Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte
Band: 68 (1993)

Artikel: Expert system applied in state engineering offices
Autor: Shuyu, Kan / Qi, Fang / Feng, Cheng
DOI: https://doi.org/10.5169/seals-51851

Expert System Applied in State Engineering Offices

Système expert mis en application dans les services techniques nationaux

Expertensystem im Einsatz bei staatlichen Planungsabteilungen

Kan SHUYU
Associate Professor
Northern Jiaotong Univ.
Beijing, China

Kan Shuyu, born 1935, has graduated from Tangshan Railway College. He was responsible for the Expert System for Reconstruction Schemes of Single-Track Railway in China.

Fang QI
Lecturer
Northern Jiaotong Univ.
Beijing, China

Mrs. Fang Qi, born 1950, got her master degree of Computer Eng. in Northern Jiaotong Univ. She is mainly involved in developing expert systems.

Cheng FENG
Lecturer
Northern Jiaotong Univ.
Beijing, China

Cheng Feng, born 1962, has graduated Civil Eng. of NJU in 1983, and got the master degree in the same subject. His major work is in the application of computer in civil eng.

SUMMARY

This system is able to simulate the complicated thinking processes that railway experts make out all kinds of technical reconstruction measures. It drafts the feasible technical innovation schemes by adopting mulitple knowledge-representation methods and the technology of optimizing knowledge base and using forward-backward and two-stage combined type of inference and the imprecise-reasoning model which is based on the interval representation and determines the recommended plans according to the fuzzy-overall-level concept by applying the similarity-preference-ratio theory on fuzzy mathematics. And then it evaluates economy of the recommended plans and completes the decision. Now this system is being applied in the governmental engineering consultive services.

RÉSUMÉ

Le système expert présenté dans cet article est en mesure de simuler les processus de raisonnement que doivent effectuer les concepteurs des chemins de fer, pour tous les genres de mesures techniques à prendre dans les travaux de construction. Le développement de solutions innovatrices réalisables se fait à partir d'innombrables méthodes de représentation de la connaissance et de techniques d'induction à plusieurs niveaux. Le système expert détermine les recommandations de planification d'après un concept flou généralisé, en y appliquant la théorie du rapport des préférences aux similitudes tirée du problème mathématique des incertitudes. La décision finale découle d'une étude comparative de rentabilité. A l'heure actuelle, ce système expert est mis à l'essai dans les services techniques nationaux.

ZUSAMMENFASSUNG

Das vorgestellte System simuliert die komplizierten Denkprozesse von Eisenbahnplanern bei allen Arten technischer Baumassnahmen. Mögliche innovative Lösungen werden aus mehrfachen Methoden zur Wissensdarstellung und mehrstufigen Induktionstechniken gewonnen. Das System bestimmt die Planungsempfehlungen nach einem übergreifenden Fuzzy-Konzept, indem die Theorie des Verhältnisses von Aehnlichkeit zu Präferenz aus der unscharfen Mathematik angewendet wird. Die endgültige Entscheidung wird nach einem Wirtschaftlichkeitsvergleich gefällt. Zur Zeit steht dieses System bei staatlichen Projektierungsstellen in Erprobung.

1. FOREWORD

In China,the railway passenger-and-freight volume is about 2/3 of the total volum of transportation. However, the total length of the railway network is short, the technical facilities are backward and tension is felt both in freight and passenger transportation. Besides building a lot of necessary new tracks in the future, it is important to increase the capacity of the existing railways, especially that of the 40 thousand single tracks which accounts for more than 3/5 of the total lenght of the network. This is a very important measure since it demands smaller amount of investiment but benifits more and more quickly. Then,to build an enlarging- capacity reconstruction and artifitial decision- assistant surporting system to make decision scientific is of great significance.

In the recent 40 years, China has undertaken technical reconstruction of the railways, such as Beijing-Guangzhou, Beijing-Shanghai, Beijing—Harerbin and those in the southwestern mountain areas and has got good results. During this process the railway experts have accumulated plentiful experience. So we built An Expert System for Reconstruction Schemes of Single-Track Railway (ESORR). Since it has rational structure, rich knowledge and dear man-machine interface, and the enlarging-capacity plans it gives are feasible in economy, the system is emphasized by authoritive engineering consultive service. It has formally applied to assist to make decisions in railways engineering consultation with good results.

The system is composed of the scheme drafting,scheme evaluating and selecting, scheme economy evaluating,and decision file compilation sub-systems. Its structure is shown in fig.1.

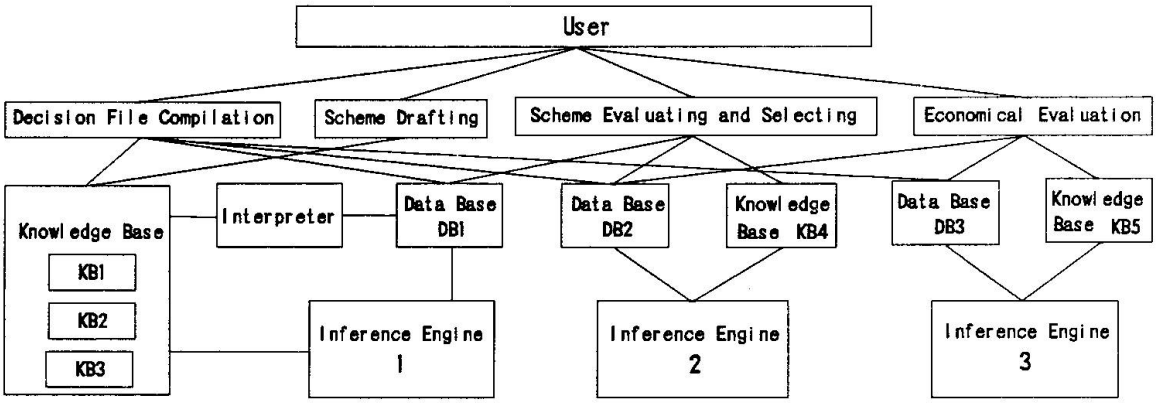

Fig.1 Structure of ESORR system

2. THE SCHEME DRAFTING FOR RAILWAYS TECHNICAL RESTRUCTION

The drafting of reconstruction schemes is an important procedure which is most capable of reflecting the plentiful experience of experts in deciding the technical reconstruction of single-track railways.

2.1 Structure Analysis of Subject Knowledge-Base

2.1.1 Resolutionability

The objective concept of reconstruction measure in the knowledge of subject of the existing lines technical reconstruction has the structure shown in fig. 2. K_i represents the scheme i.

2.1.2 Multi-objectives

Any above reconstruction measure K_i also comprise a number of specific transforming plans. Figure 3 shows it.

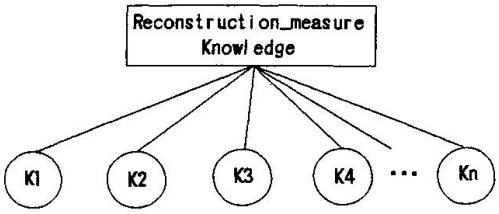

Fig.2 State Knowledge (1)

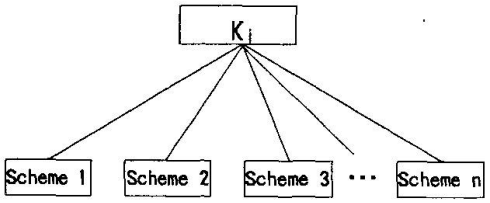

Fig.3 State Knowledge (2)

Scheme i is an arbitrary non-decomposability sub-objective, namely the implementing scheme. It can be processed as an independent knowledge cell. The pre-conditions binded it decides whether the scheme is right or not. The specific plan is discribed with one or multiple production-rules. Therefore, the knowledge in this subject should have the following structure type, as demonstrated in figure 4.

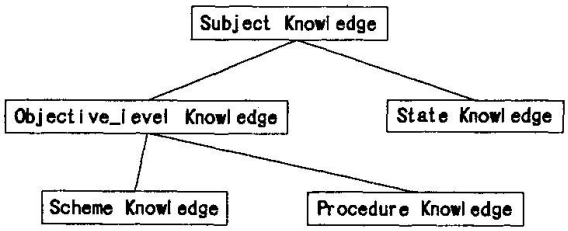

Fig.4 The Structure of Subject Knowledge

The statement knowledge is that to decompose an objective concept into the sub-objective ones. The object-level knowledge means the knowledge which directly relates with the solution finding of problems. In object level, the scheme knowledge is a kind of empirical and enlightening knowledge, it gives the effect and cause relationship of establishing the programme. The procedure knowledge provides the necessary data for the establishment of the schemes it is composed of some computing models.

2.2 Knowledge Representation

The traditional methods of knowledge representation are not suitable to the field of decision for the technical reconstruction of the existing lines since in this subject the decision of a problem does not totally rely upon the judgement of pure logic inference, it also needs organical data calculation, and analyses, evaluates, compares and decides all kinds of possible rusults as in order to produce feasible plans which could be chosen. For this reason, the research group adapts a type of comprehensive knowledge-representation method and uses multiple kinds of methods to optimize the knowledge base while setting it up on the basis of researching the structure characteristics of the subject knowledge.

2.2.1 Fact Expression

This sub-system expresses facts by predicate (logical method) . There are one- element predicate and multiple-elements ones, such as:

Q(a), Ix(b,c)

Q, Ix , the names of predicate, indicate the attribute of a or the relationship between b and c.

2.2.2 Representation of Expert Experiences Knowledge

It is very appropriate to represent the experience knowledge of specific experts in the aspect of technical reconstruction of the existing lines with the production rules. In this system, The rules are placed in the knowledge bases KB1 and KB2.

Example: in KB2, there is a rule:

IF the ruling grade is Ii=6‰,
and the local topographic form belongs to Ⅱ class,
and the horizontal and vertical condition of the line permits the extension of station tracks,
and the effective length of the arrival and departure tracks can not meet the demands of future trains.

THEN the length of the tracks should be extended to 550m (CER–R=0.8).

Here "CER–R=0.8" means that the confidence degree of this rule is 80 percent.

2.2.3 Representation of The Procedure Knowledge

This system adapts sub–program and predicate to represent the procedure knowledge.

In this system, there are two major goals to apply procedure knowledge. One is to carry out all kinds of calculation which inference needs, to analyse the capacity of schemes, to get the value of capacity which could satisfy the needs of future transportation volume, and to take this as the basis of empirical inference. The other is to manage the system, such as to dynamically modify some rules in knowledge base etc.

2.2.4 Representation of State Knowledge

Generally speaking, the structure of the knowledge of this sub–system reflects the thought of "sorting–and–choosing". The system uses the methods of knowledge–representation which combine the object–orientated and production–rule.

For example a kind of reconstruction measure can be expressed as the following object:

object–name: to transfer traction power
super–level object: reconstruction measure
sub–level object: to change the types of locomotives
method 1: information model: input data, output result
method body: to call procedure, to compute data
(example: to calculate the capacity of the line)
method 2: information model: to display the basis situation of the result
method body: to call data base

There are 11 types of objects in the system. They makes up a object–type tree, in which every object has several sub–categories, and each object may have many methods to realize respective functions of the object.

2.3 Inference Machanism

The technical reconstruction decision for single–track railways involves many factors and its procedure is complicated. In order to be fitful to the pratical situation, the designing of inference machanism of this system satisfies the following four aspects of demands: to be able to simulate the process by which the human experts resolve practical problems; to be able to solve the problem which correlative evidences are not suitable for one–time inputting; to be able to analyse problems quantatively and qualtatively; to be able to deal with the problems with the nondeterminacy of origional data and rules.

2.3.1 Interence Strategy

The reasonning type of this system is called two–stage–combined—initiative inference, that is the type of reasonning which combines forward–backward mixed inference with the

information which the customer provides.

The foreward inference makes the customers always focus on the most hopeful reconstruction measures. It makes the system be able to determine the feasible schemes according to the major data of existing lines even under the pre-conditions which the evidences have not been defined (since under most conditions the states of the existing lines are quite different, it is very difficult to input the relative materials and data one-time).

After the forward inference finishes, the output will come out if the system has found some kind of technical reconstruction measure existing; otherwise system enters the process of backward inference. The backward inference network is designed to furtherly test the feasibility of schemes.

In the backward inference,the system considers feasible technical reconstruction schemes with preference, then require customers for proofs which haven't input into data base according to the structure of knowledge base.

2.3.2 Application of Imprecise Inference

There are three major kinds of nondeterministic information which we possibly meet in the technical reconstruction of single-track railways:

The first kind is of "nature of probability",since the conditions are not enough and there aren't identified cause-and-effect relationships between conditions and incidents. Volume index, for example, can be produced indirectly in the way of comparing other traffic volumes which have some similarity if the customers can not define it.

The second kind of the nondeterminacy which is caused by fuzzy concepts belongs to "ambiguity", such as the set of topography conditions (class I. II, III, IV, V) . The classes are fuzzy concepts. This kind of nondeterminacy is expressed with subordinate function.

The third displays the degree which customers don't understand facts because of incomplete information.

To use the numbers of intervals to express nondeterministic information can integratedly indicate the above three. On the basis of the above thoughts a type of imprecise inference model expressed by the numbers of intervals is provided, and it has been used in the reasonning of the system.

2.4 Function of System Interpretation And Knowledge-aquirement

The system provides interpretation under the following two situations. One is that the system gives explanation when customers don't understand the questions which it asks them while in backward inference.The other is that the system will provide the procedure of inference after it produces schemes.The inference interpretation of the system uses the method of execution-track.

The knowledge aquirement of the system is established to further develop and improve knowledge base. The subject experts needn't know the inside expressing types of principles, and needn't input the whole principle word by word. The system will automaticly transform the information into a complete inside representation type of principle as long as the relevent data are input according to the system's reqirement.

3. COMPREHENSIVE EVALUATION OF TECHNICAL RESTRUCTION SCHEMES

The scheme-drafting sub-system will reccomend more than two feasible technical-reconstruction plans in most cases. Therefore,the reccomended schemes must be evaluated in order to select the best alternative on the whole. For this aim the comprehensive evaluation sub- system for technical reconstruction scheme is designed.

3.1 Evaluation Indexes Setup

Generally, an evaluated matter are influenced by many factors. The degrees of importance of each factor in the matter are very different from expert to expert and from condition to condition. These factors are called evaluated indexes. This sub-system adapts nine evaluated

indexes of engineering investment, repaying period, project time, environment protection and net cash-value rate, inner profit rate, transportation capacity reserve rate, capacity coordinating degree, construction interference degree etc..

In most cases the weights of the evaluated indexes are different with different lines. Therefore,to the special line which will be remaked the primary task to evaluate several feasible technical-reconstruction schemes is to identify the weights of indexes. In this sub-system, the weights of indexes are identified with man-machine interaction according to the experiences of experts and subjective conditions.

3.2 Estimation of Engineering Cost

Among indexes, there is a very important one, engineering investment. Because there are many factors affecting investment, and even most of them cann't be totally forecasted, the estimation of investment is a complicated procedure to an engineering project, especially a railway technical-reconstruction program.

There are two major methods for the estimation of engineering investment. One is rough-estimate, the other is meticulous-caculation.This system uses the former since it is applied in the feasibility research stage of technical-reconstruction of railway. The investment-estimation principle is that under the pre-condition that the objective conditions of the line of reccommended schemes are equal, the major engineering investment of each reconstruction scheme is calculated with "price system" method.

3.3 Method of Comprehensive Evaluation-and-selection

There are a lot of comprehensive evaluation-selection methods.What the system uses is the method to comprehensively evaluate the indexes of every scheme and select the best one with similarity-priority-ratio theory of fuzzy mathimatics and the concept of set- overall- level provided on this base. This method is rigorous,simple and reliable since it is realized through a set of algorithms. The detailed is in document[6].

The basic procedure of the Comprehensive-evaluation-selection is firstly to constitute an ideal specimen-scheme. Every feasible plans then are compared with the specimen- schemen in each index. The plan which has the most closeness to the specimen on the whole is the best one The process of the evaluation-and-selection of the schemes is as the follows:

(1) To choose the best values of the indexes from the given reccomended plans builds a specen as the rule of evaluation-and-selection if it doesn't exist; (2) The closeness- distance between the values of indexes of each plan with those of the specimen- scheme is calculated with Haiming length; (3) To produce the overall level of each plan in order to comprehensively evaluate and select the closeness-distance of any alternative to the specimen-scheme; (4) To express each plan's degree of closeness to the specimen-scheme with quantative methods; (5) In order to really reflect each reccomended plan's closeness to the specimen-scheme, the system regulates the closeness-degree from the importance of each index, and brings forth the reccomended scheme which is closest to the specimen.

The result of evaluation-and-selection is to get an alternative which the overall- level of all indexes is the highest in the reccommended schemes. while the best scheme comes out, the computing values of the many economical indexes of the scheme,such as the data of repaying period of investment, the annual investment distribution in project time ect., will be stored in data base in order to be used by the sub-system of economical evaluation.

4. TEST AND APPLICATION OF ESORR SYSTEM

After it had been tested and improved during the process of research, the system has been used by the authoritive organization-China International Engineering Consulting Company, in the technical-reconstruction decision-assisting for several trunk lines: Chengdu-Kunming, Baotou-Lanzhou and Lanzhou-Xinjiang of the grand Asia-Europe bridge, and comparatively

satisfactory results are achieved.At the same time the acquired information have further improved the system. The Designing Institute of Beijing Railway Bureau also successfully used it to carry out the decision-assisting to the technical- reconstruction of Beijing- Chengde railway. The brief introduction of the technical-reconstruction decision- assisting of the several above lines are the following.

4.1 Technical reconstruction of Chengdu—Kunming Railway

The railway from Chengdu to Kunming,total length of 1100 kilometers, passing the industrial, mineral, hydro-electric bases in Leshan,Xichan, Panzhihua and Kunyang ect. , with abundant resources of iron, coal, phosphorus, woods and hydro-power along it , is an important trunk line to develop the economical construction of the southwestern China.

The Chengdu—Kunming line was open on July 1, 1970, and formerly began to operate in 1971. At the present time, the existing line is not fitful for the demand of the increasement of transportation. The occupying rates of the passing capacity of each segment of the 559 kilometers section from Chengdu to Xichang were over 85 percent in 1985 and over 100 in 1987. The volume has been overflow and the line is operating over its load.The total length of the Chengdu—Yangang section is 157 kilometers. With 13 segments it is one of the busist sections of Chengdu-Kunming line.In 1989, the Second Designing Institute of Railway Ministry conducted the feasibility reserach about the technical-reconstruction of electrification to this section, and its results are consistant with what the ESORR system achieved on the whole. See table 1.

Table 1

	Content of Scheme	Long Term Traffic Capacity	Engineering Cost
The second Design Institute of Railway Ministry in ChengDu	1. To adopt SSI electric locomotive traction; 2. To extend the effective length of arrival & departure tracks to 850 meters; 3. To add a dividing intermediate station between GongXing - PuXing section.	18.8 million tons per year	184.21 million yuan (in 1979 price)
ESORR	1. To adopt SSI electric locomotive traction; 2. To extend the effective length of arrival & departure tracks to 850 meters; 3. To set up two dividing intermediate stations one between GongXing-PuXing section,another between PuXing-Qing LongChang section.	20.6 million tons per year	207.32 million yuan (in present price)

4.2 Technical reconstruction Decision-assisting of Lanzhou-Xinjiang Railway

Lanzhou-Xinjiang Railways has a total length of 1904 kilometers.It is the only grand trunk of China accessing the northwestern border areas.In order to cooperate with the opening of the Asia-Europe Grand Land Bridge, and much more importantly to exploit the plentiful mineral resources in Xinjiang and to develop the economy in the minority nationality regions, the country has decided to invest to carry out technical reconstruction in the Eighth Five- Year Plan to this single-track railway, which has got a very tense capacity already. The First Designing Institute of Railway Ministry Had provided a feasibility research report at the end of 1990. And the China International Engineering Consulting Company Carried out a decision

assisting with ESORR system.

To the most difficult controlling section, from Jiayuguan to Harmi, the system puts forward all possible reconstruction schemes, and outputs their investment,designing capacity and the concerned technical-economical indexes, and compares their advantages and disadvantages in accordance with the different transportation volumes of the near and far future Therefore,the objective and dispartial suggestion are quickly, completely provided to the decision- making organization. According to the decision-assisting report the expert group made their minds up and gave the finnal decision suggestion. China International Engineering Consulting Company is very satisfied with the results of ESORR system.

4.3 Technical reconstruction Decision-assisting of Baotou-Lanzhou Railway

The large amount of freight transported by the southern part of Baotou-Lanzhou railway is mainly coal. The line's transportation capacity has already been saturated. During the research of technical-reconstruction, the designing institute provided the reconstruction plan of electrification only But the experts were diffcult to decide whether the double-line needed or not. After the consulting company meticulously calculated and optimatically selected all feasible schemes with ESORR system, the double-line plan was abandoned. This Decision-assisting saved more than one million Yuan of survying cost, and half a year of the earlier stage of the project was shortened. And it was highly praised by the concerned institutions.

REFERENCE:

1.Donald A. Waterman, A Guide to Expert System, Addison Wesley Publishin Company, Inc., 1986.

2.P.Chatalic, D.Pubols, and H. Prade, An Approach to Approximate Reasoning Based on the Dempster Rule of Combination, International Journal of Expert Systems Research and Applications,1987/1988, volume 1, Number 1.

3.J.R. Quinlan, Consistency and Plausible Reasoning, Proc, 8th International Joint Conference on A.I., Karlsruhe, FKG, 1983.

4.He Zhongxiong, Fuzzy Mathimatics and Application, Tianjin Science & Technology Publishing House. 1985.

5.Northern Jiaotong University, Research Report on An Expert System for Reform Schemes of Single track Railway. 1991.

6.The National Planning Committee, Economical Evaluation Methods and Parameters of Building Projects China Planning Publishing House.

7.Xu Zhufeng, Evaluation Rules of Projects, China Translating Publishing House.