COMPUTER SUPPORT FOR THE RESTORATION OF UNDERGROUND CRITICAL INFRASTRUCTURE

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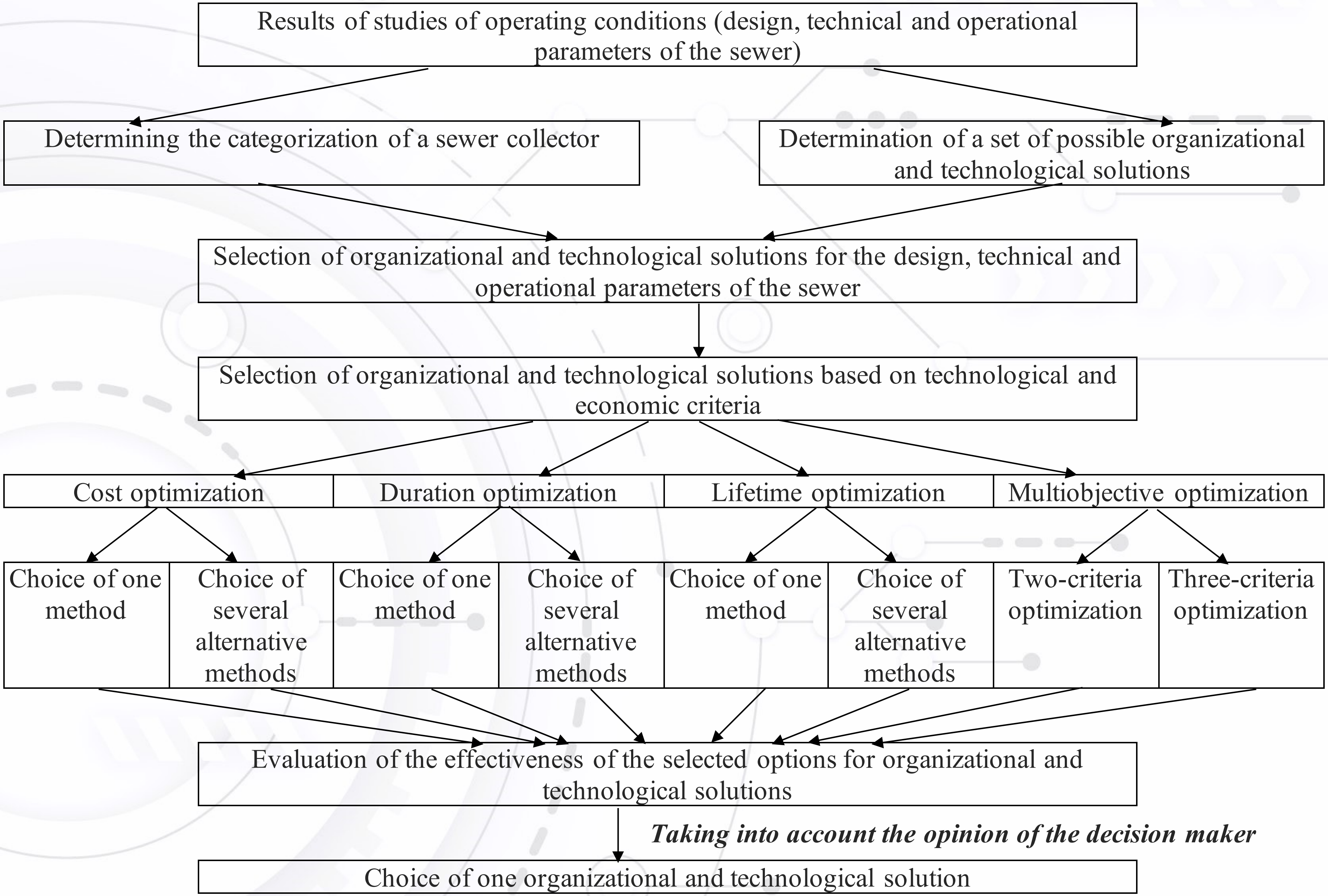
The aim of the study is theoretical substantiation and development of a system of reasonable choice of organizational and technological solutions that ensure an increase in the operational life of sewer collectors, which is based on the principles of a systematic approach and takes into account the entire set of design, technical, organizational, technological and economic factors of functioning, repair and operation of the sewer network, and also allows you to ensure that the optimal solution according to the selected criterion is obtained, taking into account the available resources.

ILLUSTRATION OF THE DESTRUCTION OF UNDERGROUND INFRASTRUCTURES IN THE CITY OF KHARKOV

ORGANIZATION SYSTEM OF A COMPLEX OF SOLUTIONS FOR EXTENDING THE OPERATING LIFE OF A SEWER COLLECTOR



METHODOLOGICAL AND SOFTWARE TOOLS FOR DETERMINING THE CATEGORY OF SECTIONS OF SEWER COLLECTORS

When determining the categorization of an object, it is advisable to consider the risk of an accident as one of the optimization criteria:

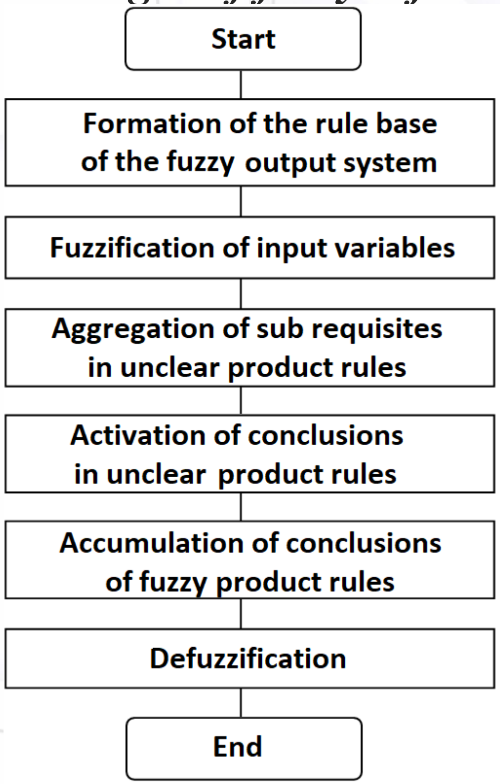
$$R(x)=P_x(H)\cdot P_x(U/H)\to \min_{x},$$

where x is the conditional serial number of the network section;

$P_x(H)$ is the probability of an accident for section x;

$P_x(U/H)$ is the probability of damage in the event of an accident for section x.

Main stages of fuzzy inference



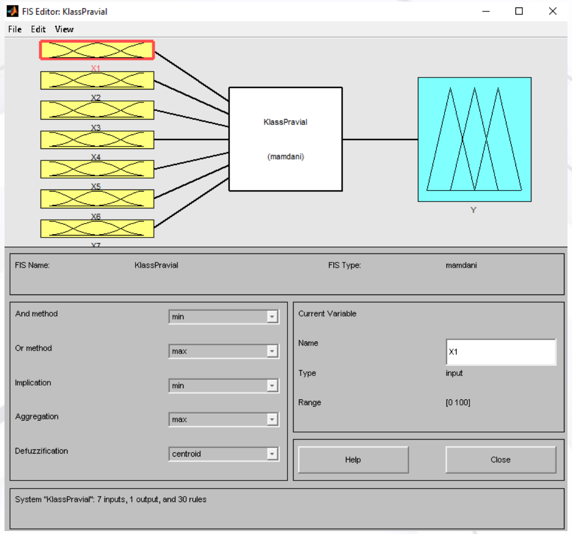
1. Formation of the rule base of fuzzy inference systems - the representation of empirical knowledge or expert knowledge in the form of a finite set of fuzzy production rules. At the same time, in each of the fuzzy statements, the membership functions of the term-set values for each linguistic variable must be determined.
2. Fuzzification is a procedure for finding the values of the membership function of fuzzy sets (terms) based on ordinary (not fuzzy) input data.
3. Aggregation is a procedure for determining the degree of truth of conditions for each of the rules of the fuzzy inference system.
4. Activation is a procedure for finding the degree of truth of each of the subconclusions of the fuzzy production rules.
5. Accumulation is the procedure for finding the membership function for each of the output linguistic variables.
6. Defuzzification is a procedure for finding a normal (not fuzzy) value for each of the output linguistic variables.

VARIABLES, TERM-SETS AND TERMS OF A COMPUTER MODEL FOR DETERMINING THE CATEGORY OF SEWER NETWORK SECTIONS

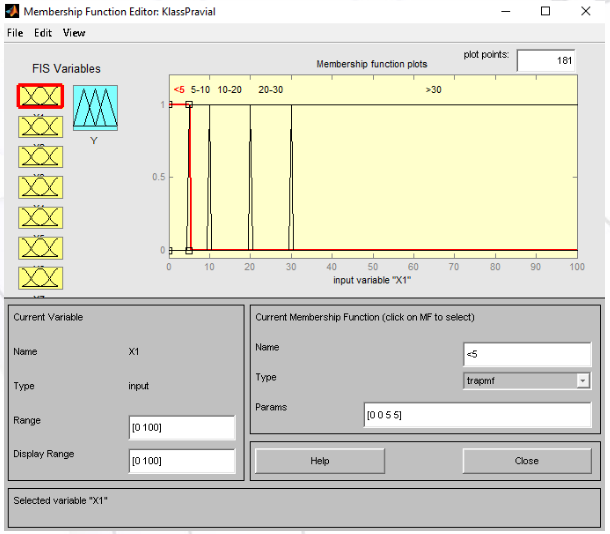
Variable	Term set	Index	Thermae	Description
Incoming variables				
X1	Cross section reduction	Cross section reduction, %	[0;5] [5,1;10] [10.1;20] [20.1;30] [30.1;100]	not significant (from 0 to 5%) permissible (from 5 to 10%) medium (from 10 to 20%) maximum allowable (from 20 to 30%) critical (more than 30%)
X2	Presence of cracks	Crack (width), mm	[0;0.5] [0.6;2] [2,1;5] [5,1;10] [10.1;100]	not significant (from 0 to 0.5 mm) permissible (from 0.5 to 2 mm) medium (from 2 to 5 mm) maximum allowable (from 5 to 10 mm) critical (more than 10 mm)
X3	Presence of deformation	Deformation, %	[0;6] [6,1;10] [10.1;20] [20.1;40] [40.1;100]	not significant (from 0 to 6%) permissible (from 6 to 10%) medium (from 10 to 20%) maximum allowable (from 20 to 40%) critical (more than 40%)
X4	The presence of a pipe rupture	Pipe rupture, cm	[0;5] [5;100]	critical (less than 5 cm) emergency (more than 5 cm)
X5	Presence of corrosion	Corrosion of reinforced concrete, %	[0;10] [10.1;30] [30.1;50] [50.1;70] [70.1;100]	not significant (from 0 to 10%) acceptable (from 10 to 30%) medium (from 30 to 50%) maximum allowable (from 50 to 70%) critical (more than 70%)
X6	Degree of wastewater pollution		[0;1] [1,1;2] [2,1;3]	rainwater pretreated wastewater untreated waste water
X7	Presence of wet soils along the pipeline route		[0;0.5] [0.51;1]	No Yes
Outgoing variable				
Y	Lot category		[0;1] [1,1;2] [2,1;3] [3,1;4] [4,1;5]	state class 0 - emergency state class 1 - pre-emergency state class 2 - critical condition class 3 - not satisfactory condition class 4 - satisfactory

EXPERT SYSTEM FOR DETERMINING THE CATEGORY OF SECTIONS OF SEWER COLLECTORS

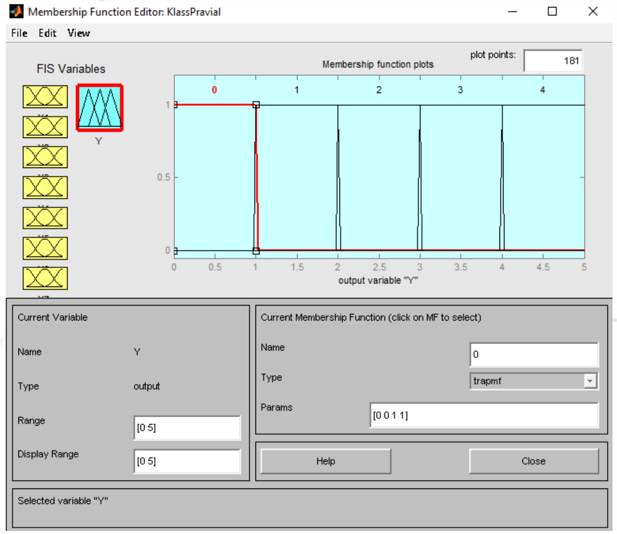
General view of the window F IS -editor of the MATLAB system for determining the categorization of sections of the sewer



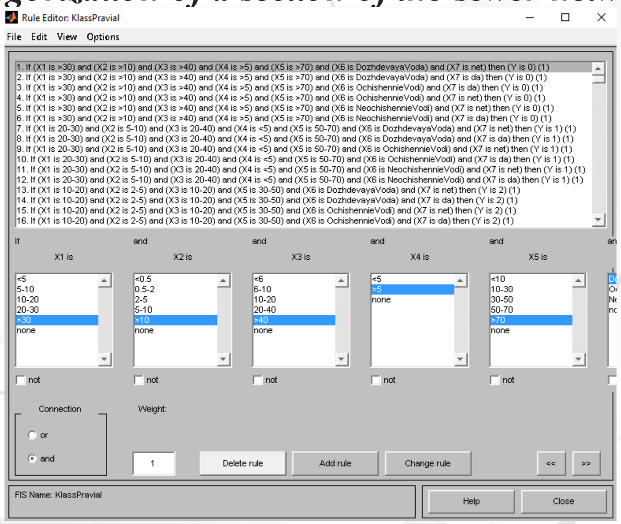
Description of the input variable that takes into account the reduction in cross-section



Description of the outgoing variable that determines the categorization of the sewer section



A fragment of the knowledge base for determining the categorization of a section of the sewer network



The result of the system operation based on the given values of the input variables

EVALUATION OF THE POSSIBILITY OF APPLICATION OF DIFFERENT METHODS OF REPAIR AND RESTORATION OF A SEWER MANIFOLD WITH A GIVEN CATEGORY OF ITS SECTIONS

Results of collection, processing and analysis of expert opinions

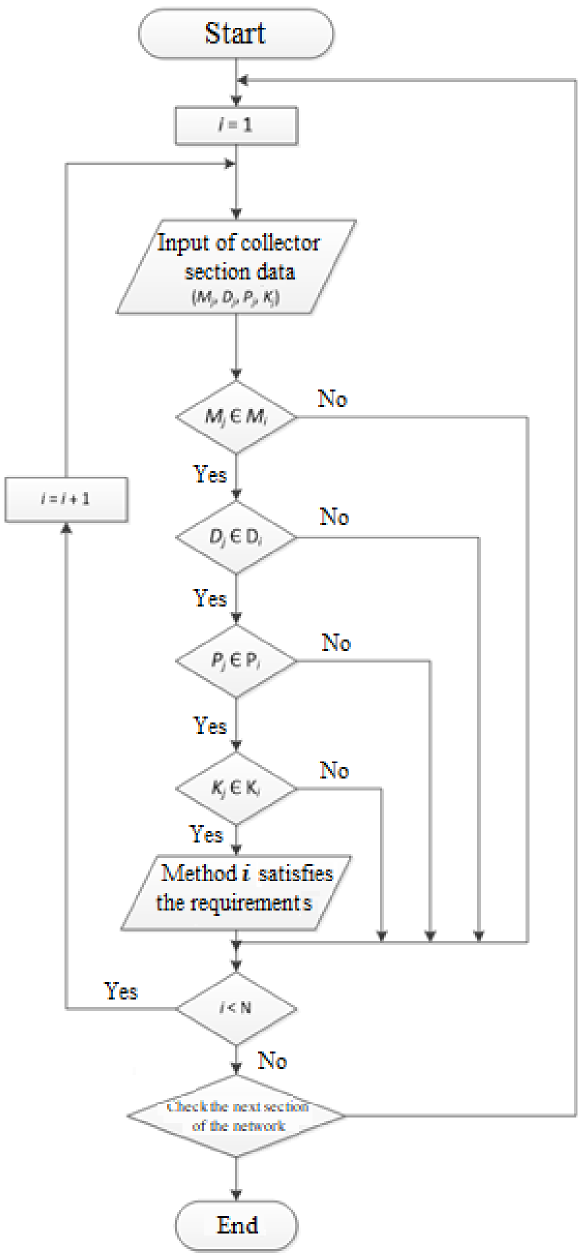
Experts

Method Number	1					2					3					4					5					The number of experts who voted for the state class				
	State class					State class					State class					State class					State class									
	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
1				3	4			2	3	4				3	4			2	3	4			2	3	4			3	5	5
2				3	4			2	3	4			2	3	4			2	3	4				3	4			3	5	5
3			2	3	4			2	3	4				3	4				3	4			2	3	4			3	5	5
4			2	3	4				3	4			2	3	4				3	4				3	4			2	5	5
5			2	3	4				3	4				3	4			2	3	4			2	3	4			3	5	5
6				3	4			2	3	4				3	4				3	4				3	4			1	5	5
7				3	4			2	3	4				3	4				3	4			2	3	4			2	5	5
8				3	4				3	4			2	3	4				3	4				3	4			1	5	5
9				3	4			2	3	4				3	4				3	4				3	4			1	5	5
10				3	4				3	4				3	4				3	4				3	4				5	5
11			2	3	4				3	4				3	4			2	3	4			2	3	4			3	5	5
12			2	3	4				3	4			2	3	4				3	4				3	4			2	5	5
13			2	3				2	3				2	3				2	3				2	3				5	5	
14		1	2			0	1	2				1	2				1	2	3			1	2	3		1	5	5	2	
15		1	2				1	2			0	1	2				1	2				1	2	3		1	5	5	1	
16		1	2				1	2			0	1	2				1	2				1	2			1	5	5		
17	0	1	2				1	2				1	2				1	2				1	2	3		1	5	5	1	
18		1	2			0	1	2				1	2				1	2				1	2			1	5	5		

The possibility of applying repair and restoration methods for various categories of sections of the sewer network based on the expertise

Method No.	Status class	Method No.	Status class
1	3, 4	10	3, 4
2	3, 4	11	3, 4
3	3, 4	12	3, 4
4	3, 4	13	2, 3
5	3, 4	14	1, 2
6	3, 4	15	1, 2
7	3, 4	16	1, 2
8	3, 4	17	1, 2
9	3, 4	18	1, 2

ALGORITHMIC MODEL FOR A JUSTIFIED CHOICE OF THE METHOD OF REPAIR AND RECOVERY OF A SECTION OF THE SEWER COLLECTOR



Legend:

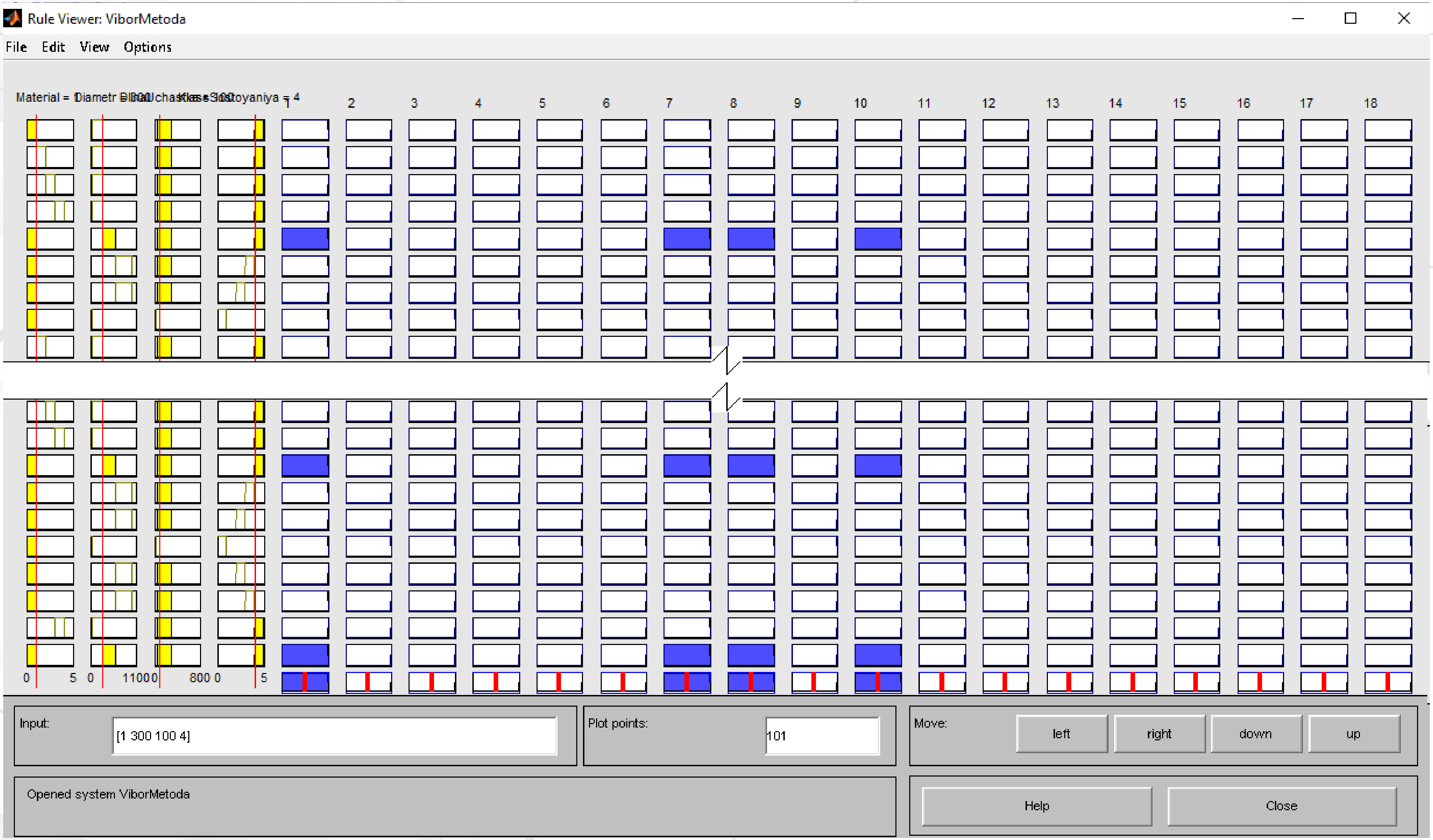
i is the number of the repair method, $i = \overline{1, N}$;
N is the number of repair methods under consideration;
j is the number of the sewer section, $j = \overline{1, Z}$;
Z is the number of sections of the sewer network;
Mi is the material for which *method i* can be applied;
Di is the diameter for which *method i* can be applied;
Pi is the length for which *method i* can be applied;
Ki – categorization for which the i method can be applied;
Mj – material of the collector section *j*;
Dj – diameter of the collector section *j*;
Pj – length of the collector section *j*;
Kj – categorization of the collector section *j*.

SOFTWARE TOOLS FOR THE IMPLEMENTATION OF AN ALGORITHMIC MODEL OF A JUSTIFIED CHOICE OF THE METHOD OF REPAIR AND RECOVERY OF A SECTION OF THE SEWER MANIFOLD

Variables, term-sets and terms of the expert system for a reasonable choice of the method of repair and restoration of a section of the sewer network

Variable	term set	Thermae	Description
1	2	3	4
K1	Sewer section material	[0;1] [1,1;2] [2,1;3] [3,1;4] [4,1;5]	reinforced concrete ceramics steel cast iron asbestos
K2	Sewer section diameter	[0;49] [50;299] [300;599] [600;999] [1000;3600]	up to 50 mm 50-300 mm 300-600 mm 600-1000 mm over 1000 mm
K3	Sewer section length	[0;24] [25;49] [50;299] [300;599] [600;1000]	up to 25 m 25-50 m 50-300 m 300-600 m over 600 m
K4	Categorization (state class) of the sewer section	[0;1] [1,1;2] [2,1;3] [3,1;4] [4,1;5]	state class 0 - emergency state class 1 - pre-emergency state class 2 - critical condition class 3 - not satisfactory condition class 4 - satisfactory
Outgoing variables			
M1	Methods of repair and restoration of the sewer	[0;1]	method 1
M2		[0;1]	method 2
M3		[0;1]	method 3
…..			
M17		[0;1]	method 17
M18		[0;1]	method 18

THE RESULT OF THE SYSTEM OF REASONABLE SELECTION OF THE METHOD OF REPAIR AND RECOVERY OF THE SECTION OF THE SEWER COLLECTOR BASED ON THE SET VALUES OF THE INCOMING VARIABLES



IMPLEMENTATION OF ALGORITHMIC MODEL

Workspace for user entry of input parameters of the sewer section and automated selection of repair methods

Fields for filling in coristuvacem	
Enter material number	
Enter pipe diameter in millimeters	
Enter the length of the plot in meters	
Enter category	

1 - cast concrete
2 - ceramics
3 - steel
4 - cast iron
5 - asbestos

The area of automated selection of the method of repair and restoration of the sewer section

Automation of the choice of repair method

Repair method number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Exchange for material																		
Diameter limit																		
Section length limit																		
Exchanges by category																		
Methods that can be applied																		

Recommendations for choosing a repair method, taking into account all the parameters of the sewer section

Fields for filling in coristuvacem	
Enter material number	1
Enter pipe diameter in millimeters	300
Enter the length of the plot in meters	200
Enter category	3

Automation of the choice of repair method

Repair method number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Exchange for material																		
Diameter limit																		
Section length limit																		
Exchanges by category																		
Methods that can be applied																		

MATHEMATICAL MODELS OF SINGLE-CRITERIA OPTIMIZATION UNDER THE CONDITION OF SELECTING A SINGLE METHOD FOR REPAIRING A SECTION OF THE SEWER COLLECTOR

$$\sum_{i=1}^{n} c_i \cdot l \cdot x_i \to min, \quad \begin{cases} x_i \in \{0;1\}, \quad i=\overline{1,n}; \\ \sum_{i=1}^{n_i} x_i = 1; \\ c_i \in C_{i_k}, \quad k=\overline{1,m}, \end{cases} \quad (1)$$

$$\sum_{i=1}^{n} t_i \cdot l \cdot x_i \to min, \quad \begin{cases} x_i \in \{0;1\}, \quad i=\overline{1,n}; \\ \sum_{i=1}^{n_i} x_i = 1; \\ t_i \in T_{i_k}, \quad k=\overline{1,m}, \end{cases} \quad (2)$$

$$\sum_{i=1}^{n} z_i \cdot x_i \to max, \quad \begin{cases} x_i \in \{0;1\}, \quad i=\overline{1,n}; \\ \sum_{i=1}^{n_i} x_i = 1; \\ z_i \in Z_{i_k}, \quad k=\overline{1,m}, \end{cases} \quad (3)$$

where (1) – a mathematical model in which the optimization criterion is the cost of producing a complex of repair works;

(2) is a mathematical model in which the optimization criterion is the duration of the production of a complex of repair works;

(3) is a mathematical model in which the period of trouble-free operation is the optimization criterion;

i – number of repair and restoration method; $i = 1, \dots, n$;

n is the number of repair methods;

c_i – cost a complex of repair works (including the cost of materials and the cost of performing work) for 1 lin. m sewer collector i -th method;

t_i – duration complex of repair works for 1 lin. m sewer collector i -th method;

z_i - the period of subsequent trouble-free operation, subject to the repair of the sewer collector by *the* i -th method;

l – length of the repaired section, m;

x_i *is* a logical variable that reflects the choice of the i -th repair method: $x_i = \begin{cases} 1, \text{if the repair method } i \text{ is selected} \\ 0, \quad \text{in the opposite situation} \end{cases}$

C_{i_k} - cost characteristics of a set of repair methods i that can be applied on the site, depending on its design, technical and operational parameters k;

T_{i_k} - characteristics of the duration of a set of repair methods that can be applied on the site, depending on its design, technical and operational parameters k;

Z_{i_k} - characteristics of the subsequent trouble-free operation of a variety of repair methods that can be applied on the site, depending on its design, technical and operational parameters k;

m - the number of repair methods that can be applied on the site, depending on its design, technical and operational parameters.

MATHEMATICAL MODELS OF SINGLE-CRITERIA OPTIMIZATION UNDER THE CONDITION OF THE CHOICE OF SEVERAL METHODS OF REPAIRING A SECTION OF THE SEWER COLLECTOR

$$\sum_{i=1}^{n}\sum_{j=1}^{m} c_{ij}\cdot l_j\cdot x_{ij}\to min,\quad \begin{cases} x_{ij}\in\{0;1\}, & i=\overline{1,n},\quad j=\overline{1,m};\\ \sum_{j=1}^{n_i} x_{ij}=1, & i=\overline{1,n};\\ c_{ij}\in C_{ij_k}, & k=\overline{1,p}, \end{cases} \quad (1)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} t_{ij}\cdot l_j\cdot x_{ij}\to min,\quad \begin{cases} x_{ij}\in\{0;1\}, & i=\overline{1,n},\quad j=\overline{1,m};\\ \sum_{j=1}^{n_i} x_{ij}=1, & i=\overline{1,n};\\ t_{ij}\in T_{ij_k}, & k=\overline{1,p}, \end{cases} \quad (2)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} z_{ij}\cdot x_{ij}\to max,\quad \begin{cases} x_{ij}\in\{0;1\}, & i=\overline{1,n},\quad j=\overline{1,m};\\ \sum_{j=1}^{n_i} x_{ij}=1, & i=\overline{1,n};\\ z_{ij}\in Z_{ij_k}, & k=\overline{1,p}, \end{cases} \quad (3)$$

where (1) - the mathematical model in which the optimization criterion is the cost of producing a complex of repair works;

(2) - the mathematical model in which the optimization criterion is the duration of the production of a complex of repair works;

(3) - the mathematical model in which the period of trouble-free operation is the optimization criterion;

i – number of repair and restoration method; $i = 1, \dots, n$;

n - number of repair methods;

j - number of the sewer collector section; $j = 1, \dots, m$;

m - the number of sections of the sewer collector to be repaired;

c_{ij} – cost a complex of repair works (including the cost of materials and the cost of performing work) for 1 lin. m section j sewer collector i -th method;

t_{ij} - duration complex of repair works for 1 lin. m section j sewer collector i -th method;

z_{ij} - period of subsequent trouble-free operation, subject to the repair of section j of the sewer collector by *the* i -th method;

l_j - the length of the repaired section j , m;

x_i *is* a logical variable that reflects the choice of *the* i -th repair method: $x_i = \begin{cases} 1, & \text{if the repair method } i \text{ is selected}\\ 0, & \text{in the opposite situation}\end{cases}$

C_{ij_k} - cost characteristics of a set of repair methods i that can be applied on site j depending on its design, technical and operational parameters k ;

T_{ij_k} – duration characteristics of multiple repair methods i, which can be applied on section j depending on its design, technical and operational parameters k .

Z_{ij_k} - characteristics of the subsequent trouble-free operation of a set of repair methods i that can be applied on site j depending on its design, technical and operational parameters k;

p is the number of repair methods that can be applied on the site, depending on its design, technical and operational parameters.

MATHEMATICAL MODELS OF MULTI-CRITERIA OPTIMIZATION FOR SOLVING THE PROBLEM OF SELECTING THE METHOD FOR REPAIRING A SECTION OF THE SEWER COLLECTOR

$$\sum_{i=1}^{n}\sum_{j=1}^{m}\left(v_c(c_{ij}\cdot l_j)+v_t(t_{ij}\cdot l_j)\right)x_{ij}\to min,\quad \begin{cases} x_{ij}\in\{0;1\}, & i=\overline{1,n},\quad j=\overline{1,m};\\ \sum_{j=1}^{n_i}x_{ij}=1, & i=\overline{1,n};\\ c_{ij}\in C_{ij_k},\ t_{ij}\in T_{ij_k}, & k=\overline{1,p}, \end{cases} \quad (1)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m}\left(v_c(c_{ij}\cdot l_j)+v_t(t_{ij}\cdot l_j)-v_z\cdot z_{ij}\right)x_{ij}\to min,\quad \begin{cases} x_{ij}\in\{0;1\}, & i=\overline{1,n},\quad j=\overline{1,m};\\ \sum_{j=1}^{n_i}x_{ij}=1, & i=\overline{1,n};\\ c_{ij}\in C_{ij_k},\ t_{ij}\in T_{ij_k},\ z_{ij}\in Z_{ij_k}, & k=\overline{1,p}, \end{cases} \quad (2)$$

where (1) - the mathematical model of two-criteria optimization in terms of cost and duration of a complex of repair works;

(2) - the mathematical model of three-criteria optimization in terms of cost, duration of a complex of repair work and the period of subsequent trouble-free operation;

v_c - weight coefficient from the cost of work;

v_t - weight coefficient of the duration of work;

v_z - weighting factor for the period of subsequent trouble-free operation.

The weighting factors are calculated as follows:

$$v=\left|\frac{1}{a_b-a_w}\right|,$$

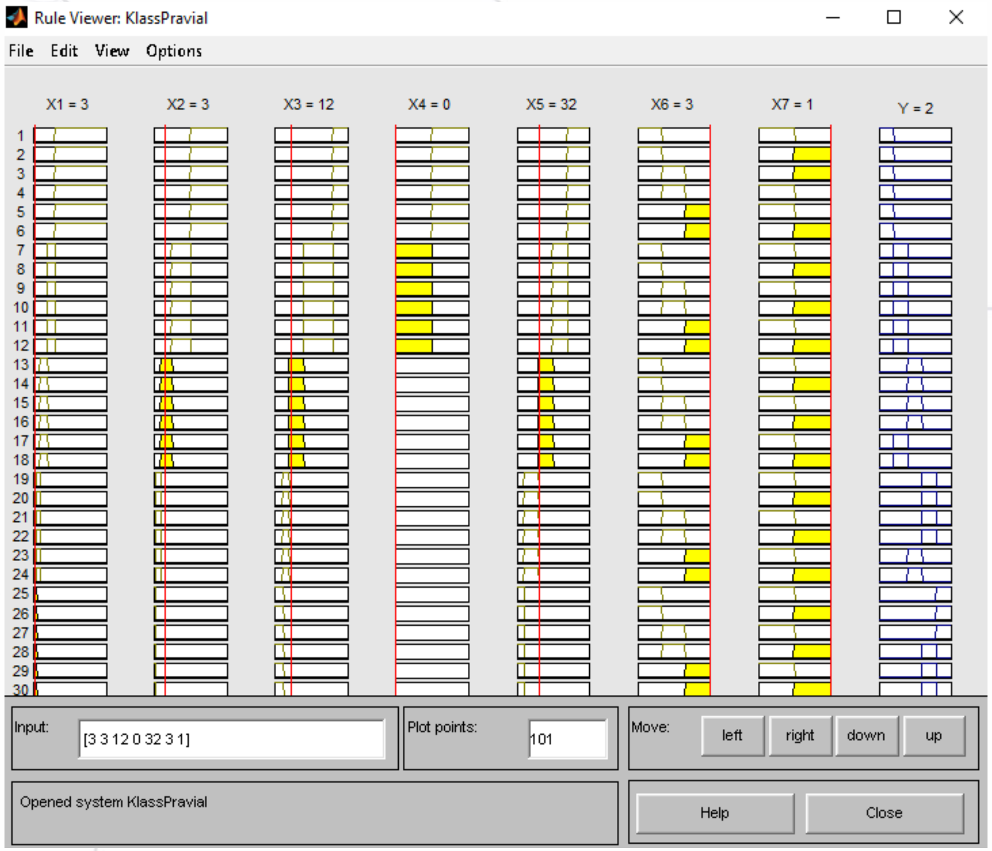
a_b - the best value of the criterion indicator;

a_w - the worst value of the criterion indicator.

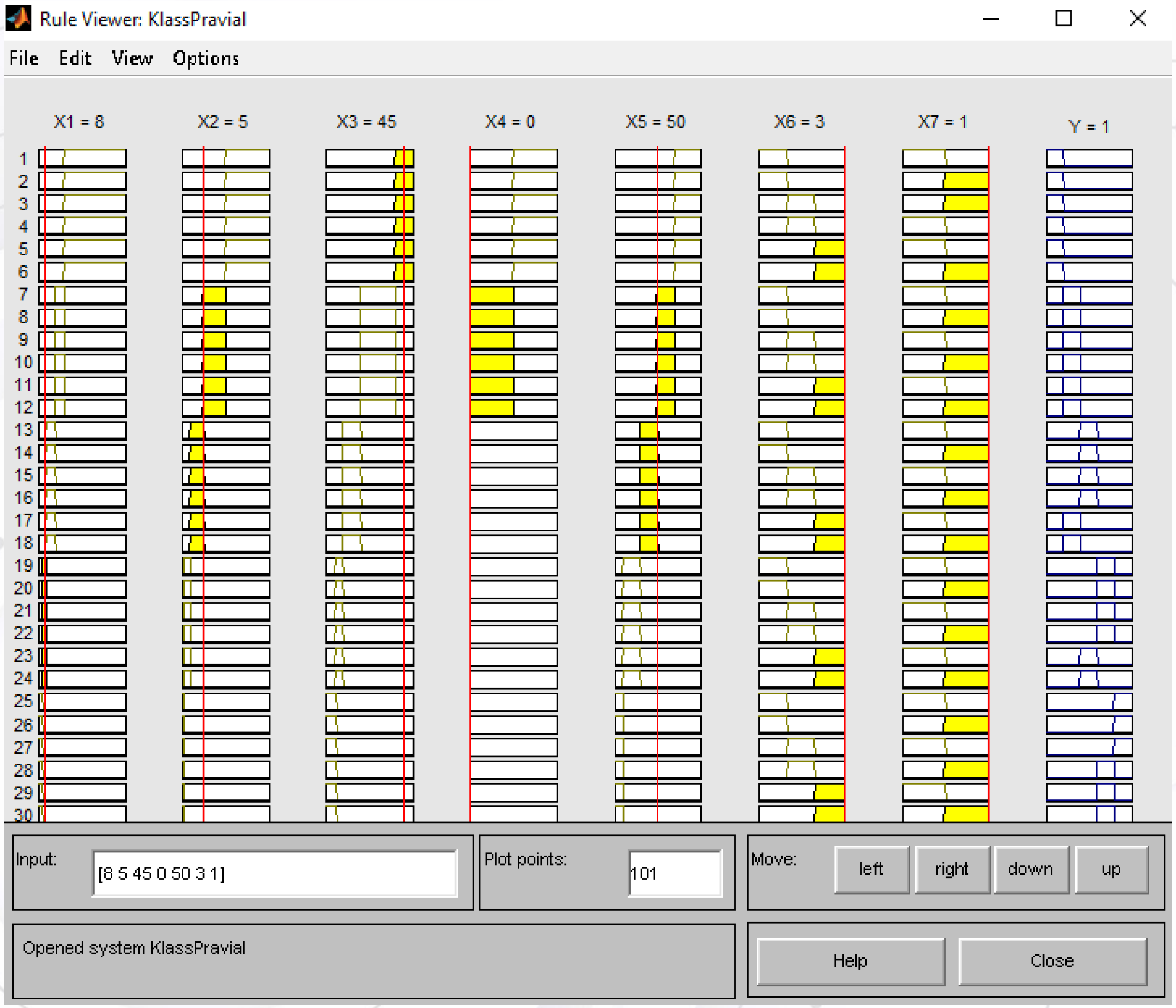
Collector damage

Damage	Place	Characteristic
Plot 1		
Cross-section reduction		3 %
Crack	Arch	2.8 mm
Deformation	Arch	12 %
Corrosion	Arch	32 %
Plot 2		
Cross-section reduction		8 %
Crack	Arch	1.4 mm
Deformation	Arch	6 %
Corrosion	Arch	21 %
Plot 3		
Cross-section reduction		3 %
Crack	Arch	0.9 mm
Deformation	Arch	2 %
Corrosion	Arch	5 %
Plot 4		
Cross-section reduction		5 %
Crack	Arch	1.2 mm
Deformation	Arch	45 %
Corrosion	Arch	30 %
Plot 5		
Cross-section reduction		5 %
Deformation	Arch	25 %
Corrosion	Arch	38 %
Plot 6		
Cross-section reduction		20 %
Crack	Arch	5.0 mm
Deformation	Arch	20 %
Corrosion	Arch	50 %
Plot 7		
Deformation	Arch	25 %
Corrosion	Arch	34 %

Categorization of the first section



General categorization of the reservoir under consideration



Categorization of plots and general categorization of the reservoir

Lot number	Plot categorization	General categorization
1	2	1
2	3	
3	4	
4	2	
5	2	
6	1	
7	2	

JUSTIFICATION OF THE CHOICE OF THE METHOD OF REPAIR AND RESTORATION OF THE SECTION OF THE SEWER COLLECTOR

Recommendations for choosing repair methods when the manifold is considered as a whole

Fields for filling in coristuvacem

Enter material number	1
Enter pipe diameter in millimeters	600
Enter the length of the plot in meters	236
Enter category	1

Automation of the choice of repair method

Repair method number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Exchange for material																		
Diameter limit																		
Section length limit																		
Exchanges by category																		
Methods that can be applied																		

Recommendations for choosing repair methods for the first section of the collector

Fields for filling in coristuvacem

Enter material number	1
Enter pipe diameter in millimeters	600
Enter the length of the plot in meters	50,8
Enter category	2

Automation of the choice of repair method

Repair method number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Exchange for material																		
Diameter limit																		
Section length limit																		
Exchanges by category																		
Methods that can be applied																		

Summarized information on the recommended methods of repair and restoration of the collector

Lot number	Numbers of Recommended Methods	Numbers of recommended methods if the collector is considered as a whole
1	11, 12, 16, 17, 18	12, 16
2	1, 2, 3, 5, 8, 10, 11	
3	1, 2, 3, 5, 8, 10	
4	11, 12, 16, 17, 18	
5	11, 12, 16, 17, 18	
6	12, 16, 17, 18	
7	11, 12, 16, 17, 18	

APPLICATION OF MATHEMATICAL MODELS OF SINGLE-CRITERIA OPTIMIZATION UNDER THE CONDITION OF SELECTING A SINGLE REPAIR METHOD FOR A SEWER COLLECTOR

Technological and economic characteristics of the methods of repair and restoration of the sewer

No	Repair method	The cost of work for 1 lin. m, UAH	The duration of work for 1 run. m, working shifts	Period of trouble-free operation, years
1	Method Supersilic	853.4	0.35	10
2	Centri method	953.8	0.56	10
3	Injection method	783.6	0.48	8
4	ZM Method	1053.6	0.42	10
5	The Tate method	956.4	0.32	10
6	Sitchoment Method	896.4	0.45	10
7	Preload method	645.9	0.39	10
8	Method "Stelvord"	876.2	0.46	12
9	Method "Hydrozan"	1059.4	0.59	15
10	Epoxy resin application	987.6	0.49	15
11	Setriline method	856.2	0.50	10
12	Method "Incoment"	1268.3	0.65	15
13	PF method	1687.5	0.36	10
14	PR Method _	1965.8	0.47	40
15	PM Method	1985.3	0.67	45
16	Relining method	2165.8	0.37	50
17	Insituform method	859.4	0.60	15
18	Eterling method	2059.3	0.68	45

THE RESULT OF SOLVING THE PROBLEM OF COST OPTIMIZATION

No. of the lot	1	2	3	4	5	6	7	
material	1							
diameter, mm	600							The length of the plot
length, m	50,8	52,9	51	32,9	21	15,9	11,1	235,6 m
category	2	3	4	2	2	1	2	
total collector category	1							

Numbers of repair methods

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Methods that can be applied											+	+				+	+	+
Cost of work for 1 linear meter, UAH											856,20	1268,30				2165,80	859,40	2059,30

Select method

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Methods collected
Choice of method (so(1)/no(0))	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Total cost, UAH	0	0	0	0	0	0	0	0	0	0	0	298811	0	0	0	0	0	0	
Purpose function, UAH	298 811,48																		
method number	12																		
Total duration, working shifts	153,14																		
The term of trouble-free operation, life	15																		

APPLICATION OF MATHEMATICAL MODELS OF SINGLE-CRITERIA OPTIMIZATION UNDER THE CONDITION OF THE CHOICE OF DIFFERENT REPAIR METHODS FOR SECTIONS OF THE SEWER COLLECTOR

The result of the search for a solution to the problem of single-criteria cost optimization, subject to the choice of different repair methods for reservoir sections

No. of the lot	1	2	3	4	5	6	7
material	1						
diameter, mm	600						
length, m	50,8	52,9	51	32,9	21	15,9	11,1
category	2	3	4	2	2	1	2

Numbers of repair methods for the lot 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Methods collected
Methods that can be applied											+	+				+	+	+	
Cost of work for 1 linear meter, UAH											856,20	1268,30				2165,80	859,40	2059,30	
Choice of method (so(1)/no(0))	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Total cost, UAH	0	0	0	0	0	0	0	0	0	0	43495	0	0	0	0	0	0	0	
The cost of work on lot 1, UAH	43495,0																		

Numbers of repair methods for the lot 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Methods collected
Methods that can be applied	+	+	+		+			+		+	+								
Cost of work for 1 linear meter, UAH	853,40	953,80	783,60		956,40			876,20		987,60	856,20								
Choice of method (so(1)/no(0))	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Total cost, UAH	0	0	41452	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
The cost of work on lot 2, UAH	41452,4																		

Numbers of repair methods for the lot 7

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Methods collected
Methods that can be applied											+	+				+	+	+	
Cost of work for 1 linear meter, UAH											856,20	1268,30				2165,80	859,40	2059,30	
Choice of method (so(1)/no(0))	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Total cost, UAH	0	0	0	0	0	0	0	0	0	0	9503,8	0	0	0	0	0	0	0	
The cost of work on lot 7, UAH	9503,8																		

Purpose function, UAH	194 228,46

GENERAL RECOMMENDATIONS FOR THE SELECTION OF METHODS OF REPAIR AND RECOVERY OF THE SEWER COLLECTOR

No. of the lot	1	2	3	4	5	6	7
material	1						
diameter, mm	600						
length, m	50,8	52,9	51	32,9	21	15,9	11,1
category	2	3	4	2	2	1	2
Collector category	1						
Head length of the collector, m	235,6						

Collector is viewed as a single unit (alternative A^1)

Cost optimization (alternative A^1_c)		Duration optimization (alternative A^1_t)	
Total cost, UAH	298 811,48	Total duration, working shifts	87,17
method number	12	method number	16
Total duration, working shifts	153,14	Total cost, UAH	510 262,48
The term of trouble-free operation, year	15	The term of trouble-free operation, year	50
Optimization of the term for trouble-free operation (alternative A^1_z)			
The term of trouble-free operation, year	50		
method number	16		
Total cost, UAH	510 262,48		
Total duration, working shifts	87,17		

A selection of different methods for collector sections (alternative A^2)

Cost optimization (alternative A^2_c)							
plot number	1	2	3	4	5	6	7
method number	11	3	3	11	11	17	11
Total repair cost, UAH	194228,46						
Total repair time, working shifts	117,31						
Average term for trouble-free operation, year	10,1						
Duration optimization (alternative A^2_t)							
method number	16	5	5	16	16	16	16
Total repair time, working shifts	81,98						
Total repair cost, UAH	384605,82						
Average term for trouble-free operation, year	38,6						
Optimization of the term for trouble-free operation (alternative A^2_z)							
method number	16	10	10	16	16	16	16
Average term for trouble-free operation, year	40						
Total repair cost, UAH	387847,50						
Total repair time, working shifts	99,64						

The results of multiobjective optimization (alternative A^3)

Optimization for two criteria (cost, duration) (alternative A^3_{ct})							
No. of the lot	1	2	3	4	5	6	7
method number	11	5	5	11	11	17	11
Total repair cost, UAH	212182,38						
Total repair time, working shifts	100,69						
Average term for trouble-free operation, year	10,71						
Optimization for thoma criteria (cost, duration, operation) (alternative A^3_{ctz})							
method number	16	5	5	16	16	16	16
Total repair cost, UAH	384605,82						
Total repair time, working shifts	81,98						
Average term for trouble-free operation, year	38,6						

The proposed choices are divided into alternatives, which are assigned letter designations in the following order:
alternatives A^1 - options for carrying out repair work, obtained as a result of solving problems of single-criteria optimization, subject to the choice of one repair method, and the alternative:

A^1_c – solution variant obtained as a result of cost optimization;
A^1_t – solution variant obtained as a result of duration optimization;
A^1_z is a solution option obtained as a result of optimizing the period of subsequent operation;

alternatives A^2 - options for carrying out repair work, obtained as a result of solving problems of single-criteria optimization, subject to the choice of different repair methods, and the alternative:

A^2_c – solution variant obtained as a result of cost optimization;
A^2_t – solution variant obtained as a result of duration optimization;
A^2_z is a solution option obtained as a result of optimizing the period of subsequent operation;

alternatives A^3 - options for carrying out repair work, obtained as a result of solving problems of multi-criteria optimization, subject to the choice of different repair methods, and the alternative:

A^3_{ct} – solution variant obtained as a result of cost and duration optimization;
A^3_{ctz} is a solution option obtained as a result of optimization according to three criteria (cost, duration, period of subsequent operation).

Analysis of the main indicators of the selected repair methods for alternative options for solving optimization problems

Alternatives	**Total repair cost, UAH**	**Total repair time, working shifts**	**Average term for trouble-free operation, year**
A^1_c	298 811,48	153,14	15
A^1_t	510 262,48	87,17	50
A^1_z	510 262,48	87,17	50
A^2_c	194 228,46	117,31	10,1
A^2_t	384 605,82	81,98	38,57
A^2_z	387 847,50	99,64	40
A^3_{ct}	212 182,38	100,69	10,71
A^3_{ctz}	384 605,82	81,98	38,6
Best showing value	**194 228,46**	**81,98**	**50**
Alternative	A^2_c	A^2_t, A^3_{ctz}	A^1_t, A^1_z

COMPARISON OF THE MAIN INDICATORS OF THE ALTERNATIVES WITH THE BEST VALUE OF EACH INDICATOR

Alternatives	**Cost deviation from the best value**	**Duration deviation from the best value**	**Service life deviation from the best value**
A^1_c	35%	46%	70%
A^1_t	62%	6%	*the best*
A^1_z	62%	6%	*the best*
A^2_c	*the best*	30%	80%
A^2_t	49%	*the best*	23%
A^2_z	50%	18%	20%
A^3_{ct}	8%	19%	79%
A^3_{ctz}	49%	*the best*	23%

The comparison made allows us to conclude that the deterioration of the main indicators of the complex of repair works varies according to:

total cost - in the range from 8 to 62%;

total duration - in the range from 6 to 46%;

the average period of subsequent trouble-free operation - in the range from 20 to 80%.

ECONOMIC EFFICIENCY ASSESSMENT OF THE USE THE ALTERNATIVE OPTIONS FOR REPAIRING THE SEWER COLLECTOR

Alternatives	Total repair cost, UAH	Estimated economic effect	
		UAH	at %
A^1_c	**298811,48**	35850,00	12,00
A^1_t	**510262,48**	55066,10	10,79
A^1_z	**510262,48**	55066,10	10,79
A^2_c	**194228,46**	20302,55	10,45
A^2_t	**384605,82**	51400,56	13,36
A^2_z	**387847,50**	49005,10	12,64
A^3_{ct}	**212182,38**	25254,79	11,90
A^3_{ctz}	**384605,82**	42400,65	11,02

THANK YOU FOR YOUR ATTENTION