EXACT AND HEURISTIC MODELS IN LOGISTICS

MALINDŽÁK Dušan[1]

[1]*Technical University of Košice, Faculty BERG, Institute of Logistics, Košice, Slovakia, EU,*
dusan.malindzak@tuke.sk

Abstract

To solve specific complex logistics tasks, for example, the creation of models of operational production plans, especially if the role is large, given by a large number of machines and equipment involved in production processes, a wide range of products, a long production cycle, the plan is being prepared for several planning periods, pass through several production segments and need to coordinate these plans, the model must respect different types of constraints, etc., then it is difficult or sometimes impossible to create a mathematical model. To adapt the problem to some known mathematical model, e.g. linear optimization model, or the dynamic programming model, which at first glance are addressing the solution /, i.e., Its idealization often leads to the neglect of the essential features of the modelling problem, thereby reducing the practical usability of the results obtained through such models [1]. But people, logistics, planners, managers, solve such problems routinely in business management. One and often the only option to solve such problems is to model the procedures for solving these expert-heuristic approaches, using the appropriate exact models and the possibilities of computer science in those activities where its strength is greater than the force of man. The article has a theoretical character, but it is a generalization of dozens of solved logistics through a heuristic approach in practice. [2] The article defines the properties of the heuristic models, it compares them with exact methods, it defines common characteristics and differences. The exact and heuristic methods are not in an antagonistic relation; on the contrary, the heuristic methods after a proposal, are applied on the principle of" precision lead method "as an exact method. The heuristic approach combines the strong stand of the both methodologies. From heuristic methodology, this is especially modelling of decision-making processes and creative aspects of solution, from the exact methodologies it is performance of information systems.

Keywords: Heuristics, model, decision-making, assignment problem

1. INTRODUCTION

For example, the role of production scheduling needs to be addressed.

We produce quantity of product M_1 - product V_1, M_2 - product V_2 ...

M_1-V_1, M_2-V_2, M_3-V_3, M_4-V_4,…. , M_{PV}-V_{PV} where I = 1,2,3, ... ,PV is the number of products.

We produce V_1 to time DD_1, V_2 to DD_2, V_3 to DD_3,... , V_{PV} to DD_{PV}. It is technically necessary to produce product V2 before product V1 and the like. , i.e. the product sequence is not arbitrary. The products are manufactured on machinery, equipment, with capacities:

KM_1, KM_2, KM_3,…, KM_{PS}, where J = 1,2,3,... , PS- number of machines.

The operating time for product unit V_1 on machine Z_1 is t_{11}. Generally, the operating time of product I on machine J is $t_{I,j}$. The products can be manufactured by several processes. The operation can be performed on multiple machines [9].

This problem is a typical assignment problem. Standard analytical methods for solving the assignment problem are the linear optimization model (LOM), and the discrete dynamic programming method, nets methods, multi-criteria methods, etc. [5], [6].

If it is necessary to create a model for operational planning that ensures minimal production costs / for the problem formulated, we cannot solve the model based on the linear optimization model because it does not take into account the order of the manufactured products or the time of their production [3]. In fact, the problems are much more complicated. Unknown in the linear optimization model is the amount of product I produced on machine J-$M_{I,J}$. However, this amount is calculated irrespective of time, technological limitations, etc. This model is unusable for practice, where we always have no one optimization criterion, Total cost of production, but also other criteria such as:

- maximum profit,
- max. use of equipment capacity,
- maximum compliance with DDI terms,
- minimization of energy consumption,
- optimal sequence of products in terms of their chemical composition, dimensions, temperature, etc.
- optimal production and transport batch and the like.

The discrete dynamic programming method that can be used to optimally allocate a "resource" can be used if:

A) The source that is distributed is the bottle neck of the production,
B) If it is certain that, if the production manages a bottle neck, the other workplaces will handle it.
C) Then, the generic discrete dynamic programming formula can be applied

$$f_N(KM_J) = \max (M_N * C_N + f_{N-1}(KM_J - M_N * t_{N,J})$$

where: $f_N(KM_J)$ is the maximum gain when using the KM_J source.

The dynamic programming method has the following limitations [9]. We can find only a static place of production, even if the product is produced only in one way:

- we can use it for unlimited sales,
- we do not guarantee the static calculation of narrow spots that if you can handle a narrow place, you can handle other machines,
- it is just one optimization criterion,
- the method calculates how much individual products are to be produced in order to maximize profit, but the problem is defined oppositely. We know orders, how many products we have to produce in the given planning period, but we do not know in what order the production batches and so on,
- for the calculation, the number of products is limited to a maximum of tens, due to the number of combinations being n. For this reason, dynamic programming is not a way to solve, for example, production scheduling tasks.

2. HEURISTICS APPROACH

People, experts, planners, and logisticians regularly deal with these roles in business. What are their practices, methodologies that they can handle? Previous reasons have forced to develop qualitative new methods of solving complex tasks by applying information technology, modeling the processes of human creative processes for repeatedly solving problems and problems in practice [8], [9].

Such approach is called a heuristic approach. A heuristic method is one that uses a heuristic approach, i.e. unlike accurate analytical methods, it is supposed to model the principles and rules derived from the analysis of processes that are repeatedly applied by man-expert in solving the problem for which we want to create a model for its automated solution. Such a model is called a "heuristic model".

- By the L.D. Fogel [2] are define three type of the decision making processes:
  - deductive, abductive and inductive.

When:

- X_i - inputs information to the decision making process
- R - rule of decision-solution
- Y_i - output of the decision making

Figure 1 Decision making process

Than:

- deductive decision making process:

$$Yi = R(Xi),$$

deductive decision making is exact, unambiguously to each Xi for the known rule Ri is assigned by Yi.

- abductive decision, based on the use of previous attempts, i.e. if, for example between inputs Xi and outputs Yi is detected relationship (R rule), then the most likely cause of a new effect Xi,Yi is a prerequisite; then we can write:

$$Xi = R^{-1} (Yi),$$

- inductive decision constitutes an inductive process of finding the most likely patterns (rules R) based on the known input information and anticipated solutions Xi Yi.

$$R = f (Xi,Yi).$$

Inductive decision making closest to the creative activity of man. It should be stressed that the operator / decision / - R is not unique. Deductive decision making is exact deciding, adductive decision is on the border and belongs to the exact and heuristics decision-making and inductive decision -making is heuristic.

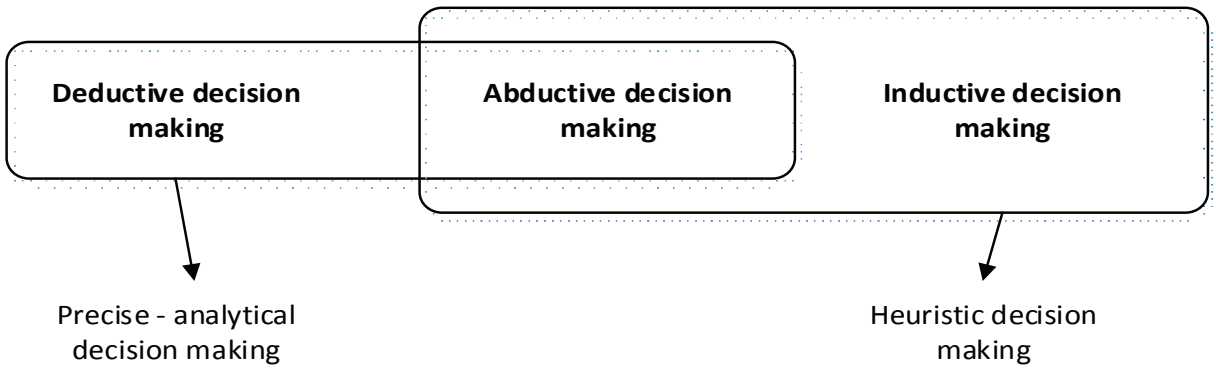

Figure 2 Types of decision-making processes [2]

The rules created by deduction are exact decision rules. Rules created on the basis of abduction and induction, need to form a repeat attempt, analogy and memory, therefore they are heuristic rules. They represent practice, experience, intuition.

Example of decision types:
The type of decision we know is an unknown example

Deduction	X_I, R_I $Y_I=4$	Y_I	$X_I=2, R_I = X_I^2$
Abduction	Y_I, R_I $X_I=2$ or - 2 (ambiguous)	X_I	$Y_I=4, R_I = X_I^2$
Induction	X_I, Y_I	R_I	$X_I=2, Y_I=4$ R_I=? e.g.: X_I^2, or $2X_I$, or $3X_{I-2}$... (ambiguous)

But in case of a repeated attempt, the solution will be: $X_I=2, Y_I=4$
$X_I=3, Y_I=9$
$X_I=2.5, Y_I=6.25$…

With repeated experiment / analogy, experience, practice /, the results are clear that $R_I=X_I^2$
We mean heuristics in two meanings:

A) How to model the model based on the application of principles, rules and procedures that a successful expert uses.
B) As a rule, it is obtained on the basis of abduction and induction, based on repeated analogy. [2]

3. PRECISION AND HEURISTIC METHODS, MATCHES AND DIFFERENCES

By analyzing the models and programs that simulate human behaviour in solving different tasks, it shows that, in addition to the precise analytical methods, various heuristic studies are applied that allow and improve their solutions and applications.

It is generally respected that algorithms are the basic form of presentation of models dedicated to precise methods in the development of computerization and automation models. The basic properties of algorithms according to [3], [10] are:

- discretion,
- determinacy,
- elementality of steps,
- direction,
- massivity.

Heuristic models, the more that many rules in them are hard to describe in mathematical terms, in their final applications are all realized in algorithms and programs. Their creation, perception, however, shows different properties as in algorithms of precise methods. If we want to compare them then best to compare them in the basic properties of the algorithms listed above.

The algorithm is a process of sequential calculus of quantities, in a **sequence of discrete time points,** by inputting the final set of quantities at each input, and in each step the system of quantities is recalculated according to the defined rule into a new state. This is defined as the discretion of algorithms of the exact methods.

Heuristic algorithms also apply **discrete mode**. The opposite of the exact methods algorithm is that each subsequent step leads not to a new state-system of quantities, according to one rule, but several new states, according to several possible rules. The rule is chosen from a set of rules, which need to be applied in the model to solve the problem. The choice of rules can be obtained heuristically again, from the activities of the experts, respectively. Based on the relationship between the rules or the base of a value of a variable during the application of the model. The rule selected with the application is excluded from the set of rules for the following calculation steps. If the rule is selected before the application in the next step, it is applied as a rule

in the algorithms of the exact methods. This property is called the selectivity of the rules. If the rule selection and the sequence of rules are implemented before the model is applied, the algorithm is executed as accurate when it is made, not when implementing the model application.

The algorithm determines the property that the system of variables is defined by the set of variables in the previous step. As described in the previous heuristic methods, they are characterized by the "ambiguity" of the results in the individual steps, which does not, however, prevent outputs and the ultimate solution..The source of ambiguity / final / intermediate result is the character of the heuristic process of modeling as the invading process. The second cause of ambiguity is the position of the rule in the sequence of the applied set of rules, the priority of the rule. Order of application, we will get a new path, another model other results in individual steps and overall results.

Elementarity of steps is the basic characteristic of algorithms of precise methods. For exact methods, the transition to the next state must be simple and local. [3] This rule in heuristic methods - algorithms does not apply absolutely. It results from the fact that the rules in heuristic models are the result of generalization - induction, empirical information, results of previous experiments, experience. That is why the principle of elementarity is applied as a "soft rule." The rules of law can be linked to the so- Integrated heuristics.

Chain: $S_i \; R_j \, S_{i,j} \, R_k \, S_{i,j,k}$

We will replace: $S_i \; R_{i,k} \, S_{i,j,k}$

where $R_{i,k}$ is integrated heuristics

Direction is another important feature of algorithms that determines the sequence of elementary step instructions. If in the exact methods the next step does not produce the correct results, it is the error of the algorithm construction. In the heuristic methods, in particular, solutions in the form of a decision tree, hierarchical structures is different. If a solution is not found within the defined rules, they need to be redefined. If this does not work, then it is not possible to solve these rules.

Massivity - it results from the fact that if a number of rules are to be applied in the solution, for example, the number of possible solutions and the choice of "good" solution is almost infinite number of variants given by the sequence of rules. With the exact algorithms the solution variants can be changed only by a set of input Values, not order by rule, because it is given by the construction of the exact method. Abstraction, formalization, thinking in concepts and categories are the fundamental property that heuristics takes from mathematics, because modeling processes in the human brain are not yet known.

Yet another characteristic is characteristic of heuristic models - algorithms of selectivity of rules. Under the selectivity of the heuristic algorithm, we understand that the selected criterion in the next step satisfies the set of solutions "A", and the set "B" does not suit. In the next process of creating the algorithm model, we only deal with the set "A". In addition, the applied rule excludes from the set the rule for the further construction of the model. Selectivity reduces a number of other solutions in the solution. Group "A" may, however, also contain unrealistic solutions, as the rules were also created on the basis of induction, resulting in their inaccuracy and uncertainty.

When comparing totally exact and heuristic algorithms, they are different especially in the construction phase. It is unclear. The difference is the uncertainty of choosing the next step, because of the choice of the following rule and the uncertainty of heuristic rules, based on abduction and induction. But if we define the rules and their sequence before the model construction, then the difference between the precise and the heuristic algorithms is not the heuristic algorithm or the exact algorithm.

Heuristic and analytical methods are not contradictory and are not mutually exclusive. Frequently the heuristic method by multiple use, refinement and mathematical description of elementary steps and rules becomes the

exact method. It can be said that the heuristic model is heuristic only in the process of modeling, and the application process is the exact solution. This property of heuristic algorithms is called "suicide". Heuristic and precise methods complement each other.

4. CONCLUSION

In the previous chapters, there has been shown that the theory of heuristic decision-making as a part of cybernetics deals with the mechanisms of perception, thinking and behavior from the point of view of informatics. Serious, specific information approach in the theory of heuristic decision-making and modeling is the human approach to problem solving, based on abstraction and acquisition of properties and rules from real bearers-experts, experts that are necessary for discovering procedures, conditions for solving particular problems, tasks.

The fundamental role of the theory of heuristic solutions, from a technical point of view, is the realization of information processing on computer-based computer resources as they are carried out in highly organized living organisms - people who are associated with their productive creative activity. The problem of modeling is not only at the technical level of information technology and its equipment, but in the basic possibilities of modeling the lawfulness of the work of man's discovery, understanding, abstraction, formalization and transformation into algorithms and programs.

REFERENCES

[1] MALINDŽÁK, D., et al. Design of logistics systems /Theory and Applications/, Open science, New York, 2015

[2] FOGEL, L. J., OWENS A. J. and WALSH, M. J. Artificial Intelligence through a Simulation of Evolution, Chichester, Washington, D.C, UK: WILEY, 1966.

[3] ALEXANDROV, E. A. Osnovy teorii evrističeskych rešeni, Moskva, Sovetskove radio, 1975

[4] Heuristics. Available on: http://www.psychologia.sk/portal/?pojem=Heuristika

[5] STRAKA, M., BINDZÁR, P., KADUKOVÁ, A. Utilization of the multicriteria decision-making methods for the Leeds of mining industry. In: *Acta Montanistica Slovaca*. Vol. 19, No. 4, (2014), pp. 199-206.

[6] TREBUŇA, P., STRAKA, M., ROSOVÁ, A., MALINDŽÁKOVÁ, M. Petri nets as a tool for production streamlining in plastics processing. 2015. In: *Przemysl chemiczny*. Vol. 94, no. 9 (2015), p. 1605-1608. ISSN 0033-2496.

[7] FABIANOVÁ, J., KAČMÁRY, P., MOLNÁR, V., MICHALIK, P. Using a Software Tool in Forecasting: a Case Study of Sales Forecasting Taking into Account Data Uncertainty. 2016. In: Open engineering. Vol. 6, no. 1 (2016), p. 270-279.

[8] MARASOVÁ, D., ANDREJIOVÁ, M., GRINČOVÁ, A. Applying the heuristic to the risk assessment within the automotive industry supply chain, In: *Open Engineering.* Vol. 7, No. 1 (2017), p. 43-49. - ISSN 2391-5439

[9] MALINDŽÁK, D. Production Logistic, Stroffek Publishing, Košice, 1998,

[10] JADLOVSKÝ, J., JADLOVSKÁ, A., JADLOVSKÁ, S., ČERKALA, J., KOPČÍK, M., ČABALA, J., ORAVEC, M., VARGA, M., VOŠČEK, D. Research Activities of the Center of Modern Control Techniques and Industrial Informatics, In: SAMI 2016. - Danvers: IEEE, 2016 p. 279-285.