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Preliminary Contribution

Expert Systems in Railway Traffic Planning

Adaptation of passenger and freight transport companies to new market requirements takes much more effort in respect of the others, which is primarily due to the very nature of transport services. Any analysis of a railway company's business operations and of the transport services market will show that the success of the whole management system is correlated to the accomplished degree of market adaptation. Hence the crucial importance, both tactical and strategic, of supporting the decision-making process affecting the transport services market.

The paper analyse the potential advantages of an expert system which would help decision-makers arrive to right business conclusions, suggest actions to be taken, evaluate the current state of affairs and anticipate events relevant to the position of the Croatian Railways on the transport services market.

Key words: decision-maker, expert system, market requirements, railway traffic, traffic planning.

1. Introduction

As the prospective investments in technical and technological modernisation of railway traffic are limited, greater traffic rationality and efficiency in the following development period should primarily rely on organisational improvement and business promotion of the railway company.

One of the ways to reach these goals is a more market-oriented railway policy which makes allowance for the need to adapt to specific requirements of domestic and international transport services market in terms of scope, type and quality of services rendered, which will at least reduce irrational behaviour within the traffic system and help stabilise the national economy as well as bring certain income in the process.

The follow-up of market requirements, relations and changes and the efficiency in mobilising internal potentials require the availability of certain information. Considering the importance of such information, its flow, processing, use and storing cannot be left to inertia and chance. Instead it should be purposefully organised within an appropriate information system. This is vital for ensuring access to the right kind of information for successful planning and market-oriented business policy and thereby for efficient and rational operation of the entire management and information system.

In order to make conventionally programmed computers directly usable as support in the decision-making process, the decision-makers ought to know how to tackle the problem of decision-making, whereas the procedure itself should be expressed by means of an algorithm allowing computer programming. In this case the solution to a decision-making process will be well-defined and the output decision will be automatically determined through the input of data into the programmed problem-solving model. Such software, where only quantitative data are entered into problem-solving model and the outgoing solutions are made possible by firmly defined algorithms, are conventional computer applications. Such software products do not possess any "knowledge of their own" which would be capable of modelling and finding solutions to problems.

There are far more decision-making problems whose solving process can be only partly presented by means of algorithms, either as a result of their poor efficiency or inadequately articulated problems. Such problems can only be solved by experts in specific problem situations who use their expertise gained through training and working experience. Owing to the continuous progress made in the computer technology, expertise can be stored today in the computer by means of artificial intelligence techniques.

2. Analysis of the management and decision-making process in the Croatian Railways

2.1. Time determinants in the decision-making process

The basic working plan of the Croatian Railways is the timetable regulating the organisation of passenger and freight transport. Consequently, all decisions are directly or indirectly related to it or its constituent elements. These decisions are made on strategic, tactical and operative levels within various time limits set for their implementation. The time dimension and the framework of strategic decision-making can be best presented by creating the basic working plan of the Croatian Railways, and that is the timetable being prepared on yearly basis. Various activities (traffic, train traction, civil engineering, electrical engineering), their co-ordination, the capacity to carry out assigned tasks, the defined development and business policy, all constitute a functional whole. Defining the required availability of traction and driving vehicle's infrastructure, staff, organisation and technology of passenger and freight train traffic are basic prerequisites for an operable railway traffic system. The proper co-ordination of well-formed decisions will ensure required technical facilities and staff support in transportation whereas the well-run organisation and operational technology of passenger and freight trains will meet market demands for railway transport services.

Over the one-year timetable period various factors will appear which will interfere in the implementation of some elements of the timetable. By choosing certain organisational and technological modalities it is possible, on the tactical level, to determine two characteristic periods of market imbalance in the demand for transport services: summer and winter seasons. Opting for particular solution variants will optimise the supply of transport services and the costs generated by it and will also meet the market demands for transport services, which have changed as a result of new circumstances.

Everyday influences, above all the uneven flow of passenger or freight traffic and the need to maintain infrastructure facilities, will be dealt with through operational decisions at the level of particular services or organisational units. The day-to-day planning of the freight transport is the best example of how operational decisions are made within a given time framework, with maximum allowance being made for all relevant parameters materialised within the annual timetable.

2.2. Structure of decisions and their interdependence

The complexity of the railway traffic system is reflected in the structure of decisions, the nature of which can be:

- technical,
- technological,
- commercial
- legal

The structure of decisions, due to the highly correlated elements involved, is an important factor in the operation of each organisational unit in particular and the Croatian Railways in general. Failure of any unit to fulfill a coordinated and agreed-upon task will undermine the task and thereby the set goal, leading to negative financial consequences. The company's business policy and business plan for the current year can be significant in the implementation of quarterly, semi-annual and annual plans, but their application will not necessarily give results equal to the set goals. The interdependence of decisions in the technical and technological area is quite obvious, but inadequate anticipation of commercial factors will, on the whole, have a detrimental financial effect on all three levels of decision-making.

2.3. Decision-makers and the cybernetic model

As in other dynamic systems, the management of a railway company is a process involving all its activities aimed at the attainment of certain goals. Basic processes are being corrected by control actions carrying certain information and operating within a feedback mechanism. Due to the interdependence of the system and its environment, management must ensure a balanced business operation of the railway company within the transport end economic system of the country and in compliance with the set goals.

For market-oriented transport companies the most important segment of the environment is the transport services market. That is why the success of the whole management system can be evaluated by the achieved accomplished degree of the company's adaptation to market requirements or the extent to which the goals of market-based business and development policies have been achieved. Indeed, it is the market that provides the most important feedback, without which the management system of a transport company could not function.

2.4. Sources of information in the decision-making process

1. Sources of information in profit centres

   - Information dependent on the demand for passenger transport services
   - Information linked to the costs and earnings in passenger transport
   - Information dependent on the demand for freight transport services
   - Information linked to the costs and earnings in freight transport
   - Derived values - effects of work

2. Information gained along business line on the management level

   - Information from internal sources
   - Information from external sources:
     - information about general business conditions
     - information about transport market potential
     - information about competitors

3. Creating an expert railway transport planning system

Basic requirements of the Croatian Railways information system should be met by:

- ensuring and providing information support for control and management of business activities, and
- providing support for decision-making and inspection of the implementation of decisions made

An analysis of the business operations of a railway company and an analysis of the transport services market show that success of the entire management system can be evaluated in terms of degree of adaptation to market requirements. Hence the crucial importance, both tactical and strategic, of the support to the decision-making process affecting the transport services market. The creation of an expert system is designed to help decision-makers arrive to right business conclusions, suggest actions to be taken, evaluate the current state of affairs or anticipate events relevant to the position of the Croatian Railways on the transport services market.

3.1. Expert system model

Having defined the objective of creating a system based on artificial intelligence techniques, we proceed to choosing the best-suited system. We have opted for the expanded architecture expert system which comprises the following components:

- Data Base
- DBMS - Data Base Management System
- Knowledge Base
- Model Base
- MBMS - Model Base Management System
- Glossary of Terms
- Inference Engine
- User Interface

3.2. Database

For easier access to data and their easier processing, a database is organised within the expert system to comprise all data related to planning and standard values and influencing the process of solving the problems involved. Stored in the database are timetable data and all technical and technological elements that the functioning of the timetable depends on, along with the standardised indicators required for comparison with the materialised ones. The database must be connected with other databases of the integral Croatian Railways system to ensure that the stored data are updated. In order to:

- avoid unnecessary redundancy,
- ensure flexible access to data,
- define relations among entities or types of files and facilitate the searching of data against these relations,
- ensure data independence,
- safeguard their integrity and reliability and
- achieve complete data safety,

in the database, **the Database Management System (DBMS)** is used.

3.3. Creating a knowledge base

The expert system, the creation of which is presented here, is designed to provide support in making decisions related to planning the organisation of passenger train traffic in the area covered by the Croatian Railways and meeting the requirements of the transport services market.

The factual knowledge required for solving this problem is presented in the form of a tree of attributes, the root of which is the decision attribute (concerning the rendering of new passenger traffic services). The presentation of factual knowledge is based on the technique of sets of certain "attribute-value" pairs. The technique consists in splitting the decision-making problem into more attributes (criteria), the values of which determine the outcome of the final decision. The attributes the decision-making problem is decomposed into create the problem solution model, the so-called tree of decision-making attributes, where each attribute is a knot of this tree, whereas the root of the tree structure is the solution to the decision-making problem.

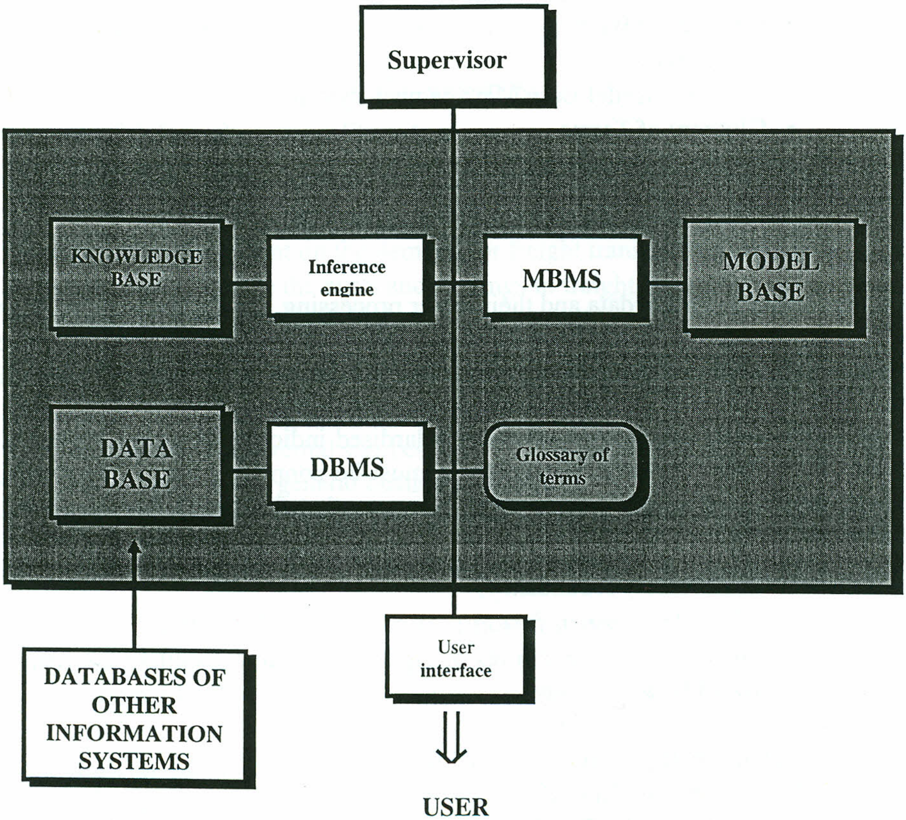

Fig. 1: Expert system architecture

Attributes with their source within the limits of the Croatian Railways operation system:

– the possibility of entering the transport services market:

- implementation of the set transport organisation,
- set plan of transport organisation (timetable),
- available capacities,
- commercial results,
- offered transport services quality,
- promotional market activities,
- investments of the Croatian Railways in development and modernisation.

Attributes with their source in the business environment:

- market demands for transport,
- supply of transport services by other transport branches,

- institutional conditions.

The tree of attributes is shown in Fig. 2.

3.3.1. Knowledge formalisation

Determining the range of attribute values

The formalisation of knowledge is started by determining the range of attribute values. The basic attributes are broken down to other attributes, viz:

A) prospects of entering the transport services market

- set plan of transport organisation (timetable):
  - number of trains,
  - planned composition of trains,
  - planned number of passengers,
  - standard coefficient of the utilisation of seats,
  - planned immobilisation;
- implementation of the set transport organisation:
  - average number of operating trains over a given period,
  - materialised composition of trains,
  - number of transported passengers;
- available capacities:
  - wagon stock on list,
  - wagon stock in use,
  - number of locomotives,
  - number of locomotives in use,
  - actual immobilisation,
  - capacity of railway line;
- commercial results:
  - actual costs,
  - actual earnings,
  - planned costs,
  - planned earnings;
- existing quality of offered transport services:
  - price of transport,
  - commercial speed,
  - transport frequency,
  - travelling safety,
  - transport regularity and accuracy,
  - coefficient of the utilisation of seats,

- promotional market activities,
- investments in development and modernisation.

B) market demand for transport:

- actual demand for transport,
- planned demand for transport,
- extraordinary demand for transport.

C) power of competition:

- capacity utilisation,
- scope of competitive market,
- competitors' costs,
- competitive prices of services,
- competitive speed of transport,
- organisation of competitive transport,
- competitive quality of services,
- competitors' investments in development and modernisation .

D) institutional conditions

- limitations,
- incentives.

Having defined the attributes, we can proceed to determining possible values that each of them may assume (attribute range). The method of defining possible attribute values starts from structure sheets (sheet - attribute having no subordinate attribute). The attribute values are shown in the qualitative format.

Production rule techniques

Having assigned values to the attributes, we can choose one of the knowledge presentation techniques. Considering the characteristics of the production rules: ***modularity*** - the possibility of adding, eliminating or changing a particular production rule irrespective of its relations to other rules (because rules communicate exclusively through contextual data structures) - ***uniformity*** - reflected in a homogeneous knowledge presentation for easier understanding by other persons - and ***naturalism*** in the structuring of production rules analogous to the problem-solving methods in human thinking (in a given situation they best express "what to do next"), the production rules have been chosen for knowledge presentation.

Attribute		Value	Type
	Rendering of new passenger transport services	**CANCEL / INTRODUCE/ SAME**	logical
A	possibility of entering the transport services market	high, medium,low,∇*	logical
B	market demand for transport	high, medium,low,∇*	logical
C	power of competition	high, medium,low,∇*	logical
D	institutional conditions	Limitations, Incentives, None	logical
Aa	set transport organisation plan (timetable)	oversized, optimal, unsatisfactory, ∇	logical
Ab	implementation of the set transport organisation plan	high, medium,low,∇*	logical
Ac	availability of capacities	high, satisfactory,insufficient, ∇	logical
Ad	commercial results	above expectation,as expected, below expectation, ∇	logical
Ae	existing quality of supplied transport services	high, medium,low,∇*	logical
Af	promotional activities on the market	high, medium,low, none,∇*	logical
Ag	investments in development and modernisation	high, medium,low,∇*	logical
Aa1	number of trains	(1......n) , ∇	numerical
Aa2	planned train composition	(1......n) , ∇	numerical
Aa3	planned number of passengers	(1......n) , ∇	numerical
Aa4	standardised seat utilisation coefficient	(%), ∇	numerical
Aa5	planned immobilisation	(%), ∇	numerical
Ab1	average number of realised trains over a given period	(1......n) , ∇	numerical
Ab2	realised train composition	(1......n) , ∇	numerical
Ab3	number of transported passengers	(1......n) , ∇	numerical
Ac1	inventoried wagon stock	(1......n) , ∇	numerical
Ac2	wagon stock in use	(1......n) , ∇	numerical
Ac3	number of locomotives	(1......n) , ∇	numerical
Ac4	number of locomotives in use	(1......n) , ∇	numerical

Attribute		Value	Type
Ac5	actual immobilisation	(high, standardized,low), ∇	numerical
Ac6	capacity of railway lines	(1......n train/day) , ∇	numerical
Ad1	incurred costs	(1......n) , ∇	numerical
Ad2	realised earnings	(1......n) , ∇	numerical
Ad3	planned costs	(1......n) , ∇	numerical
Ad4	planned earnings	(1......n) , ∇	numerical
Ae1	price of transport	high, medium,low,∇	logical
Ae2	commercial speed of trains	high, medium,low,∇	logical
Ae3	transport frequency	high, medium,low,∇	logical
Ae4	travelling safety	high, medium,low,∇	logical
Ae5	regularity and accuracy of transport	high, medium,low,∇	logical
Ae6	seat utilisation coefficient	high, medium,low,∇	logical
Ba	planned transport requirements	(1......n) , ∇	numerical
Bb	actual transport requirements	(1......n) , ∇	numerical
Ca	capacity utilisation by competitors	high, satisfactory,insufficient, ∇	logical
Cb	range of market competition	broad,narrow, ∇	logical
Cc	competitors' costs	high, medium,low,∇	logical
Cd	competitors' transport prices	high, reasonable,low,∇	logical
Ce	competitive speed of transport	high, medium,low,∇	logical
Cf	quality of competitive services	high, reasonable,low,∇	logical
Cg	competitors' investments in development and modernisation	high, medium,low,∇	logical

* "∇" denotes an attribute value having no bearing on the decision-making process

Table 1: Scopes of attribute values

Examples:

Rule 1: **if** B (high)
A (very high)
C (insufficient)
D (I or N)
then DECISION YES

Rule 2: **if** B (high)
A (insufficient)
C (very high)
D (∇)
then DECISION NO

Rule 3: **if** B (high)
A (very high)
C (very high)
D (I or N)
then (Ab check, Ac check)

Rule 4: **if** Ab (low), Ac (high)
then DECISION YES

This shows how we can define all possible rules and install them in the knowledge base.

Search techniques

Forward chaining is used for searching in the knowledge base to find a condition fulfilled on the basis of given data. Once the condition has been found, further data and reports are generated. This technique is used when exactly defined values of subordinated attributes are available so the superordinated attributes can be generated from them and the decision be made.

Backward chaining is used when inference departs from the conclusion so the condition for proving the truth or falsity is developed. Therefore, if we have made a *decision to render new services* to transport users, we are searching in the knowledge base to make sure the values of particular attributes permit it. Also, if we argue that an attribute has a certain value, we can use this technique to search for the subordinated attributes to make sure that the argument is true.

3.4. Creating the Model Base

The functional connection between the knowledge base and the inference engine is achieved through the model base. By using mathematical-statistical and logical models, methods and techniques, sets of indicators are prepared and formed in the model base on the basis of quality data, whereas the processed knowledge on them is stored in the knowledge base.

The model base management system (MBMS) enables the user to define by himself a combination of guidelines for independent formulation of a complex model. Its role is to bridge the gap between the model base and the database, so that the impact of any changes in the database on the chosen model is practically eliminated in terms of content.

The model services as a foundation for planning the supply of passenger transport services are as follows:

Transport demand forecast model

Investigation of the patterns of passenger and freight transport trends by means of statistical methods usually involves the use of one or more factoring models. The model is designed in several stages the most important of which are:

- choice of factors crucial for a forecast value, and
- choice of the most complete functional dependence

Travel distribution model by individual transport routes

Once the existence of transport has been projected, it is necessary to embark on a procedure by which the journeys starting in a particular zone will be distributed among other zones. It links the extent of creating journeys in the observed area to possible destinations, without choosing the way along which a journey will take place.

The gravitational model is one of the first travel distribution models and the one most used so far. According to this model, the amount of travel between two zones is proportionate to the function of the amount of creating journeys in these zones and inversely proportionate to the function of resistance dividing these zones.

Inter-zone travel distribution model by means of transport

One of the models used so far to choose the means of transport in inter-zone traffic is the abstract vehicle procedure, based on the assumption that the demand for transport is not only a function of the price of the means of transport concerned, but also of some other feature. The choice of the means of transport is derived by maximising the *function of benefit* based on:

- suitability
- comfort
- costs
- speed

In terms of the function of benefit the price of travelling by a particular means of transport should reflect all the costs involved from the starting point to destination, as well as the money value of comfort and suitability.

Number of trains determination model based on the number of passengers

3.5. Glossary of terms

In order to ensure the precise meaning of concepts in the description of a system, the description of all attributes and their cross-references is included in the **glossary of terms.**

New service	*decision based on four basic factors* = Own possibility of entering the market requirements + power of competition + institutional conditions [YES; NO]
actual immobilisation	* percentage of rolling stock out of order* [1.....n]
actual seat utilisation coefficient	* the actual number of passengers per seat * [low, standardised, high]
availability of capacities	* mobile and immobile capacities available for the implementation of the current timetable * = inventories wagon stock + wagon stock in use + working stock + number of locomotives + actual immobilisation + capacity of railway lines [high, satisfactory, insufficient]
average number of realised trains over a given period	*number of trains actually run over a given period of time* [1.....n]
capacity of railway lines	*daily quantity of trains which can pass along a line in terms of its exploitation capacity - computed by a special methodology using a model* [1.....n]
capacity utilisation by competitors	*how competitors use their capacities* [high, satisfactory, insufficient]
commercial results	* difference between earnings and costs * = incurred costs + earnings + anticipated costs + anticipated earnings [above expectation, expected, below expectation]
commercial speed of trains	*train speed on a particular section representing the relationship of total travel time and covered kilometres* [high, medium, low]
competitive speed of transport	*realised speed of travel on a particular route* [high, medium,low,]

competitors' costs	*competitors' costs in rendering transport services on a given route* [high, medium, low]
competitors' investments in development and modernisation	* amount of competitors' investments in development and modernisation expressed in terms of quality* [high, medium, low]
competitors' transport prices	* price per unit of travel expressed in monetary terms * [1.....n]
existing quality of supplied transport services	* indicators of the existing quality of transport services as an important factor of a new offer* = price of transport + speed of transport frequency + travel safety and comfort + transport regularity and accuracy + set utilisation coefficient [high, satisfactory, medium, low]
implementation of the set transport organisation plan	* monitoring of implementation of the timetable considering all the elements determining it * = average number of realised trains over a given period + realised composition of trains + number of transported passengers [high, =, low]
incurred costs	* earnings actually realised - to be obtained by FIM * [1.....n]
institutional conditions	*conditions operating outside the business system itself, the nature of which can be legal,commercial, etc.* [limitations, incentives, none]
inventoried wagon stock	* total number of passenger coaches available to the Croatian Railways * [1.....n]
investments in development and modernisation	*amount of Croatian Railways investments in development and modernisation expressed in terms of quality * [high, medium, low]
market requirements	*market requirements for passenger transport* = existing transport requirements + anticipated transport requirements + extraordinary transport requirements [high, medium, low]
number of locomotives	*total number of locomotives available to the Croatian Railways * [1.....n]
number of locomotives in use	*actual number of traction locomotives* [1.....n]

number of transported passengers	*actual number of transported passengers over a given period of time* [1.....n]
planned costs	* costs planned for the set transport organisation * [1.....n]
planned earnings	* earnings planned for the set transport organisation * [1.....n]
planned immobilisation	*percentage of rolling stock estimated to be out of order* [%]
planned number of passengers	*number of planned passengers obtained by estimating the generation of travel in one of the three ways in the model base, further distributed by routes and means of transport* [1......n]
planned number of trains	* number of planned trains obtained on the basis of the planned number of passengers that the preparation of the timetable relies on* [1......n]
planned train composition	*planned composition of trains expressed in terms of the number of seats per train* [1......n]
planned transport requirements	*amount of transport needs computed by means of a forecast method in the model base* [1.....n]
possibility of entering the transport services market	*potentials of the Croatian Railways to come up with a transport offer relying on their organisation, own capacities, economic power and other business factors* = plan of set transport organisation (timetable) + implementation of the timetable + availability of the capacities + commercial results + existing quality of supplied transport services + promotional activities on the market + investments in development and modernisation [high, medium, low]
power of competition	*possibility of other transport branches to compete in rendering transport services on the market* = utilisation of capacities + scope of market + costs + price of services + competitive speed of transport + quality of services + competitor's investments in development and modernisation [high, medium, low,]
price of transport	*price per unit of travel expressed in monetary units * [1.....n]

promotional activities on the market	* promotional activities by the Croatian Railways on the transport services market* [high, medium, low, none]
quality of competitive services	*assessed by conducting a survey among passengers* [high, reasonable, low]
realised earnings	* costs actually incurred - to be obtained by FIM * [1.....n]
realised train composition	*train composition actually realised over a given period, expressed in terms of the number of seats* [1.....n]
regularity and accuracy of transport	* travel regularity and accuracy means maximum maintenance of travel elements set in the timetable * [high, reasonable, low]
scope of competitive market	*size of area served by competitors* [wide narrow]
set transport organisation plan (timetable)	*general working plan used by the Croatian Railways, an annual timetable which contains all arguments affecting it* = number of trains + planned composition of trains + planned number of passengers + set utilisation coefficient + planned immobilisation [oversized, optimal, satisfactory, unsatisfactory]
standardised seat utilisation coefficient	*coefficient showing the average number of passengers per seat * [%]
transport frequency	*number of trains per unit of time on a given route* [high, reasonable, low]
travelling safety	* a safe and comfortable journey is the one passed without any incident from the starting point to the destination* [high, reasonable, low,]
wagon stock in use	*total number of passenger coaches in use according to the planned timetable* [1.....n]

Legend:

* * comment on definition
= consisting of
[ ] values of the concept defined

4. Conclusion

The decision-making process in business systems is determined by corresponding institutional framework in which these systems operate. In the area of business, unlike the private sphere, the decision-making process is reflected, in dependence on the level and place of decision-making and the company size, on a greater or smaller number of the company's employees, sometimes all of them. This alone justifies the need to approach the business decision-making with more care.

In the time of fast and discontinuous changes forming , a dominant feature of the turn of this century, business decision-making is unthinkable without strong information support at all levels. Hence the imperative to create an efficient business information system designed to provide support in the decision-making processes. In these process computers are man's perfect tools, indispensable in large-scale data processing (especially when simultaneous and parallel-running processing is required), and they make up for man's reasoning based on incomplete data, assessments, etc.

Attempts have been made at the Croatian Railways to cope with the decision-making problems outlined above by applying theoretical knowledge about the techniques and methods of artificial intelligence in creating an expert system as a means of support in the decision-making process. The greatest problems encountered in this paper were associated with choosing the right system from a wide range of problems, as well as with the task of defining the influential factors determining the company's position on transport services market.

Further work would require more detailed research into the business system of the Croatian Railways, since the presented material does not make allowance for all the factors determining the demand and supply pattern of transport services, whichis partly due to an exceptionally great number of these factors, partly to impossibility of their structuring. Undertaking additional research in the area of artificial intelligence in order to arrive at methods and techniques more appropriate for these problems would be more than welcome. Anyway, it can be said with certainty that the use of an expert system in dealing with the decision-making problems involving risks would help make right decisions at the Croatian Railways. The extent to which it would be helpful will be possible to tell only after its full incorporation into the information system of the Croatian Railways.

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Starešinčić D. Ekspertni sustavi u planiranju željezničkog prometa

Sažetak

Prilagodba poduzeća koja se bave prijevozom ljudi i tereta novim zahtjevima tržišta, zahtijeva mnogo veće napore u odnosu na druge, prvenstveno zbog karakteristika prijevoznih usluga. Svaka analiza poslovanja željezničkog poduzeća i analiza tržišta prijevoznih usluga pokazala bi da je uspjeh cjelokupnog sustava upravljanja u korelaciji s dostignutom razinom prilagodbe tržišnim zahtjevima.

Zbog toga je od izuzetnog značenja podrška donošenju odluka o nastupu na tržištu prijevozničkih usluga i na strateškoj i na taktičkoj razini.

U radu se istražuju potencijalne prednosti ekspertnog sustava koji će pomoći donosiocu odluke u donošenju poslovnih odluka, sugerirati mu korake koje treba poduzeti, te mu pomoći u procjenjivanju situacije i predviđanju događaja koji mogu utjecati na položaj Hrvatskih željeznica na tržište prijevoznih usluga.