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Dušan MALINDŽÁK[1]
Jana VRLÍKOVÁ[2]
Aboubaker ALTIAIEB MOUSSTTFA[3]

THE SYNTHESIS OF THE LOGISTIC SYSTEMS WITH APPLICATION OF THE HEURISTIC APPROACH

In the paper a heuristic approach for design logistic systems is described. Heuristic approach is established on the modeling of the human mental activities by the solution of an interesting problem. In management practices exist many activities-problems, which cannot be modeled or solved by a mathematical – analytical method, but the man is able successfully to solve this. One of the way, is to analyze the process of problem solution by man and define from it the rules, principle which applied by the man/human intelligence/ and to support it with information technology /artificial intelligence / and get it to algorithm - model. This approach is very successful mainly in creation the models for executive – aggregate planning, capacity planning, scheduling, decision making. Rules are classified as heuristics, expert rules, technological rules, limitations and optimization criteria. In the paper is described "roads methods –sequential criterion application method", which define the sequence of rules, out from decision tree, on the relations among the rules and their priority. The methodic described in this paper is a result of the induction from many applications of the real solution of the logistic problem in practice.

Keywords: logistic systems, heuristic approach, information technology.

1. INTRODUCTION

The heuristics from the Greek (heuristikó) is the method for the problems solution, for the algorithm does not exist. The heuristic approach method is the creation of the algorithm on the basis of experiences, practice, approximate idea of man from the solutions of similar problems. [1]

Vogel [2] defines three types of decision making processes: deduction, abduction and induction. Deduction decision making is exactly decision making and abduction and induction has a probable character – it is heuristic decision making. The Heuristic approach is an approach with the applying of rules created on the basis of the abduction and induction. [2]

According to Perl,heuristic is the strategy which is applied by man and machine for problem solutions using available information. [3]

The heuristic method is an algorithm which applies the heuristic approach, it means in opposite of the analytical methods heuristic algorithm which is based on the modelling of

[1] Dr.h.c., Prof. Ing. Dušan Malindžák (autor korespondencyjny), CSc. Faculty of Management, Rzeszow University of Technology, e-mail: dusan.malindzak@tuke.sk, al. Powstańców Warszawy 8, 35-959 Rzeszów, tel. (17) 865 18 03.

[2] Ing. Jana Vrlíková, FBERG, TU Košice, ÚLPaD.

[3] Mousstfa Abou Baker Altiaieb,SjF,TU Košice.

processes which is realized by man in individual steps in problem solutions. The Heuristic algorithm applies the rules – heuristics, i.e. rules created on the abduction and induction thinking, on the basis of repeating the solution of man. [4]

Xin SheYang defines the category heuristics and metaheuristics as heuristics meaning „to find" or discover the algorithm by „trial and error", on the elementary rules of heuristics. Solution to the problem – optimization of the problem, can be found as a reasonable solution, but there is no guarantee of an optimal solution. Metaheuristc algorithm (model) is a further development over the heuristics algorithm. „Meta" – means a bigger level and generally performs better than simple heuristics. [5]

Heuristics is the way – by „trial and error" to produce an acceptable (good) solution to a complex problem in reasonably practical time. [5]

The elementary rules applied in heuristic and metaheuristic methods are: Simulated Annealing, Genetic Algorithms, Tabu Search, Ant Colony Optimization, Neighborhood Search , etc. The utilized idea of the selection of the path in the decision tree which describes variants of the problem solution = NP incomplete problem. These rules are applied mechanically for the selection path in the decision tree.

This way can be defined and selected by another approach too; if we know set of rules, set of limitations and the criteria of optimality set – $\bar{R}$, which have to be applied for problem solutions for the selection of a good solution path in the decision tree to have to find the optimal sequence of these rules. The sequence of the rules is developed by the priority and relation among them. In the next step the sequence is applied for the selection of the path and creation of the heuristic algorithm for solution the problem.

2. THE HEURISTIC ANALYSIS

The creation of a heuristic model as the base for a synthesis requires a precise analysis. Due to the fact that heuristics is defined as a method for mental activities modelling carried out by human beings, the biggest amount of synthesis applications is in the management processes.

Particularly in logistics, it is mostly in processes of:

- forecasting aggregate production planning model
- operative planning
- production scheduling
- supplier selection
- design of distribution network structure, etc.

This means, that it's mostly used there, where the essence of such activity or a process is decision.

Heuristic analysis should create an outlet for a heuristic model synthesis. The outlet for decision is a collection database of information and rules. When we have the input information for such decision process (e.g. heuristic basis of data about product sales), by executing an analysis we will be able to describe algorithms, sequences of steps and rules as executed by a human being during decision making.

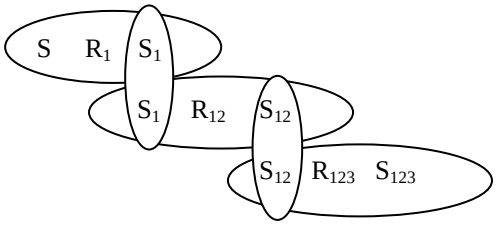
Heuristic analysis comprises principles of:

1) Theory of elementary information processes – system / process breakdown into such small processes that could be modelled and solved [4], [8]

(1)

$$S(t,\alpha(t)) \rightarrow R_1 \rightarrow S_1(t_1,\alpha(t_1)) \rightarrow \begin{cases} R_{11} \rightarrow S_{11}(t_{11},\alpha(t_{11})) \\ R_{12} \rightarrow S_{12}(t_{12},\alpha(t_{12})) \end{cases}$$
$$R_2 \rightarrow S_2(t_2,\alpha(t_2))$$
$$\vdots \qquad\qquad \vdots$$
$$R_n \rightarrow Sn(tn,\alpha(tn))$$

2) Decision tree breakdown into triads and cascades. [7]



3) As seen from 1) to be able to analyze a problem, it is necessary to know:

- group of rules $\bar{R}_i$ ... $\bar{R}_{ij}$, ...
- situation S – definition of the problem
- group of following situations $\bar{S}_i$ .... $\bar{S}_{ij}$ ...

To perform an analysis means to create a defined structure (1), more precisely define situations and rules.

4) For structure definition (1), it is sufficient to know the initial situation S (t, α (t)). (Situation S in time t, with features, parameters α(t)) and group of rules $\bar{R}$.

5) Definition of heuristics - $\bar{H}$

The heuristics are rules which are defined on the analogy and induction principles. A definition of the set of rules $\bar{R}$ bring to heuristic models, experiences, praxis and intuition because these are expressed in concrete techniques, steps, decisions, situation reactions, etc. That is why the analysis for rule definition initiates from:

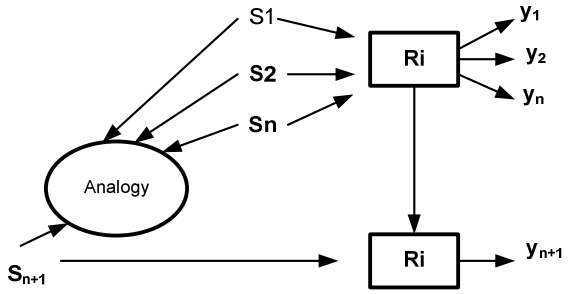
– Knowing how people do it,
– Why they do it,
– What rules they apply for a particular activity.

Repeated activity execution (during plan preparation) and the fact that praxis has verified correctness and the success of it means achieving a suitable tool for future control decision making and management.

These conclusions are based on repeated analogy and abductive and inductive decision making.

If particular rule R_i was valid for situation S_1, S_2 ... S_n and provided suitable solution y_i, then if situation S_{n+1} is analogical to situations S_1, S_2 ... S_n , rule ($\bar{R}$) is also suitable for its solution.

Fig. 1 Induction principle



Source: Malindžák D. a kolektív: *Teória logistiky*, Košice, Karnat, 2007

Heuristic rules are created by induction according to repeated analogy. It is difficult to divide the phase of analysis from synthesis especially in case of a heuristic approach. This is a model approach and it has its own specifications.

6) Definition of further rules

Several other rules need to be defined besides the group of heuristics $\bar{H}$:

$\overline{TR}$ - technological rule, are rules defined by technological regularity, e.g. duration of (slabs) movement in (push furnace) can´t exceed 120 minutes, if we load it in cold phase, because its inner material structure would be disturbed.

- slabs on a steel mill get rolled from the widest to the narrowest due to cylinder depreciation.

$\bar{O}$ - constraints – technical, economy, environmental limitation, i.e. rolling temperature of the slabs at the entry to the rolling path cannot be less than 1200ºC.

$\overline{ER}$ - expert rules, defined particular activities decided to keep in charge of a ma after creation the model – planners, logistic manager, dispatcher because:

a) Those activities are not suitable for modeling – and for automation,
b) We don't want to model them due to „user friendly" purposes and man's participation is requested.

$\overline{OC}$ - optimization criteria. Innovation, re-engineering of logistic system - LS has a defined goal implicitly and explicitly – process of system opti-

mization as an entity. LS optimization always leads to a multi-criterion optimization problem. In analysis we have to define the main optimization criterion. In synthesis it is necessary to e.g.:

- maximize machine capacity utilization,
- minimize energy consumption,
- determine the order – sequence of product manufacturing,
- optimize production progression from chemical consistence point of view, dimensions, etc.
- optimize smoothness of parameter changes,
- minimize distribution path.

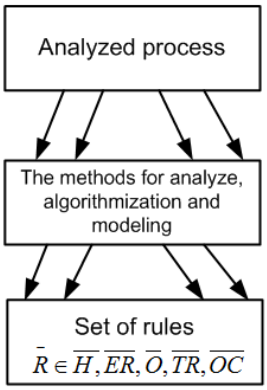
The main criterion optimalization - MCO is always the criterion of production cost because each of the above-mentioned criteria is directly or indirectly translated into expenses.

By analysis we can define rules, formulas and algorithms for calculation of these criteria and their relations either mathematically, logically or information wise.

From the practical point of view, an analysis is performed by any possible means, such as the Internet, company's materials, theory, research but mostly by a detail exploration of people, their intellectual activity during decision making and managing, by algorithmization, verbal description.

The main result of analysis for heuristic model creation is set of the rules $\bar{R}$.

Fig. 2 Principle of rule creation



Source: Malindžák D., *Production Logistics*, Košice: FBERG TU 1997.

3. LOGISTIC SYSTEM SYNTHESIS ON THE BASIS OF HEURISTIC MODEL – METHOD OF "SEQUENTIAL CRITERION APPLICATION"

A Heuristic approach of the synthesis LS assumes modeling of process principles as processing of information carried out by man on various phases of his activities and while solving various tasks. This approach is then based on a principle of a heuristic model creation. It is next described in the example of the heuristic model synthesis for the operative planning and production scheduling model.

Sequences of steps during the creation of such a heuristic model:

a) Definition of initial situation (problem definition).

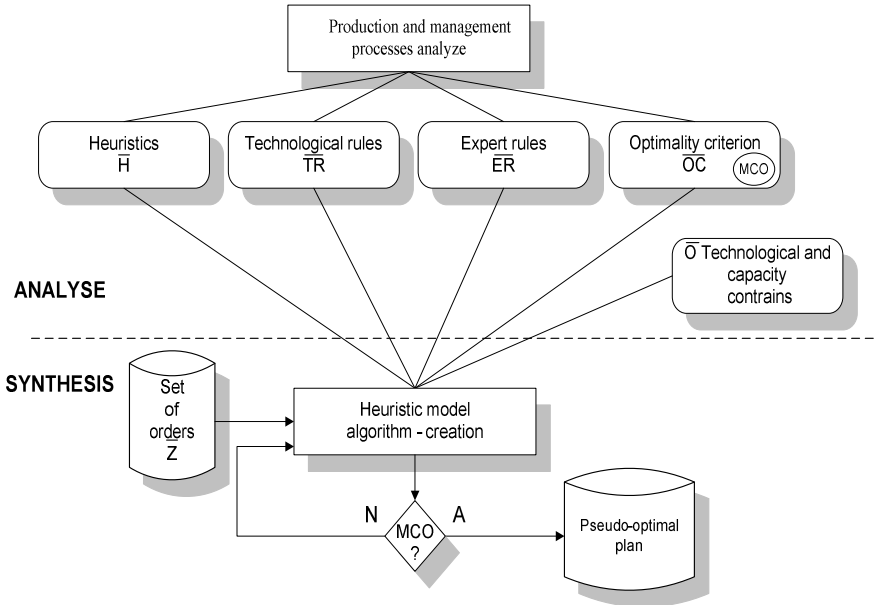
b) Creation of possible variants for further situations (possible solutions).
c) Rule creation
d) Heuristic model synthesis.
e) Heuristic model verification.

The sequences of steps for the creation of such a heuristic model are illustrated in fig. 3. The definition of rule set is performed as the result of analysis, technological processes, machines, equipment, organization and manufacturing process management, economy, capacity and optimality criterion.

Particular process, e.g. planning, has a particular entry file of orders and by its analysis the rules were defined, which need to be fulfilled by the planning process.

The synthesis objective is to create an algorithm or model from these rules and from the definition of entry files structure.

Fig. 3 The schema of the creation heuristic model



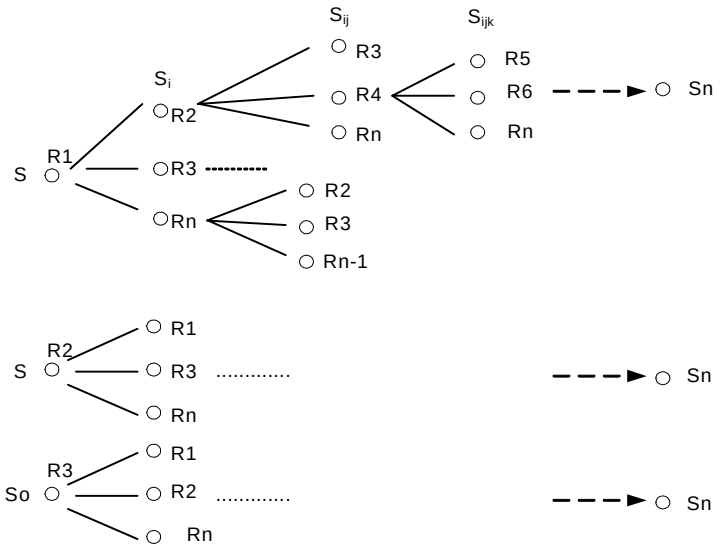
Source: Malindžák D., *Production Logistics*, Košice: FBERG TU, 1997.

Set of rules $\{\overline{R}\} \in \{\overline{H}, \overline{TR}, \overline{ER}, \overline{O}, \overline{CO}\}$ comprise of the following groups:

- Heuristic - $\overline{H}$
- Technological rules - $\overline{TR}$
- Expert rules - $\overline{ER}$
- Constraints - $\overline{O}$
- Optimality criteria - $\overline{OC}$

If we picture the solutions in the form of a decision tree, then the group of inputs (e.g. orders – for order control, group of manufacturing tasks – for operative planning and production scheduling, group of suppliers - for supplier selection, group of customers and resources for design of distribution system structure, etc.). Each group of inputs is different and must follow criteria $\overline{R}$ defined in the previous analysis. If the amount of criteria is „n“, then in group „ $\overline{Z}$ “we are able to apply these criteria in various orders. Theoretically there are ‘n’ rule sequences. That would mean to create a path in tree structures (because we can start with any of the „n“ rules).

Fig. 4 Labyrinth of tree structures presenting solutions of heuristic model



Source: developed by the author based on: Alexandrov, E. A.: *Osnovy teorii evrističeskich rešenij*. Moskva, 1975

To create a model or an algorithm means to apply in the set of orders - $\overline{Z}$ (initial situation *S)* sequence of rules and get to stage S_n (final stage). The sequence of cascades creates a model, algorithm, progression.

$$S\ R_1\ S_1$$
$$S_1\ R_2\ S_2$$
$$\vdots$$
$$\vdots$$
$$S_{n-1} R_n - S_n$$

The essential question is which of the n! sequences is the right one, the correct one, both suitable and optimal? Which can be found in the shortest time?

There are two strategies we are able to follow during synthesis [6]:

a) **Inductive-deductive strategy**, from $S \rightarrow S_n$, when we don't know the final form of the model or the process or if we look for the way how to get there by knowing the initial stage S_o and rule vector $\overline{R}$,
b) **Abductive-inductive strategy**, when we know the stage S – final form, content and we continue from back to the front. [4]

$$S_n \rightarrow R_n \rightarrow S_{n-1}$$
$$S_{n-1} \rightarrow R_{n-1} \rightarrow S_{n-2}$$
$$\vdots$$
$$S_1\ R_1\ S$$

The situation is complicated by the fact that by solving with a heuristic model we are not aiming at just finding "some" solution but a good optimal solution. That is why one part of the heuristic model synthesis is also an optimization task. LS must fulfill several criteria, e.g. minimize cost, maximize machine utilization, minimize energy consumption, etc. – an optimization problem is a multi-criterion problem.

To find an optimal path in the decision tree labyrinth means to create an optimal model.

Heuristic methods of path searching in a decision tree can be divided into:

a) Metaheuristic – one step, which ensures the movement in the decision tree one step after another – on one triad.

$S_i \quad R_{i+1} \quad S_{i+1}$

In case of a successful step – (according selected criterion) movement continues.

One step methods are:

a1) *Neighborhood search* – (next step, rule R are generated as random number), if a step is successful -> continues, if not -> back to stage S_i.
a2) Neighborhood search with Tabu search – unsuccessful tries are saved to a memory – Tabu so that they are not repeated.
a3) Hill climbing – criteria with maximal gradient are selected.
a4) Genetic algorithms base on generation of two codes where the sum of them is a random number – rule (similar to the Monte-Carlo principle).

b) Two-step methods – of simulation analysis applies the idea of returning from an unsuccessful step is not on the same path as during forward direction
- Method of branch and bound applies criteria till the next unsuccessful step. In the case of an unsuccessful step means returning back to point where the step was still successful and continues in the path that has not been tried yet. (Tabu principle)

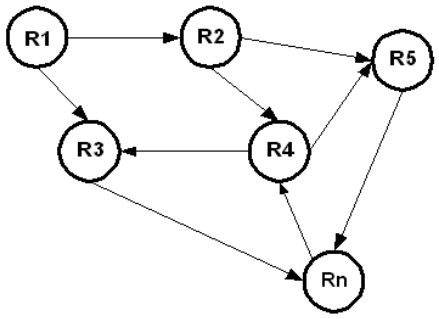
c) Way methods – where the path in decision tree on the base of the set of rules $\overline{R}$ are defined.

d) Method of sequential criterion application – msca

Is one of the path methods. This method is based on findings of an optimal sequence of rules outside the decision tree. [4]

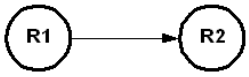
This method rises from the conclusion that rules are not independent. Many interactions and relations exist among them and are connected to the same process. They create a network.

Fig. 5 Criterion network



Source: authors own.

Links among them are quantitative – we are able to express them in numeric or relation form, respectively qualitatively. Links "direction" expresses the dependencies, e.g. rule R_2 depends of rule R_1, direction expresses also subsidiarity (reference, subordination).



Several pieces of information are coded in such a network graph which can be used during the definition of "suitable – optimal rule sequence".

Because it is necessary to solve a problem of multi-criterion optimization, it is possible to solve it by selecting one of the rules $\overline{R_i}$ as the main criterion for MCO optimization. Other criteria as a rule will be applied implicitly during creation of heuristic model.

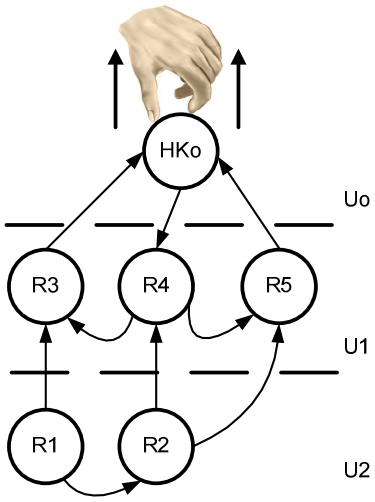
A principle of "fishing net" is applied on such rule network. If we catch this fishing net by one knot - rule defined as MCO, then a particular net will be arranged according the links to MCO. For the illustration, let us use MCO as R_n

By pulling MCO a net will be transformed into a pseudo-tree and then it is clear that rules R_i are arranged into levels. [10]

Relation of rules to MCO determines their importance in particular process and their priority while application to $\overline{Z}$. This way a „pseudo-tree“ was created.

The next step is the change of pseudo-tree of rules into a “chain” – rule sequence.

Fig. 6 Pseudo-tree criterion



Source: Malindžák D., *Production Logistics,* Košice: FBERG TU 1997.

Rule of order in the chain will be according to levels

$$\{U_o\} \rightarrow \{U_1\} \rightarrow \{U_2\}$$

It is necessary to create the order at each level. Once again subsidiarity links of the superior criterion will be used. [9]

Second criterion will be from U_1 – either R_3 or R_5. Both criteria influence the value of MCO. Criterion that MCO will react most sensitively will become the most important, that is why it will appear as the second one in the chain. For illustration, let’s say such criterion will be R_5.

Then the criteria order will look like this:

$$\text{MCO} \rightarrow R_5 \rightarrow R_3 \rightarrow R_4 \rightarrow R_2 \rightarrow R_1$$

This pseudo-optimal sequence will be applied to $\overline{Z}$ and an algorithm of heuristic model will be created. This method is the basis for heuristic model creation for LS synthesis.

4. CONCLUSION

The paper describes the method of synthesis logistics systems on the basis of heuristic models.

The method was established on the generalization and induction from many solutions of the practical problem in industry. MSCA is one of the heuristic method – paths method,

which define "path" – algorithm out from the decision once as a general "picture" of heuristic solution.

The MSCA accelerates the design of the logistic model on your synthesis, bringing into the model more intelligence than meta-heuristics methods and implicitly to solve multi-optimalization problem.

REFERENCES

[1] *Heuristika* [online], [cit. 6. 09. 2012], Wikipedie. Dostupné z www:<http://en. wikipedia.org/wiki/Heuristic?oldid=209788850>

[2] Pearl, J., *Heuristics: Intelligent Search Strategies for Computer Problem Solving*, Addison-Wesley, Reading, MA., 1984

[3] Fogel, L. J., Owens AJ, and Walsh, MJ, *Artificial Intelligence Through a Simulationof Evolution*, Chichester, Washington, D.C, UK : WILEY, 1966

[4] Malindžák, D., *Production Logistics*, Košice : FBERG TU, - 1997. - 170s.

[5] Yang X. S. (2008). *Nature-Inspired Metaheuristic Algorithms*, Second Edition, Luniver Press, UK, 2010

[6] Alexandrov, E. A.: *Osnovy teorii eurističeskich rešenij*. Moskva, 1975

[7] Malindžák, D. a kolektív : *Teória logistiky*, Košice : Karnat, 2007, ISBN 978-80-8073-893-8

[8] Malindžák, D., *Základné obraty a princípy heuristických modelov výrobného rozvrhovania*, In: Transactions of the Technical University of Košice. 3/1997 - Košice : TU, 1997 S. 14-20. - ISSN 1335-2334

[9] Malindžák, D., *Determination of the optimum sequence of heuristics in production management tasks*, In: Transactions of the Technical University of Košice 3/1993. - Cambridge : Riecansky Science Publ. Co, 1993 P. 256-259.

[10] Malindžák, D., *The synthesis of the heuristic models*, In: Automatyzacja maszyn urzadzen I procesów APRO'99. - Krakow : Gutenberg, 1999 P. 335-344. - ISBN 8386310103

SYNTEZA SYSTEMÓW LOGISTYCZNYCH Z WYKORZYSTANIEM PODEJŚCIA HEURYSTYCZNEGO

W artykule opisano podejście heurystyczne do projektowania systemów logistycznych - LS. Podejście heurystyczne opiera się na modelowaniu mentalnych działalności człowieka poprzez rozwiązywanie skomplikowanych problemów. W praktyce managerskiej istnieje wiele działań, które nie mogą być modelowane i rozwiązane matematycznie, ale dzięki metodzie analitycznej człowiek jest w stanie taki problem rozwiązać. Jednym ze sposobów, który można zastosować, jest analiza procesu rozwiązywania problemów przez człowieka i określenie dla tego problemu reguł i zasad, które mogą być zastosowane przez ludzi (inteligencja czlowieka), wsparta przez technologie informacyjne (sztuczna inteligencja) i dzięki temu można zbudować odpowiedni algorytm – model. Takie podejście jest szczególnie przydatne w tworzeniu modeli działania – planowania zintegrowanego, planowania zdolności produkcyjnych, harmonogramowania produkcji oraz procesu podejmowania decyzji. Omawiane reguły można sklasyfikować jako reguły heurystyczne, reguły eksperckie, reguły technologiczne oraz mozna zastosować kryteria ograniczające, a także kryteria optymalizacyjne. W artykule opisano „metodę drogi", czyli sekwencyjną metodę stosowania kryterium, która okresla kolejność realizacji poszczególnych reguł z wykorzystaniem drzewa decyzyjnego, biorąc pod uwagę wzajemne relacje pomiędzy regułami i priorytetami ich zastosowania. Metoda opisana w tym artykule jest wynikiem indukcji z wielu zastosowań realnego rozwiązania problemu logistycznego w praktyce, wnosi do modelu logistycznego bardziej inteligentne rozwiązania niż metody meta – heurystyczne i może przyczynić się do rozwiązania problemów multi – optymalizacyjnych.

Słowa kluczowe: systemy logistyczne, podejście heurystyczne, technologie informacyjne.

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