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Optimisation Algorithm for the Profit from Operation of a Barge Train versus Settings of the Main Engine During Inland Navigation in Varying Water Resistance Conditions (Part 1)

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Abstract

The presented paper refers to economical aspects of inland waterway transport means operation. Specifications of profit and cost areas were a basis of an economic estimation of the transport means operation. Within this framework a decision should be taken concerning the methods and scope of an economical analysis of transport means. The profit optimisation algorithm of inland waterway transport means operation was elaborated considering a division of the waterway into sectors (representing different characteristics specified by different, and temporary changing, navigation parameters). The main engine speed was established as a decision variable.

Keywords: inland waterway transport, barge train, optimisation, economic estimation

List of a Symbols Used in the Techno-Economical Model

B_h – hour fuel use in kg, kg·h^{-1},

B_{sl} – hour fuel use in litres, l·h^{-1},

C_a – fuel cost used by the current generators, €,

C_A – amortization cost, €,

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C_{AT} – amortization cost in the time of technological operations, €,
C_C – total cost of round route, €,
C_{CS} – total cost of the trip downstream, €,
C_{CW} – total cost of the trip upstream, €,
C_D – additional cost of a trip not connected directly with the ship's movement, €,
C_o – total fuel cost, €,
C_{OT} – fuel cost in the time of technological operations, €,
C_p – personnel cost, €,
C_{PT} – personnel cost in the time of technological operations, €,
C_R – cost of repairs, €,
C_{RT} – cost of repairs in the time of technological operations, €,
C_s – fuel cost used by the engines, €,
C_{TS} – total cost in the time of technological operations when navigating downstream, €,
C_{TW} – total cost in the time of technological operations when navigating upstream, €,
C_V – ship' movement cost, €,
h – water depth on the river sections, m,
i – river sector designation,
i_a, – fuel specific freight rate,
I_a – earnings from the carriage, €,
j – designation of the voyage direction,
n – main engine speeds, min^{-1},
N_d – number of the operating draught T classes,
N_h – number of the classes of the water depth h,
N_j – number of the direction of the voyage,
N_s – number of water resistance-related sections,
N_t – number of the train types or variant analyzed,
N_v – number of voyages through a given year at a given operating draught,
P_f – specific fuel oil price, €$\cdot$l^{-1},
P_k – light weight of a barge, t,
t – time of voyage, h,
T – water depth, m,
T_k – design draught of a barge, m,
V_b – ship's speed in relation to water, km$\cdot$h^{-1},
V_o – ship's speed on the lentic water, km$\cdot$h^{-1},
v_p – river current speed on the sections, km$\cdot$h^{-1},
Z_a – annual profit from the operation of a barge train, €,
ρ_f – fuel oil density, kg$\cdot$l^{-1}.

1. Introduction

In general, optimisation is a technology for calculating the best possible utilization of resources needed to achieve a desired result, such as minimizing cost or process time or maximizing throughput, service levels, or profits. Optimisation technology improves decision making speed and quality by providing businesses with responsive, accurate, real-time solutions to complex business problems.

Optimisation technology as used in practice becomes the ”engine” that quickly and accurately solves complex business problems within an application. Problems ranging from high-level planning to tactical operations – and everywhere in between – can be effectively solved using optimized applications.

Optimisation is synonymous with reducing costs, increasing productivity, and improving profitability of the company. Optimisation also speeds application development and simultaneously empowers developers to create “smarter” more feature-rich decision further improving its profitability. These benefits help optimisation technology generate the highest financial effectiveness in the industry. Optimisation can improve quality and profitability in many ways:

- optimised applications generate solutions faster than any other decision support,
- optimisation automates solution process and verifies that the solution adheres to specified business rules,
- optimisation dramatically improves business flexibility, responsiveness to changing circumstances, and ability to test “what if” scenarios,
- optimisation focuses decisions and resources on business priorities.

In commercial activity of enterprises the primary goals, against which their effectiveness is judged, are (i) increasing profits on their commercial activity and (ii) increasing the enterprises' value. One of the paths to achieve the goals is minimising business process costs incurred by the enterprise. In the case of inland navigation enterprises, that denotes minimising carriage costs and particularly minimising costs of the operation of transport means: barges or barge trains. The experience of the enterprises indicate that the essential proportion in the operating costs of transport means is represented by: (1) fuel consumption costs, and (2) crew's costs e.g. [7]. The interrelations between those costs and their actual proportion in the operating cost total depend on specific conditions in the country where transport means are operated; first of all, upon the fuel (diesel oil) price and crew's labour costs of inland watercrafts. In the event of the means of water transport one may assume that there is a substantial relationship between the amount of the operating costs and speed of travel of a means of transport. In that case there evolves a contradictory decision-making situation: (1) a high travel speed results in a higher fuel consumption, due to the resistance to motion which is dependent upon speed and, at the same time, reduced crew's costs thanks to curtailed travel times and less wages for that time; (2) whereas, a lower travel speed results in a reduced fuel consumption and concurrent increased crew's costs due to a longer working time.

So it is noticeable that there is a need to solve such a problem by optimising the operating costs incurred in practice through changes of the speed of a transport means which depend on the setting – revolutions – of the drive engine. Such a procedure may be conductive to the process of (i) managing a fleet of water transport means in a shipping enterprise or (ii) designing new means of inland water transport. So in this paper, the proposal of an algorithm is discussed that optimises profits on the operation of an inland pushed train versus the main engine settings.

It is also to be noted that the speed of the train and fuel consumption are essentially conditional on the shipping hydrological conditions. In particular, they are conditional on the waterway depth and clearance between the ship's hull and river bed (and the clearance depends upon the waterway depth and ship's draught). While on voyage, the train usually sails subsequently in sections of a waterway that differ by shipping conditions to which the manner of navigation (understood as: the ship's speed) should be adjusted. In this connection, the presented optimisation algorithm allows for changing shipping conditions within individual sections the ships sails in, permitting the identification of the main engine settings for the individual waterway sections which settings optimise the operating costs throughout the voyage that comprises the subsequent sections with variable resistance conditions.

The optimisation algorithm presented in the paper may be the basis for effectiveness analysis of selected variants of a barge train. The evaluation criterion in the optimisation procedure will be a profit gained from a operating barge train during one voyage. Profit, Z_a, will be determined as a subtraction of incomes, I_a, and total cost, C_C, of the barge train. Total cost will be the sum of operating costs and general costs. The operating cost will include the fuel consumption cost, personnel cost, amortization cost, cost of repair and other operating costs. The decision variables will be the main engine (ME) speeds n on particular, resistance changeable sectors. Parameters of the optimisation analysis will be: the operating draught of the barge T and the corresponding water depth on sectors h. For accepted operating draught values T and corresponding water depth values h we will search for optimal – profit maximization – main engine speeds.

The concept of the optimisation of the profit from operation of a barge train versus settings of the main engine during inland navigation in varying water resistance conditions used in the paper was proposed and initially elaborated by T. Lisiewicz [8], [9]. That concept, however, was not formulated by him into a complete and systematic form of a numerical optimisation algorithm and, in such a raw form, could not be used to optimisation calculations carried on with the application of numerical optimisation algorithms. Although, he used it with a success to simplified, hand made parametrical calculations. The author hereof rendered T. Lisiewicz's concept the formal structure of an optimisation algorithm [12], developed the mathematical models as necessary for systematic optimisation computations [13], [14], set up a system of computer codes that follow the developed algorithm [15], [16], and carried out a number of simulated optimisation calculations [17].

The optimisation algorithm presented in this paper was elaborated for a pushed barge train operated in changeable resistance water conditions i permits comparative researches for diverse pushed trains.

2. General Algorithm for Solving an Optimisation Task

A typical example of optimisation in design and decision making evolves when a concept (idea) of an object (whether a machine, device or process) is given, and the task of such optimisation is to determine optimal values of the main properties of such object. It is to recollect that the optimum values are such, for which an object is best under certain criteria, and concurrently it fulfils all requirements.

In the mathematical sense optimisation is the maximizing or minimizing of a given function possibly subject to some type of constraints. Broadly, the efforts and processes of making a decision, a design, or a system as perfect, effective, or functional as possible. Narrowly, the specific methodology, techniques, and procedures used to decide on the one specific solution in a defined set of possible alternatives that will best satisfy a selected criterion. The solution of the optimisation problem is a set of decision variables, $\mathbf{x} = [x_1, x_2, ..., x_p]^T$, that satisfy the constraints and for which the objective function attains a maximum (or a minimum, in a minimization problem).

The following general algorithm for solving an optimisation task is put forward:

1. [Identification of optimisation task] – the formulation of optimisation task, the identification of optimisation task.
2. [Overview of optimisation methods] – overview and discussion on the available optimisation methods in terms of their applicability to solve the formulated optimisation task.
3. [Selection of optimisation method] – selection of method for solving the formulated optimisation task. The first problem is the selection of a method of optimisation, i.e. an algorithm; now, there is very large selection of the optimisation methods. In the basic literature one may find up to a few hundreds of such methods. Selection criteria of the method are not clear a priori, i.e. one cannot foretell which of the methods is better or the best. The selection of a specific optimisation method is subjective – it is dependent on (i) what computer and software are accessible and (ii) what our preferences are in this respect. In the course of first test computations it may happen that the selected method is inefficient (no repeatable results, non-fulfilment of the constraints, a long computation time, non-convergence, etc.) and finally one may needs to use another method. Most frequently one cannot tell which method is better and which is worse until many tests on a specific task have been undertaken. An optimisation method shall be described as good, if it is promptly convergent, renders repeatable results, does not require much labour, e.g. entering a starting

point that falls within a set of permissible solutions, allows implementation on a given computer.

4. [Development of optimisation model] – the development of optimisation method suitable for the adopted method (algorithm) of optimisation. Decision variables, parameters, criterion (criteria) of optimisation, constraints, control parameters.
5. [Development of computation tool] – the development of computation tool (computer software system): computer aided implementation of the selected optimisation method (algorithm) and of the developed optimisation model.
6. [Test computations] – some test computations and discussion on the correctness of the developed computation tool. Test computations shall be done for several starting points, where also parameters and control parameters undergo the variations, e.g. weight coefficients, penalties, adopted structural materials, conditions for the computations to be ceased. In the course of first test computations it may happen that the selected method (algorithm) is inefficient (no repeatable results, non-fulfilment of the constraints, a long computation time, non-convergence, etc.) and in such case one needs to consider an attempt to use another optimisation method.
7. [Regular computation program] – the development of program for regular optimisation computations on the developed models, making use of the developed computation tool.
8. [Regular optimisation computations] – the conduct regular optimisation computations on the developed models, making use of the developed computation tool, in compliance with the formulated program.
9. [Analysis and discussion] – analysis and discussion of the results of the optimisation computations on the constructed models, making use of the constructed computation tool.
10. [Conclusions] – drawing conclusions based on the optimisation computations.

The developed scheme is represented graphically in Fig. 1.

3. Formulation of Optimisation Task of the Profit from Operation of a Barge Train versus Settings of the Main Engine During Inland Navigation in Varying Water Resistance Conditions

Task of optimisation of the profit from operation of a barge train versus settings of the main engine (ME) during inland navigation in varying water resistance conditions is formulated as follows: find the values of ME speed $n(i)$ in each resistance characteristic river sector i (design variables) which satisfy some constraint functions and maximise the annual profit $Z_a(n)$ ($Z_a(n) = I_a(n) - C_C(n)$, objective function). In mathematical form formulated optimisation problem can be written as:

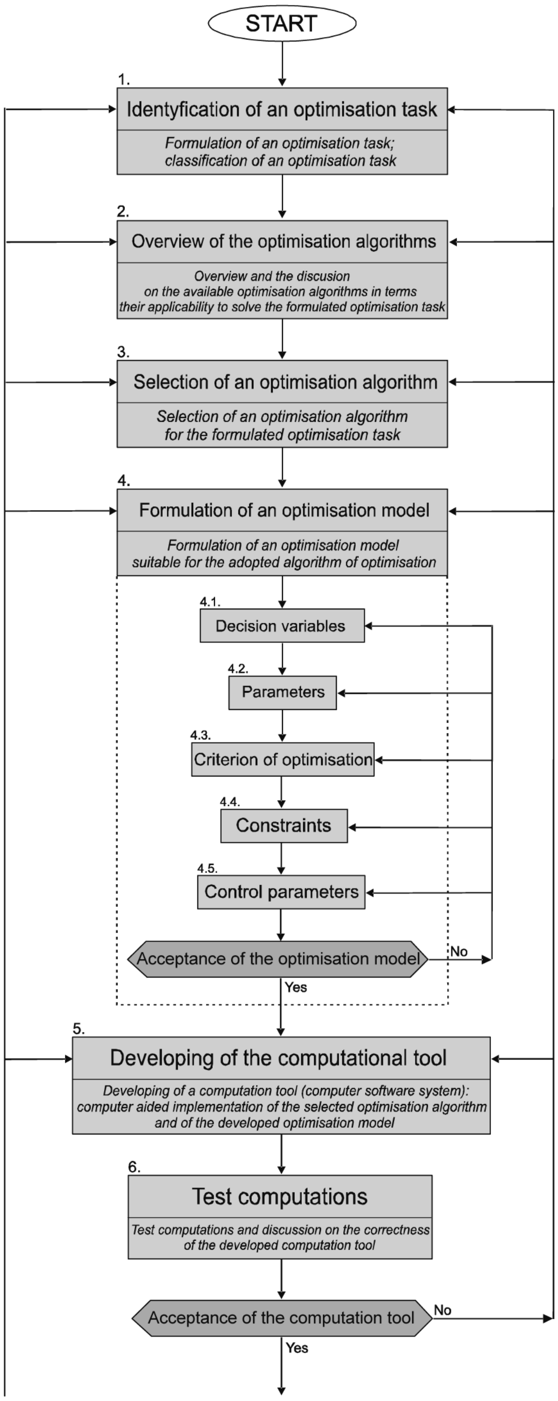

Fig. 1. The flowchart of the developed algorithm for solving optimisation task

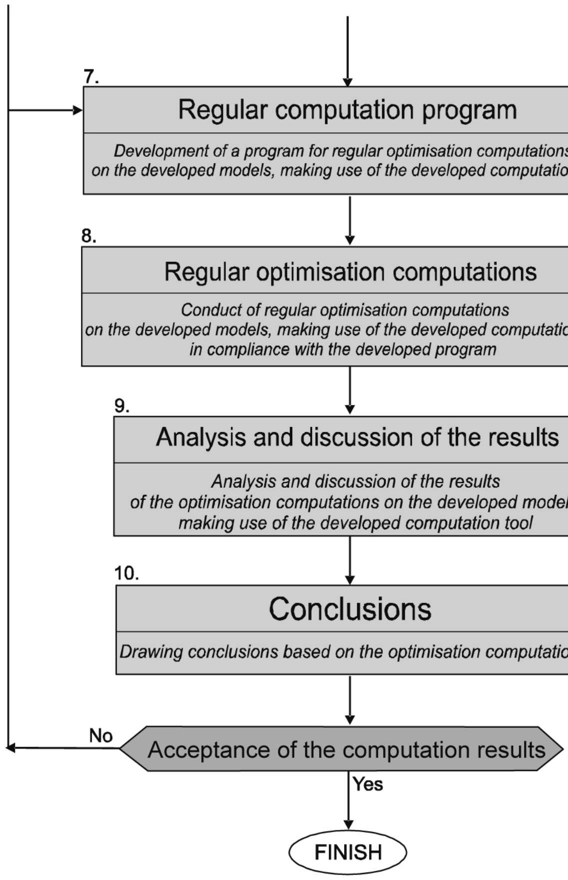

Fig. 1. The flowchart of the developed algorithm for solving optimisation task, continued

$$\max Z_a(n) \ (Z_a(n) \rightarrow \max!)$$

$$\text{subject to } n^l(i) \leqslant n(i) \leqslant n^u(i),$$

where $n^l(i)$ and $n^u(i)$ are lower and upper bound value of ME speeds in river sectors.

For solving of that formulated optimisation task Genetic Algorithm (GA) will be used.

4. Elaboration of Genetic Algorithms

There is a large number of known and applied optimisation algorithms, but these are imprecisely described in books or monographs giving only some information on their type or general properties. One of the possible way to classify algorithms is presented on Fig. 2 and classification of genetic algorithms (GA) is presented too.

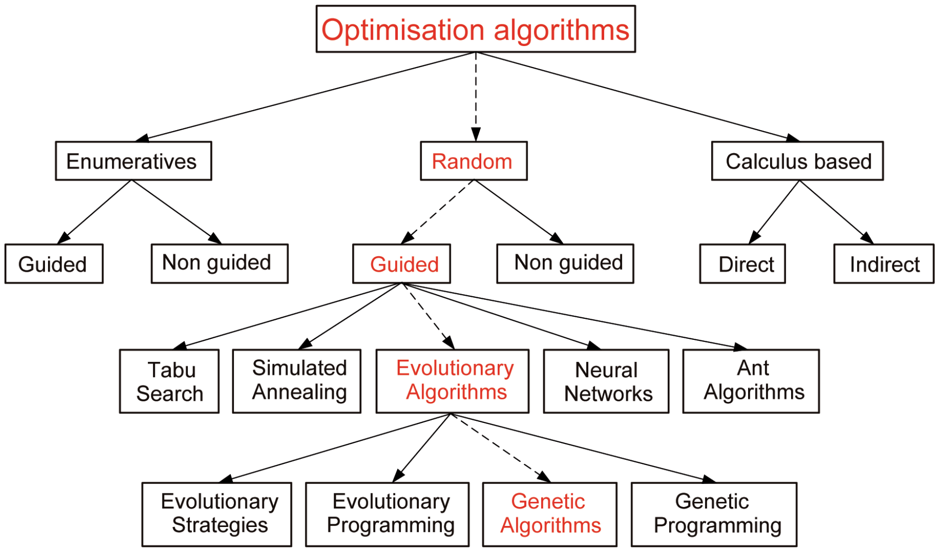

Fig. 2. Proposed classification of optimisation algorithms

Classic algorithms use a deterministic approach to find solution going through path dictated by successive solutions. These are chosen from the contiguity of the antecedent solutions respecting some rules, usually based on first of second rank gradients of objective function. However, the classic techniques fail many times in case of high restrictions of mathematical structure of the optimisation task.

GA were inspired by biology where mechanisms of natural evolution of living bodies are investigated. The aim of works leaded by precursors of GA was to simulate a natural process using computers. GA solve optimisation problems using basic rule simulating real mechanism of evolution, that is the Darwin's best individual survival rule. GA emphasize the role of genetic operators (selection, mutation, crossover). These algorithms are successfully applied for real tasks where heuristic and analytic methods failed.

Available written sources, e.g. [1], [2], [3], [4], [5], [6], [10], [11] give an information on a basis and advanced techniques applied for different realization of GA. Despite obvious differences between variants of GA, these all fulfil common biologic rules on abstract level:

– searching solutions by evolution process of existing population of solutions,
– inheriting information by individuals in the consecutive population,
– changing information by individual by crossover and mutation of solution,
– selection of individuals due to best fit to the problem solution.

Appealing to biology one can assume that general GA idea is based on simulating of processes proceeding in chromosomes population under the influence of natural environment. Chromosomes correspond to elements of task solution space or optimisation. In this simulated environment, the process of individual solution selection is realized due to fitness function, according to inheriting and exchange of information using crossovers of solutions or its mutations.

GA is a simulation of natural process of individuals evolution, created by population of existing solutions, in artificial environment which is represented by fitness function. Moreover, it is assumed that evolution process is optimisation algorithm itself.

The main differences between GA and classic algorithms are:

– GA path is determined by population of solutions, not by a particular solution,
– GA solutions are coded in a form of limited length strings of signs; signs belong to the limited alphabet,
– GA are algorithms with “memory” which is used to determine new paths to search for solution; previous obtained information is used.

Strategy of GA is based on simulation of individuals relocating from one to the next population in the neighbourhood of previous population, due to some fixed rules. To generate the neighbourhood population and exploring it to find new generation the genetic operators are used: selection, crossover and mutation. The run of evolution is mainly dependent on results gained by individuals in the environment defined by fitness function.

GA is a adaptation procedure for solution searching of optimisation tasks. It works in the coded solution space and uses random processes to find path of searching. The set of decision variables of optimisation task, coded in a form of string of limited alphabet signs, is called individual or chromosome. In each case and for each particular solution it is required to assess its parameters how good are these fitted to the optimisation task. GA idea is so to look for such set of decision variables which maximizes the fitness function. It is the function assessing the solution variant if it solves the problem better or worse.

Searching process is realized simultaneously for couple of strings representing singular solutions (chromosomes). This process is an iteration. New individuals are chosen at every step of iteration, and after that these are reconstructed using genetic operators: crossover, selection and mutation. Selection is a stochastic process where the maximum probability of choice is given to the individuals with the best rate of fitness function. Application sequence of genetic operator is random, and their application to the individuals is random too, as it is stochastic process realized with accepted probability.

Definitions used in GA are mostly the same as used in natural genetic [4], [11]. The most important is fitness function (assessing), which not formally defined in natural genetic. This function allows to assess the adaptation rate of individuals. It sets a rate which is a base to choose the best individuals, as it is assumed that these generate maximum values of the fitness function.

Individuals in the population generate a code of decision variables through linking them into binary string. Length of the string is determined by required precision of decision variables. This function is an object of optimisation and it is defined as *adaptation measure*.

Genetic algorithm realizes searching of optimal solution by repeated assessing procedure of solutions and changing their shape using genetic operators.

At the beginning of algorithm it is required to decide (i) the probability of genetic operations application, (ii) shape of chromosome, (iii) numerical quantity of population, (iv) selection method, (v) setting method of fitness function and after that the initial population is generated. Subsequently the algorithm realizes cyclic operations:

– selection of chromosomes from the population, according to defined method,
– crossover and mutations of chromosomes from selected population according to defined method and probability.

During every run of algorithm the fitness function of every solution is assessed. Algorithm ends running when the stop criterion is fulfilled.

The basic GA is realized due to following process:

1. Defining of control and steering parameters:
   a. Number of bites in chromosome (determined due to set coding and decoding representation of optimisation task),
   b. Size of populations N_{pop}, describing number of chromosomes in the population,
   c. Number of generations N_{gen}, determining number of new populations in algorithm and thus sets stop criterion,
   d. Set of operators and their probabilities, including crossover and mutation operators,
   e. Fitness or matching function f_{eval},
   f. Rule of selection (procedure, selection operator),
2. Algorithm initiation, selection of initial population (randomly),
3. Iteration:
   a. Random selection of good solutions from current population,
   b. Crossover,
   c. Mutation of solutions,
4. Verification of stop criterion. If not fulfilled then back to step 3.

Practically presented process is realized as following:

– Definition of the task in fitness category (classic algorithms define the task in aim category). Consequently dependent variable can not be defined as strict mathematical value but can contain some broadening definitions, so there are no so restricted limits as it is in classic optimisation algorithms.
– Initialization of random population of potential solutions of initial population, taking onto account all restrictions and limits. Solution is coded as a binary vector (chromosome) with elements of genes and alleles.
– Iteration process of initial population selection using genetic operators to generate a descendant population as long as stop criterion is fulfilled.

The main procedures of the genetic algorithm used for the purpose of the investigations was detailed described in [10].

5. Optimisation Algorithm for a Barge Train: Optimisation of the Profit from Operation of a Barge Train versus Settings of the Main Engine in Inland Navigation in Varying Water Resistance Conditions

The macrostructure of the developed optimisation algorithm of the profit from operation of a barge train versus settings of the main engine in inland navigation in varying water resistance conditions is shown graphically in Fig. 3. The relevant microstructure is represented in Fig. 4. In the individual functional blocks of the algorithm the following activities are carried out:

1. [Start]: entry in the algorithm.
2. [Data and assumptions]: entering the general data and assumptions indispensable to assess the economic characteristics of the inland navigation transport. The data to be entered is grouped as follows:
   - 2.1. [the operator's requirements and preferences]: the route, operating speed (minimal, maximal), duration of operation of a barge train, specific freight rate i_a, fuel oil density ρ_f, specific fuel oil price P_f, depreciation costs during technological operations C_{AT}, repair costs during technological operations C_{RT}, personal costs during technological operations C_{PT}, costs of consumed fuel oil during technological operations C_{OT}, additional costs without any direct relationship with the movements of the barge train C_D;
   - 2.2. [the data on the operating environment]: the length of a navigational route, breakdown of the route into characteristic water resistance-related sections, hydrological conditions on those sections, the number of the said sections N_s, river water current speed on those sections v_p, water depth on those sections h;
   - 2.3. [the data on the values determined at the earlier stages of the analysis of a barge train]: the main dimensions, spatial arrangement, propulsion system, light weight of a barge P_k, design draught of a barge T_k, number of the operating draught classes N_d, values of the operating draught T, number of voyages through a given year at a given operating draught N_v;
   - 2.4. [the properties of a barge train]: the payload of a barge at the appropriate draught D, rated power of the propulsion;
   - 2.5. [the assessment criteria]: the annual profit from the operation of a barge train, $Z_a = I_a - C_C$.
3. [Econometric models of a barge train]: the formulation of the econometric models of a barge train:
   - 3.1. [the model for evaluation of earnings] from the carriage, I_a;
   - 3.2. [the model for evaluation of operating costs] of a barge train in varying water resistance conditions, C_C.

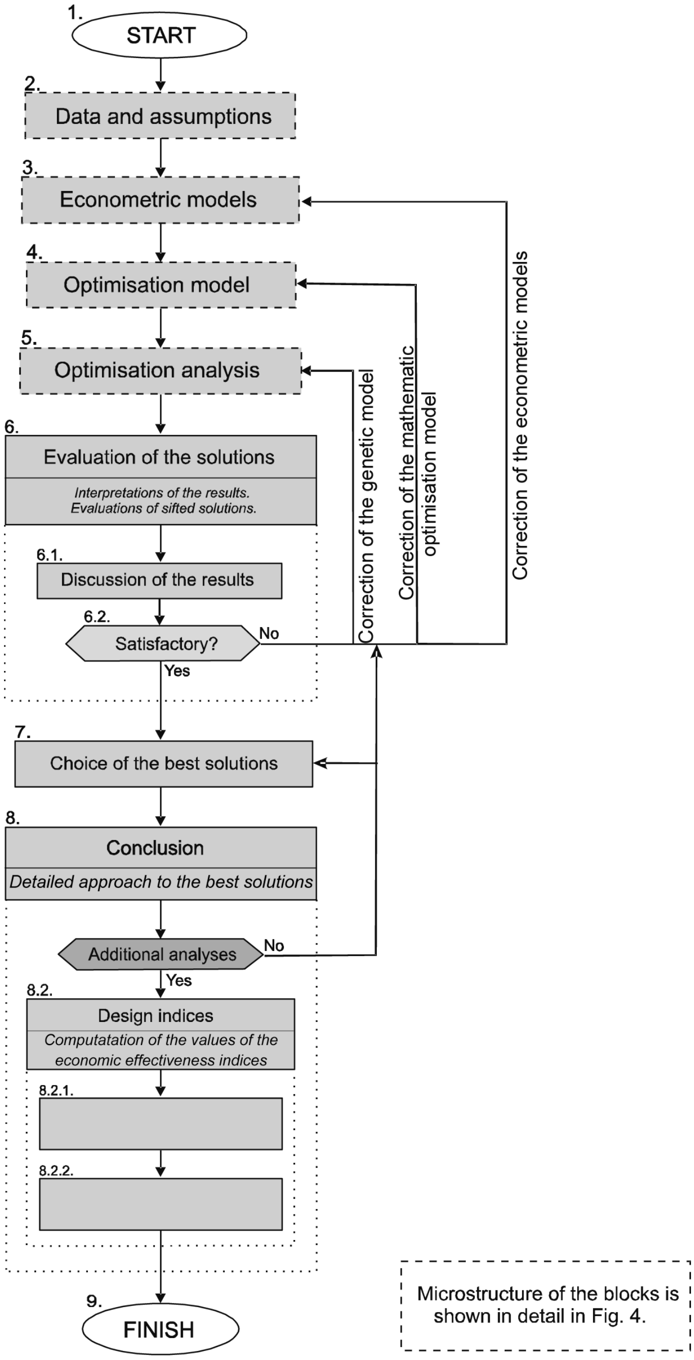

Fig. 3. The macrostructure of the developed optimisation of the profit from operation of a barge train versus settings of the main engine in inland navigation in varying water resistance conditions

4. [Optimisation model]: the formulation of the mathematical optimisation model:
   4.1. [the specification of a set of decision variables], n;
   4.2. [the specification of a set of parameters] of the optimisation model, T_k, P_k, N_d, T, N_s, v_p, h, C_{AT}, C_{RT}, C_{PT}, C_{OT}, C_D;
   4.3. [the specification of optimisation criteria] – the assessment criterion, $Z_a = I_a - C_C$;
   4.4. [the specification of the usefulness function] for the assessment criterion, u;
   4.5. [the specification of the form of the objective function], f,
   4.6. [the formulation of constraints] that shall protect a barge train against unwanted characteristics and thus differentiate between permissible and impermissible modes of operation;
   4.7. [the specification of an optimisation model].
5. [Optimisation analysis] – looking for optimal solutions to the formulated optimisation task:
   5.1. [initiating optimisation], re-formulation of the optimisation model to a form that allows for specific needs of the adopted optimisation method, creation of a primary population of test solutions;
   5.2. [the selection of values of the operating draught of a barge train], T;
   5.3. [the selection of values of the water depth h], as appropriate for the operating draught T;
   5.4. [the pre-processor]; creation of an on-going model of the operation of a barge train based upon the current values of decision variables;
   5.5. [the econometric analysis of a barge train];
   5.6. [the post-processor]; evaluation of the criterion, evaluation of operating properties of a barge train, checking out the permissibility of the solution, annual earnings from the carriage I_a, totalled voyage costs C_C;
   5.7. [fitness]; computation of the value of the fitness function for the solutions of the present population;
   5.8. [checking the condition of the conclusion of search after the optimal solution]; taking the decision on the cessation of the optimisation and a leap to another module (6.) or entering the genetic algorithm-provided changes to the population of the variants of the solution (creation of a new generation of variants of the solution of the task) and a transfer to the econometric analysis of a barge train (5.5);
   5.9. [taking the decision on a change to the water depth h] and a transfer to the next section or to section (5.3);
   5.10. [taking the decision on a change to the operating draught T] and a transfer to the next module (6.) or to section (5.2).

6. [Evaluation of the solutions]: once the optimisation analysis is completed, the automatically selected solutions undergo an assessment by an expert. The optimisation analysis dealt with in Section 5 is carried out automatically. Owing to the actual properties of an adopted optimisation method there is not any opportunity for on-going surveillance of characteristic values describing solutions being checked out. It is possible to monitor selectable global values for a current generation, e.g. the maximum, average and minimum values of the fitness function within a generation, or global values for the entire search, e.g. the number of thus far generated solutions; the number of thus far generated permissible solutions. A detailed assessment of the solutions is feasible upon completion of the computations, based on the automatically produced reports. In particular it is to assess whether or not selected solutions may be deemed as satisfactory. In the event that the indicated solutions do not fulfil expectations, one may introduce changes at the stages prior to the optimisation analysis, and the computations may be repeated.
7. [Selection of the best solutions]: out of the set of permissible solutions, the selection of solutions deemed as the best ones by the expert. The designer in association with experts shall select solutions deemed as the best ones.
8. [Conclusion: for the best solutions]: the conduct of those activities that (i) have not been allowed for in the optimisation analysis and (ii) are not indispensable for the conduct of analyses, however provide extra information about the best solutions. First of all, the values of the economic effectiveness indices for a barge train shall be computed.
9. [The end]: exit from the algorithm.

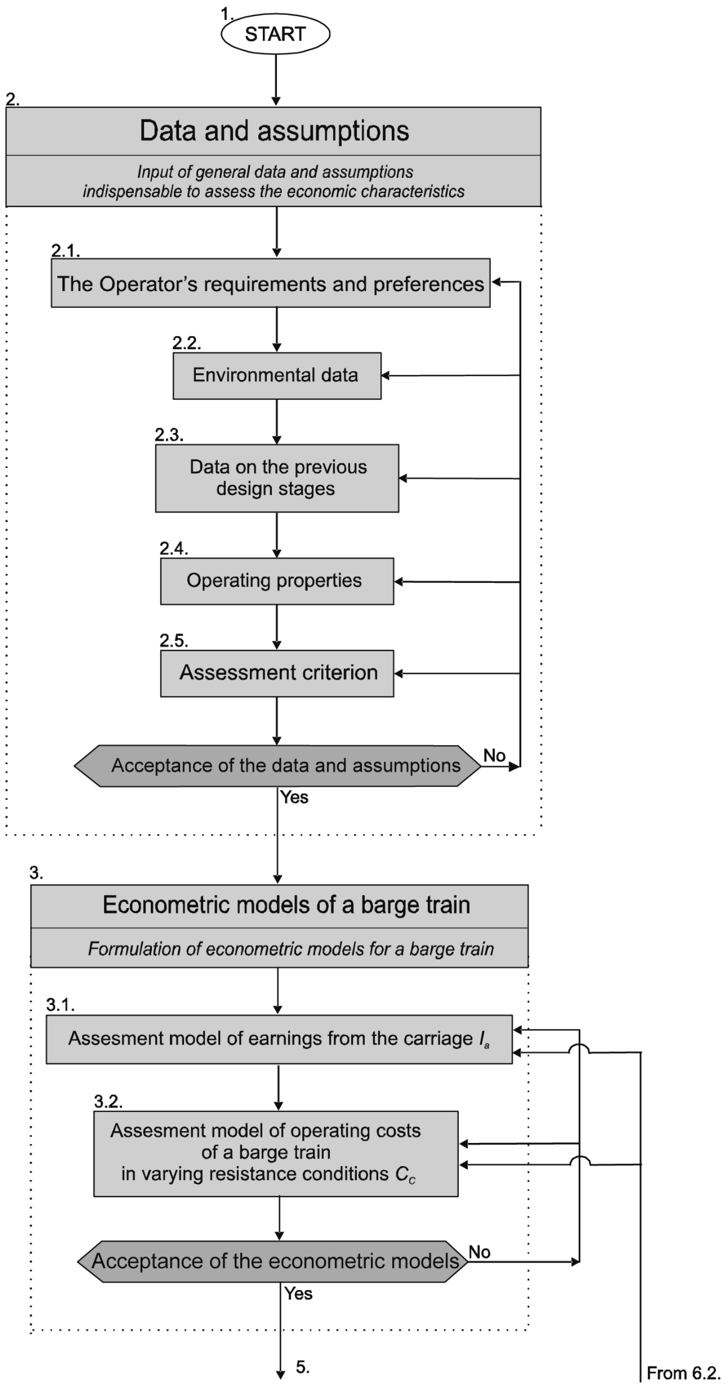

Fig. 4. The microstructure of the developed optimisation algorithm of the profit from operation of a barge train versus settings of the main engine in inland navigation in varying water resistance conditions – the data and assumptions, econometric models

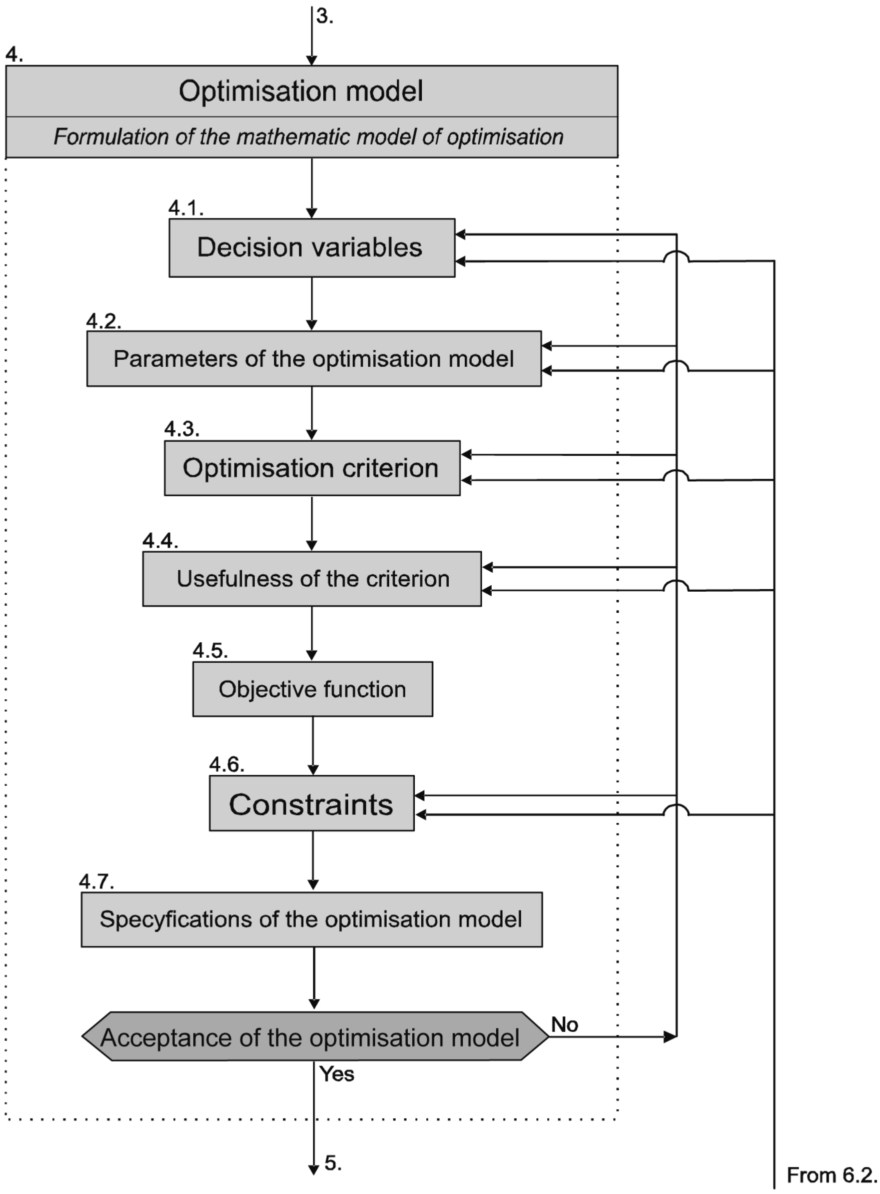

Fig. 4. The microstructure of the developed optimisation algorithm of the profit from operation of a barge train versus settings of the main engine in inland navigation in varying water resistance conditions, *cont.* – The optimisation model

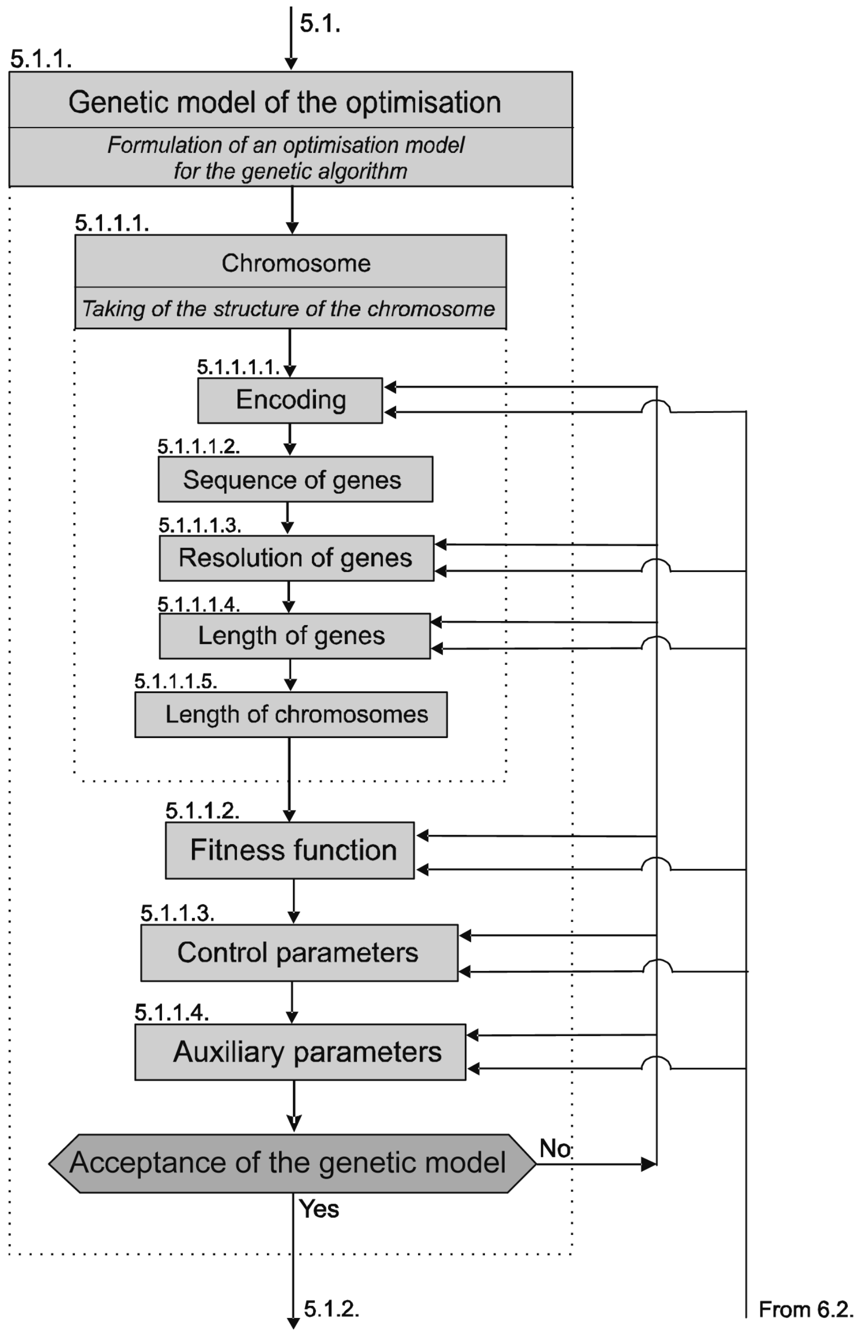

Fig. 4. The microstructure of the developed optimisation algorithm of the profit from operation of a barge train versus settings of the main engine in inland navigation in varying water resistance conditions, *cont.* – The genetic optimisation model

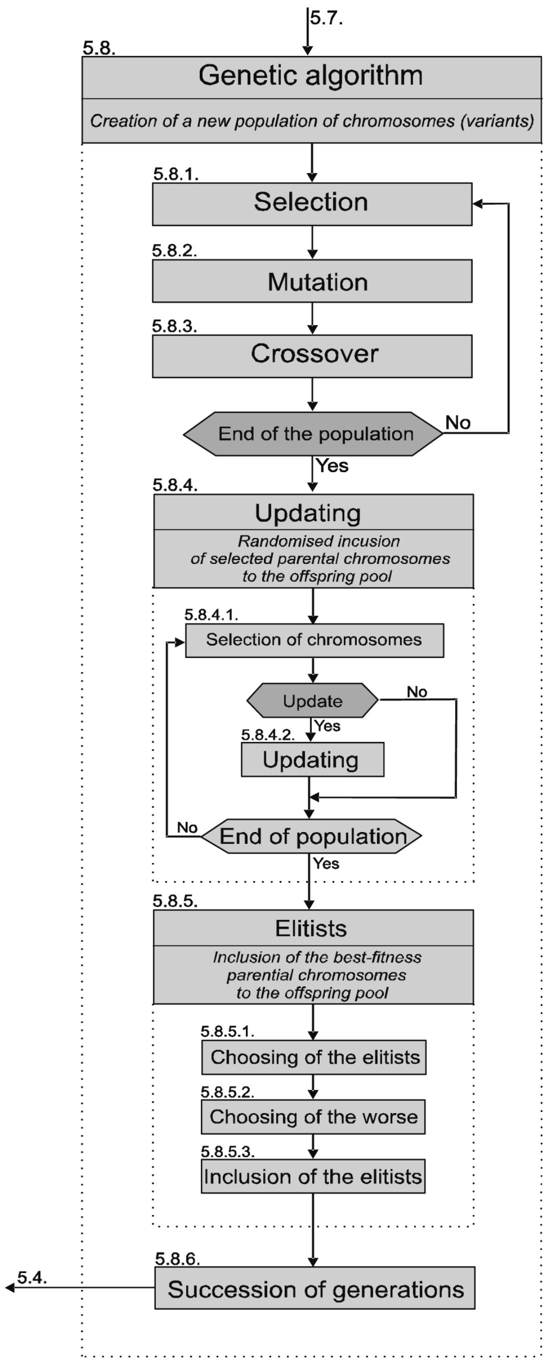

Fig. 4. The microstructure of the developed optimisation algorithm of the profit from operation of a barge train versus settings of the main engine in inland navigation in varying water resistance conditions, *cont.* – The genetic algorithm

6. Conclusions

An optimisation algorithm for a barge train that enables an optimisation of profits from the operation of a barge train versus settings of the main engine in inland navigation at varying water resistance conditions is developed. Optimisation of engine speed gave a ground here to find a maximum of profit. A computer aided computation toll, i.e. a computer implementation of the developed optimisation algorithm, will be described and tested in the Part II of this work. The correctness of the developed optimisation algorithm and of the created computation tool will be verified.

The fundamental data for efficiency of developed optimisation algorithm are the machinery – driving studies, based on the selected barge train, with the use of interpolation calculus [8]. The entire machinery – driving studies that would check all existing ships or the designing solutions for a newly built ship, should contain:

– calculation of the speed in relation to water,
– calculation of the speed in relation to the bank,
– the speed of stream and of the hydraulic gradient
– power on the tail – end of the propeller shaft,
– calculation of the propeller shaft's speeds,
– power of the main engines,
– calculation of the fuel use,
– measurements of the water depth,
– the stream's intersection on the particular sectors,
– speed and the direction of the wind,
– the quantity of the meanders, influencing on the engine load's change,
– localization of the limiting depths on the particular sectors,
– calculation of power of other power – receivers, installed in the marine power plant,
– time of starting an engine,
– untypical situations during the trip, influencing on the engine load and on the time of the trip.

The range of the machinery – driving research limits the safety of navigation and the conditions of the main engines' work – minimal speeds, time and quantity of the admissible overloads, as well of the moment, as of the engine speeds.

For detail investigation on economic of the barge train operation the future studies are required.

In the future development of the optimisation algorithm (i) the realistic constraints for barge train operation should be included, and (ii) more than one objective function should be used. In the first case they may be minimum or maximum speeds of a barge train on a particular sector, the maximum travel time, or a specified time of arrival at destination, the maximum fuel consumption during the trip, etc. In the latter case, it will be necessary to formulate and solve multi-objective optimisation task in relation is two or more optimisation criteria. Such tasks, despite the difficulties of their solutions are more realistic than the single criterion tasks.

The presented algorithm is universal as it permits variant-based research of (i) diverse inland transport means, (ii) different variants of the same transport means, or (iii) different ways of the operation of transport means. It is also open that means facilitates the introduction of improvements and modernisations as well as extensions by other elements as needed by its user.

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