, this expert system can also be used by other businesses for technical and economic evaluation. The system can also provide important support for group investment activities.

Accuracy of the raw data is the basis for project investment evaluation. Thus, metal resources database should be updated and perfected timely and regularly. Accuracy of the investment feasibility evaluation results depends more on completeness and accuracy of the basic data which are accumulated by storing the evaluation results of the existing projects through software interface. Thus, it's necessary to complete the basic data by making more evaluations with the software and accumulating relevant project data and experience.

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References

- Castellanos, V., A. Albiter, P. Hernandez and G. Barrera, 2011. Failure analysis expert system for onshore pipelines. Part - I: Structured database and knowledge acquisition. *Expert Systems with Applications*, 38(9): 11085 - 11090. DOI: 10.1016/j.eswa.2011.02.153
- Dymova, L., P. Sevastianov and P. Bartosiewicz, 2010. A new approach to the rule-base evidential reasoning: Stock trading expert system application. *Expert Systems with Applications*, 37(8): 5564 - 5576. DOI: 10.1016/j.eswa.2010.02.056
- Ebersbach, S. and Z. Peng, 2008. Expert system development for vibration analysis in machine condition monitoring. *Expert Systems with Applications*, 34(1): 291 - 299. DOI: 10.1016/j.eswa.2006.09.029
- Ertl, L. and F. Christ, 2007. Significant improvement of the quality of bystander first aid using an expert system with a mobile multimedia device. *Resuscitation*, 74(2): 286 - 295. DOI: 10.1016/j.resuscitation.2007.01.006
- Gong, Z., D. John and T. Gong, 2014. *Advanced expert systems: Principles, design and applications*. Science Press, Beijing.
- Iqbal, A., H. Ning, L. Liang and N.U. Dar, 2007. A fuzzy expert system for optimizing parameters and predicting performance measures in hard-milling process. *Expert Systems with Applications*, 32(4): 1020 - 1027. DOI: 10.1016/j.eswa.2006.02.003
- Kim, K., M. Roh and S. Ha, 2015. Expert system based on the arrangement evaluation model for the arrangement design of a submarine. *Expert Systems with Applications*, 42(22): 8731 - 8744. DOI: 10.1016/j.eswa.2015.07.026
- Koutsantonis, D. and J. Panayiotopoulos, 2011. Expert system personalized knowledge retrieval. *Operational Research*, 11(2): 215 - 227. DOI: 10.1007/s12351-009-0048-4
- Marlow, D., S. Gould and B. Lane, 2015. An expert system for assessing the technical and economic risk of pipe rehabilitation options. *Expert Systems with Applications*, 42(22): 8658 - 8668. DOI: 10.1016/j.eswa.2015.07.020
- Piltan, M., E. Mehmanchi and S.F. Ghaderi, 2012. Proposing a decision-making model using analytical hierarchy process and fuzzy expert system for prioritizing industries in installation of combined heat and power systems. *Expert Systems with Applications*, 39(1): 1124 - 1133. DOI: 10.1016/j.eswa.2011.07.112
- Polat, K. and S. Guenes, 2007. An expert system approach based on principal component analysis and adaptive neuro-fuzzy inference system to diagnosis of diabetes disease. *Digital Signal Processing*, 17(4): 702 - 710. DOI: 10.1016/j.dsp.2006.09.005
- Ruiz-Mezcua, B., A. Garcia-Crespo, J.L. Lopez-Cuadrado and I. Gonzalez-Carrasco, 2011. An expert system development tool for non AI experts. *Expert Systems with Applications*, 38(1): 597 - 609. DOI: 10.1016/j.eswa.2010.07.009
- Subelj, L., S. Furlan and M. Bajec, 2011. An expert system for detecting automobile insurance fraud using social network analysis. *Expert Systems with Applications*, 38(1): 1039 - 1052. DOI: 10.1016/j.eswa.2010.07.143
- Wan, S., T. Lei and T. Chou, 2012. A landslide expert system: Image classification through integration of data mining approaches for multi-category analysis. *International Journal of Geographical Information Science*, 26(4): 747 - 770. DOI: 10.1080/13658816.2011.613397
- Wen, W., 2010. An intelligent traffic management expert system with RFID technology. *Expert Systems with Applications*, 37(4): 3024 - 3035. DOI: 10.1016/j.eswa.2009.09.030
- Wen, W., 2008. A dynamic and automatic traffic light control expert system for solving the road congestion problem. *Expert Systems with Applications*, 34(4): 2370 - 2381. DOI: 10.1016/j.eswa.2007.03.007
- Zarandi, M.H.F. and P. Ahmadpour, 2009. Fuzzy agent-based expert system for steel making process. *Expert Systems with Applications*, 36(5): 9539 - 9547. DOI: 10.1016/j.eswa.2008.10.084