D. MALINDŽÁK, A. GAZDA, M. MALINDŽÁKOVÁ, D. VITKO

ISSN 0543-5846
METABK 52(4) 549-552 (2013)
UDC – UDK 669:658.005.5:658.5.338.3=111

THE BASIC PRINCIPLES AND RULES FOR HEURISTIC MODEL CREATION IN METALLURGY

Received – Prispjelo: 2012-12-18
Accepted – Prihvaćeno: 2013-03-20
Review paper – Pregledni rad

In management practice there are many activities which cannot be modeler solved by mathematical – analytical method, but one is able to successfully solve them. For real solution of the logistic problem, mainly in the field of capacity planning, operative planning and production scheduling, model creation most frequently appliesa heuristic approach. The heuristic approach – method is the creation of a model on the basis of experience, practice, approximate idea of the man from the solutions of similar problems. In this paper is described a principle and rules for creating heuristic models in management and logistic activities of metallurgy manufacturing.

Key words: metallurgy, manufacturing, heuristic model, analyze, synthesis

INTRODUCTION

The paper deals with the description of basic principles of the analysis for synthesis of the heuristic model of the operative planning. Induction is the basic principle for the creation of heuristic rules and inductions are taken on the basis of analogy [1].

In the solution of production scheduling problem, a multi-criterion optimization task must be solved too [2].

In the case of concrete problem solution e.g. production scheduling model development, especially in the case of large size of the task (large number of machines, products, time units), when mathematically hardly definable limitations are applied, it is difficult, and sometimes even impossible, to create a mathematical model. Problem adaptation to some known mathematical model- its idealization often leads to omission of basic properties of examined problem, so practical utilization of results, obtained from this model, is minimal.

The above reasons forced us to develop qualitatively new methods of problem solutions by computers, through modeling of various aspects of creative human activities. This approach is called heuristic approach. [1, 3]

For real solution of the logistic problem, mainly in the field of capacity planning, operative planning and production scheduling models creation, most frequently we apply case study approach [4] and heuristic approach [2, 5-7].

Heuristics (from the Greek heuristikó) is a method for problem solution, whenthere is no algorithm. The heuristic approach – method is the creation of an algorithm on the basis of experiences, practice, approximate idea of the man from the solutions of similar problems [8].

Vogel defines three types of decision making processes: deduction, abduction and induction. Deduction decision making is exact decision making and abduction and induction have a probabilistic character – it is a heuristic decision making. Heuristic approach is an approach which applies the rules created on the basis of abduction and induction [1].

According to Pearl, heuristics is the strategy which is applied by man and machines for problem solution using available information [9].

The heuristic method is an algorithm which applies heuristic approach, it means the opposite of the exact – analytical methods. The heuristic algorithm is based on the modeling of processes and is realized by man in individual steps in problem solution. The heuristic algorithm applies the rules – heuristics, i.e. rules created through abduction and induction thinking, on the basis of repeating the solution of man. [2]

Xin She Yang defines the category heuristics and metaheuristics: ”Heuristics means „to find“ or discover the algorithm by „trial and error“, the elementary rules – heuristics.” [10]

Solution of the problem – optimization problem, can be found as a reasonable solution, but there is no guarantee of optimal solution. Metaheuristic algorithm (model) is a further development of the heuristic algorithm. „Meta“ – means higher level and generally performs better than simple heuristics. [7, 10, 11]

Heuristics is the way – by „trial and error“ of producing acceptable (good) solution to a complex problem in reasonable practical time. [10]

The elementary rules applied in heuristic and metaheuristic methods are: Simulated Annealing, Genetic Algorithms, Tabu Search, Ant Colony Optimization,

D. Malindžák, A. Gazda, M. Malindžáková, D. Vitko, Technical University of Košice, BERG Faculty, Košice, Slovakia

Neighborhood Search, etc. utilizingthe idea of the selection of the way in the decision tree with described variant of the problem solution – NP incomplete problem. These rules are applied mechanically for the selection of the way in a decision tree. [6, 7, 11]

From the solution and application of heuristic models in many real projects (about forty) for metallurgical industry we tried to generalize the types of rules and principles used for heuristic models creation.

THE RULES AND PRINCIPLES FOR HEURISTIC MODEL DESIGN

An advantage of heuristic models is that they combine human and artificial intelligence [12].

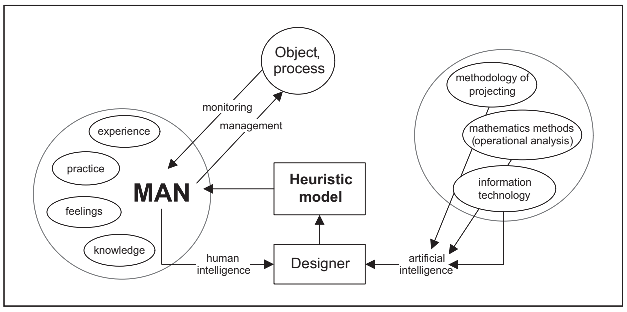


Figure 1 Application of human and artificial intelligence for heuristic model [6]

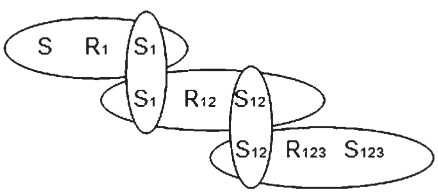
Heuristic analysis should create the basis for heuristic model synthesis. Outputs from heuristic analysis for heuristic model synthesis collected information about processes realized by man and define a set of criterion rules that were applied for problem solution Figure 1.

Heuristic analyses apply these principles:

1 **Theory of elementary information processes – system/process** breakdown into such small processes that could be modeled and solved [2].

$$\begin{aligned} S(t,\alpha(t)) &\rightarrow R_1 \rightarrow S_1(t_1,\alpha(t_1)) \text{ --- } R_{11} \rightarrow S_{11}(t_{11},\alpha(t_{11})) \\ &\rightarrow R_2 \rightarrow S_2(t_2,\alpha(t_2)) \text{ --- } R_{12} \rightarrow S_{12}(t_{12},\alpha(t_{12})) \ \ldots S_n \\ &\quad \vdots \qquad\qquad\qquad\qquad \vdots \\ &\rightarrow R_n \rightarrow Sn(tn,\alpha(tn)) \end{aligned} \tag{1}$$

2 **Decision tree chain divided into triads and cascades.** [2]



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

- group of rules $\overline{R_i}$ ... $\overline{R_{ij}}$,
- situation S – definition of the problem,
- group of following situations $\overline{S_i}$ ... $\overline{S_{ij}}$.

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

4 **For the structure** (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 $\overline{R}$ - Figure 2.

5 **Definition of the rules for heuristic model design**

5.1 Definition of heuristics - $\overline{H}$

The heuristics are rules which are defined on the analogy and induction principles. Defining the set of rules bring to heuristic models experiences, practice, 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 particular activity [9].

If particular rule R_i was valid for situation S1, S2 ... S_n and provided suitable solution y_i, if situation S_{n+1} is analogous to situations S1, S2 ... S_n, then rule ($\overline{R_i}$) is also suitable for its solution.

Most commonly applied heuristics in heuristic model in metallurgy:

5.1.1 Have to – Able to- Want to (HAW)

For example: When supplying buffers of blast furnaces from the storage of the raw materials, the interpolator moves on the rails slowly, about 3 m/min. The raw material store is about 900 m long. The materials are stored in piles next to each other.

In the case that the interpolator moves long distances to the raw material which needs to be loaded, e.g. iron pallets and will move along side the pile with limestone, which needs to be loaded next day, "model for supply" defines limestone as product "able to do". If the interpolator moves in the same track along side the pile with manganese and the buffer with this raw material has free capacity, then we "want" to load (supply) this product [2].

Very frequently this heuristic is applied in maintenance models. This heuristic can be applied in the reverse sequence too: "Want to – able to – have to" (WAH).

5.1.2 After replacing parts of equipment, after maintenance, and shutdown of equipment, are scheduled products with fewer demands on quality, e.g.:

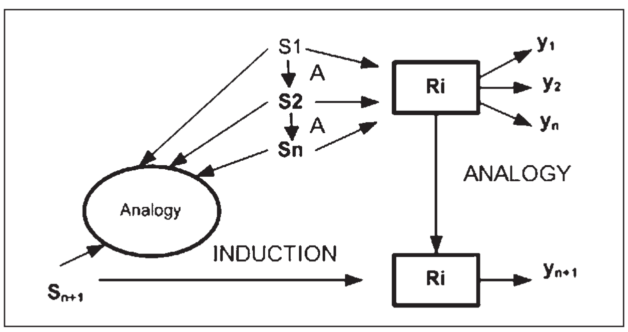


Figure 2 Induction principle [6]

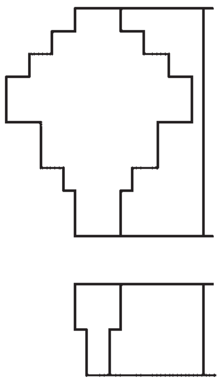


Figure 3 Typical structure of the campaign for steel mill [2]

- After regular steel mill maintenance, sheets with fewer demands on the sizes are scheduled.
- After replacement of the cylinders of the steel mill soft sheets are scheduled (because the rolls are cold) with average width (because this width is available most frequently).

5.1.3 Pooled heuristics

The individual heuristics and rules can be combined in to one "pooled heuristics", e.g. for rolling steel sheets these individual rules are combined:

- continuous change of the width of slabs;
- optimal number of the slabs of the same width into one sequence;
- after replacement of the cylinders,soft slabs are scheduled; as quickly as possible from the start the widest slabs go to rolling, etc.

From the individual rules are created typical campaigns for rolling of the steel sheets, e.g. for construction sheets, sheets for automotive industry, wrapping sheets, dynamo sheets (Figure 3).

5.1.4 "From the cleanest to dirtiest".

For the many aggregates, machines, products are arranged into a sequence by the rule from the cleanest to dirtiest e.g.:

- The sequence of the aluminum alloys for the fixer furnace, from the point of view of iron content in aluminum, is from minimum to maximum content. (Slovalco JSC Žiar nad Hronom).
- In the brasses production (content of Pb and Sn in Cu), (Považské strojárne, JSC).
- The mixing of the materials for the magnesite bricks, fireclay bricks (Keramika ltd. USS Košice).

The reason for application of this rule is the residual that remains in the aggregate after processing the previous product.

5.2 Technological rules - $\overline{TR}$,

$\overline{TR}$ are rules defined by technological regularity.

5.2.1 Continuous change of product parameters, for example:

- The width of the slabs from maximum to minimum in the rolling campaign of the steel mill.
- Continuous change of firing temperature of the bricks in loading process in tunnel furnace.
- Continuous change of the chemical element in compound.

5.2.2 Technology specialization

If the product can be manufactured on more machines,we can define "main technology" and "substitute technology".

The main technology for this product is optimal technology under criteria such as cost, profit, quality,etc. If the main technology is utilized for another product to the maximum of its capacity, then in this case the product can be processed with the substitute technology.

5.2.3 The cumulation of products.

From customer orders for the same or similar products are created virtual orders,based on cumulated groups of products andparameters.

5.3 Constraints - $\overline{O}$

$\overline{O}$ **-** values of technical, economic, time, capacity, and environmental variables, that constrain or limit the validity of the heuristic model.

Technical limitations, e.g.:

- The gradient of heating of the slabs in push furnaces
- Number of slabs in the batch for rolling.
- Size of the form which can be allocated to the press etc.

Time and capacity limitations, e.g.:

- DD – due date, defined in the orders (date of delivery for customer).
- SMT_I – shortest manufacturing time for product I.
- CM_J – capacity of the machine J.
- CS_J – capacity of the store, buffer J. etc.

Economical limitations, e.g.:

- The price and cost of the product etc.
- Repayment period.
- Payment discipline.
- Cost of inputs: material, energy etc.

Environmental limitations, e.g.:

- Utilization of the off-peak energy (the melting of the cement in cement factory).
- Minimization of the scrap (the model for the sheets cutting).
- Minimization of the transition slab in continuous-casting of the slab, etc.

5.4 Expert rules - $\overline{ER}$

$\overline{ER}$ defined particular activities decided to be kept in competence of the man (after creation and application of the heuristic model) – planners, logistic manager, dispatcher because:

- Those activities are not suitable for modeling – and for automation,
- This model is designed as „user friendly" model and man's participation is requested, for example:

a) Assignment of the orders or products to operative plan, which a model is unable to process, e.g.: model for production scheduling for steel mill TŠP 1 700 in USS is adjusted on maximum batch of the same slabs – on 20 pcs of slabs. When 22 pcs of slabs were ordered, the model scheduled only 20 pcs of slabs and 2 pcs of slabs was the remainder. The manufacture of these 2 slabs at another time exeeds loss compared to one time processing in TŠP 1 700 batch with 22 pcs of slabs.

b) Removal of orders from customers who lack-payment discipline.

c) Assignment of non-profitable orders to the production schedule from the point of other more profitable orders from the same customer.

5.5 Optimization criteria - $\overline{OC}$

Innovation, re-engineering of logistic system - LS has a defined goal implicitly and explicitly. LS optimization always leads to a multi-criterion optimization problem. During analysis we have to define the optimization criteria, e.g.:

- Maximization of profit
- Minimization of the production cost and logistic cost
- Maximization and uniformity of machine capacity utilization
- Minimization of energy consumption
- Determine the order – sequence of product manufacturing
- Optimization of production sequence from chemical composition point of view, dimensions, etc.
- Optimizationof smoothnessof parameter changes.

5.6 The main criterion optimization - *MCO*

MCO is always the criterion of production cost or profit, because each of the above-mentioned criteria is directly or indirectly projected into expenses.

For example:

- According to the situation on the market the main optimization criteria can be changed e.g. to Due Date or minimum consumption of energy.
- Models for capacity planning and scheduling should be created as flexible models, in which main criterion of optimization can be defined by the situation on the market.

The relations among criteria must be defined from the analysis.

From the practical point of view, analysis is performed by any possible means, such as internet, company's materials, study of the theory, research of the company processes, but mostly by a detailed exploration of people through interview and analyses of their intellectual activity during decision making and managing, by algorithms, verbal description.

The main result of analysis for heuristic model creation is the set of these rules [2]:

$$\overline{R}\ \varepsilon\ \{\overline{H}, \overline{ER}, \overline{O}, \overline{TR}, \overline{OC}\}.$$

Some of the projects for industry companies which applied methodology of heuristic philosophy by the authors are:

- Model for executive planning, capacity planning and scheduling P.Strojárne, P. Bystrica – Metallurgy division, 1980.
- Models for capacity planning and scheduling TŠP 1 700, a.s. Košice. 1983.
- Model for layout of raw materials store and supplying of the blast furnaces VSŽ Košice, a.s 1997.
- Model for capacity planning and scheduling for Slovalco, a.s. Žiarnad Hronom, 2008.
- Model for capacity planning and scheduling Chemosvitfólie, 2010.
- Model for capacity planning and scheduling Rosenberg Slovakia, 2012.
- Another minimum of 20 realized projects.

CONCLUSION

The paper described a methodology for the creation of basic rules for designing the heuristic model with application to metallurgy. The methodology of definition and creation of rules and principles e.g. heuristic, technological rules, expert rules, limitations, criterion optimization was established on induction principle from the solution of many practical problems-projects by authors in metallurgy industry. The paper described examples of most frequently applied rules in heuristic models for planning and management in metallurgy manufacturing.

REFERENCES

[1] L. Vogel, A. J. OWENS, M. J. WALSH: Artificial Intelligence Through a Simulationof Evolution, Chichester, Washington, D. C, UK: Wiley, 1966.

[2] D. Malindžák, Production Logistics, FBERG TU Košice. 1997. - 170.

[3] E. A. Alexandrov: Basic theory of heuristic solution, Moskva, 1975 (in russian).

[4] J. L. Vuković, A. Vuković, M. Ikonić: The importance of Case Study in Industrial Enterprises Strategy Formulation Process, Engineering Review. 28 (2008) 1.

[5] R. Lenort, A. Samolejová: Analysis and identification of floating capacity bottlenecks in metallurgical production. Metalurgija, 46 (2007) 1, 61-68.

[6] D. Malindžák, M. Malindžáková, A. Gazda: Heuristic methods for the synthesis of the logistic systems. 2012. In: Carpathian Logistics Congress 2012: 2 International Congress: 7.–9. November 2012, Spa Priessnitz, Jeseník, Czech Republic. Ostrava: TANGER, 2012, 8-14.

[7] M. Weiszer: The parameters optimization of the transport system with application of the simulation models. Thesis, FBERG TU Košice, 2012 (in slovak).

[8] Heuristika [online], [cit. 6. 012. 2012], Wikipedie. Dostupné z www: <http://en.wikipedia.org/wiki/Heuristic?oldid=209788850>.

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

[10] X. S. Yang: Nature-Inspired Metaheuristic Algorithms, Second Edition, Luniver Press, UK, 2010

[11] V. J. Rayward-Smith, I. H. Osman, C. R. Reeves, G. D. Smith: Modren heuristich search method. John Wiley & Sons, 1996.

[12] J. Źak: The concept of intelligent decision making in logistics, In: Carpathian Logistics Congress 2012: 2 International Congress: 7.-9. November 2012, Spa Priessnitz, Jeseník, Czech Republic. Ostrava: Tanger, 2012, 1-7.

Note: The responsible for English Language is L. Pivka, Košice, Slovakia