System Analysis and Control Department

International workshop:
Characteristics of Green Technological Transformation in Accordance with EGD Vision
Uzhhorod, Ukraine

Advancing sustainability in medical supply chains through two-stage continuous-discrete location problem

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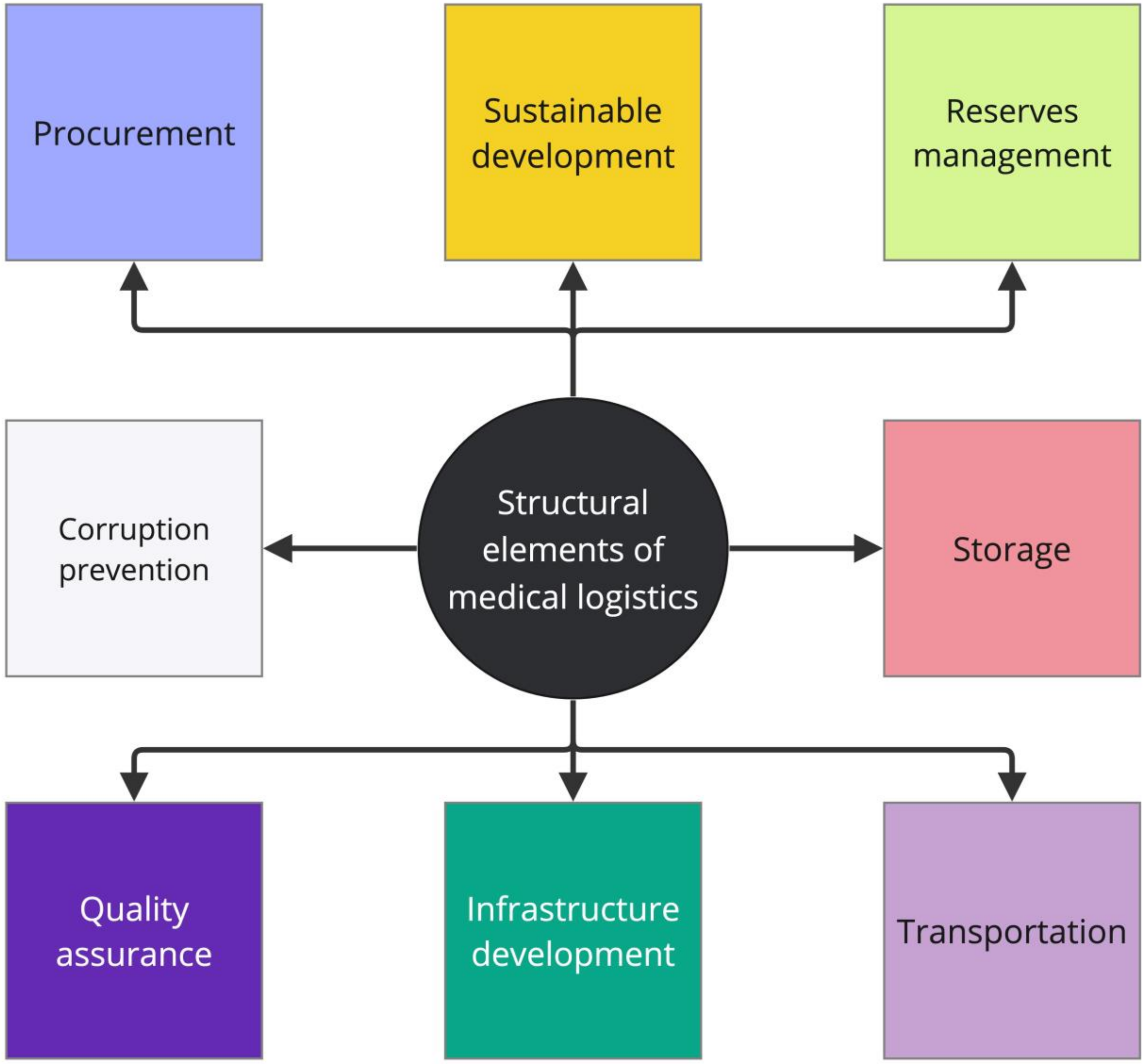
Agenda

1. Medical logistics definition
2. Medical logistics system
3. Practical problem statement
4. Mathematical model
5. Solution approach
6. Algorithm for solving
7. Model tasks
8. Future research

Medical logistics

- Medical logistics - the process of managing the flow of medical supplies, equipment, and personnel to ensure that healthcare facilities have the necessary resources to provide effective care.
- medical logistics is not a single process but a complex system of subprocesses;
- we will mainly focus on **transportation** and **infrastructure development** improvements.

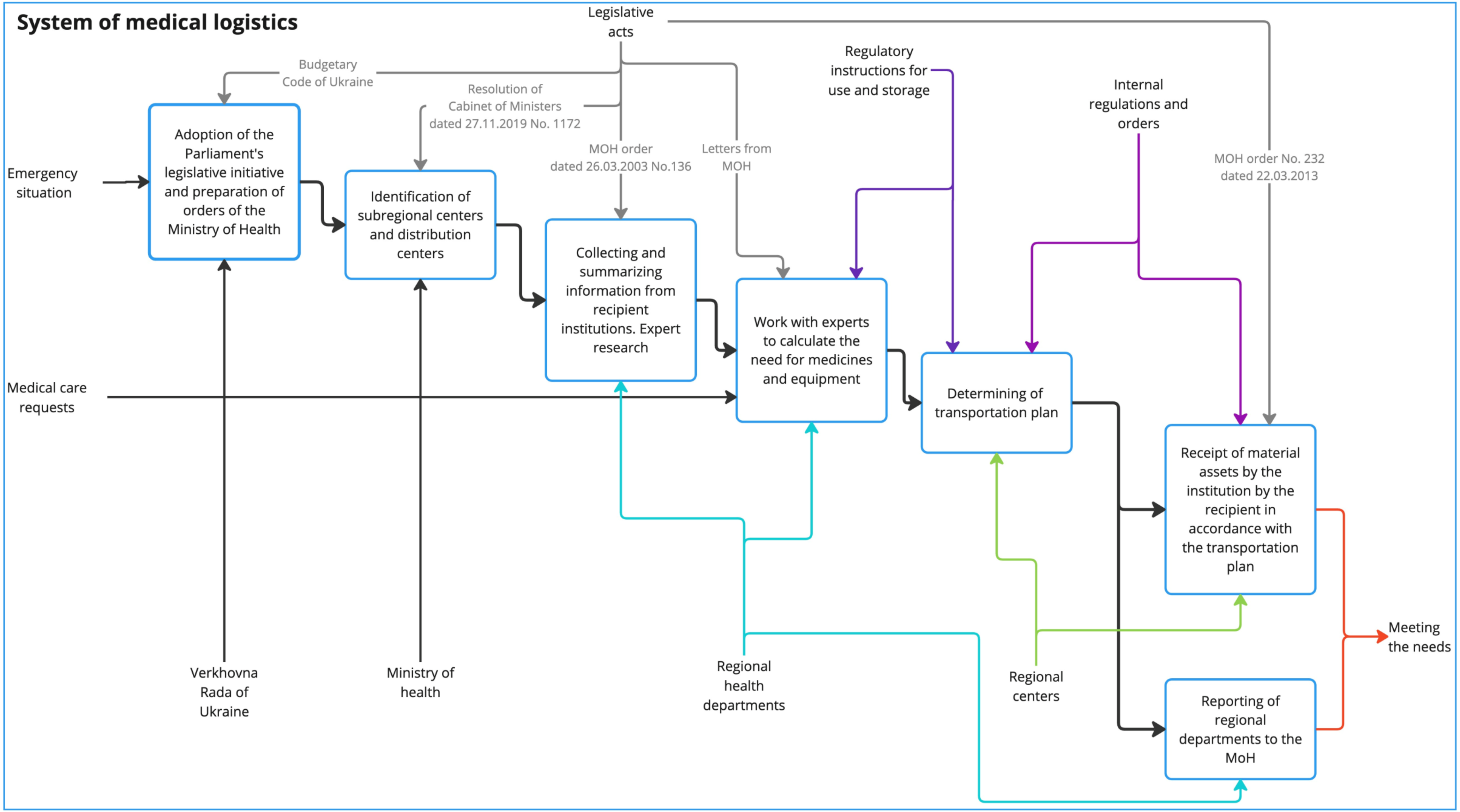


Our motivation and relevance

Optimization of processes during crisis when emergency response is required:

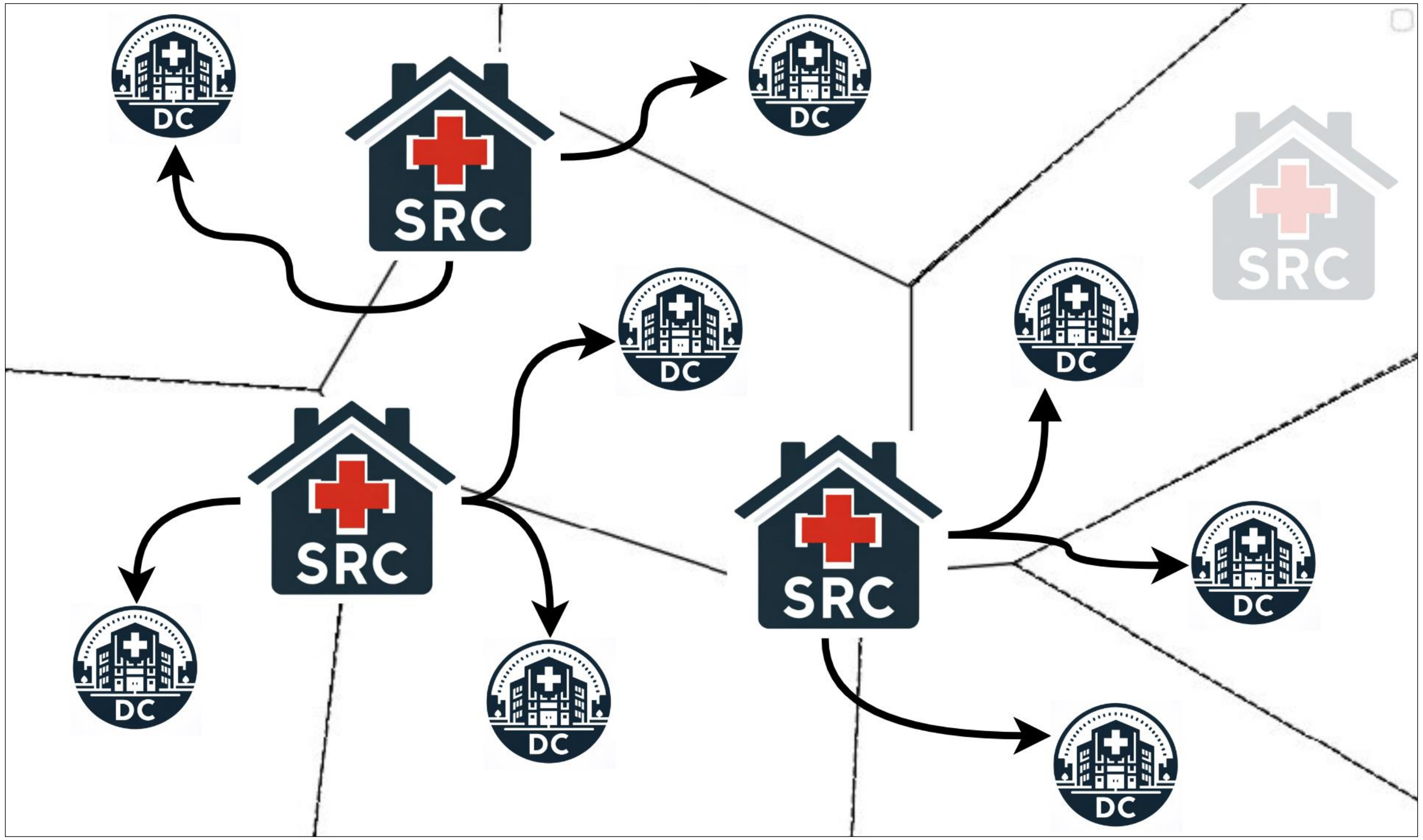
- Pandemic
- War
- Sustainability improvement
- Humanitarian aid
- New medicine supply programs

System of medical logistics



Practical problem statement

- **Subregional centers центри (SRC)**: Necessary for intermediate transportation.
- **Limitations:** only some SRCs can be activated
- **Distribution**: SRCs receive medical supplies from RCs and redistribute them to DCs.
- **Tasks**:
  - determine locations of DCs;
  - determine the effective combination of SRCs and the optimal transportation plan.
- **Goals**:
  - minimizing overall transportation costs;
  - meeting the needs of each institution for medicines and medical supplies;
  - infrastructure development.



Mathematic model

- Ω – customer distribution area;
- N – the required number of DCs;
- M – the total number of SRCs available for activation;
- L – the maximum number of possible activated SRCs;
- J – set of subregional centers available for activation;
- b_i^I – demand of the i-the DC, $i = \overline{1,N}$.
- b_j^{II} – capacity of the j-th SRC, $j = \overline{1,M}$;
- A_j – activation costs for j-th SRC;
- $c_i^I = c(x, \tau_i^I)$ - transportation cost between DC i and customer at x;
- $c_{ij} = c(\tau_i^I, \tau_j^{II})$ - transportation cost between SRC (τ_j^{II}) and DC (τ_i^I);
- $\rho(x)$ – demands from medicines in point x of the area Ω;
- $\tau_i^r = (\tau_{i1}^r, \tau_{i2}^r)$ – coordinates of DC(r=I) or SRC (r=II);
- v_{ij}^I – the volume weight units number of medicines and medical equipment transported from SRC j to DC i;
- $\theta_j = \begin{cases} 1, & if\ SRC\ j\ is\ activated, \\ 0, & otherwise \end{cases}.$

$$\min_{\theta(\cdot)\in\Gamma_2,\tau^I\in\Omega^N,v\in R^+_{NM}} \sum_{j=1}^{M} A_j\theta_j + \sum_{i=1}^{N}\int_{\Omega_i} c_i^I(x,\tau_i^I)\rho(x)dx + \sum_{i=1}^{N}\sum_{j=1}^{M} c_{ij}v_{ij}^I\theta_j, \quad (1)$$

$$\sum_{j=1}^{M} v_{ij}^I\theta_j = \int_{\Omega_i}\rho(x)dx, \qquad i = \overline{1,N}, \quad (2)$$

$$\sum_{i=1}^{N} v_{ij}^I\theta_j \le b_j^{II}, \qquad j = \overline{1,M}, \quad (3)$$

$$\sum_{j=1}^{M}\theta_j \le L, \quad (4)$$

$$\bigcup_{i=1}^{N}\Omega_i = \Omega, \quad (5)$$

$$\Omega_i \bigcap \Omega_j = 0, i \ne j, i,j = \overline{1,N}, \quad (6)$$

$$v_{ij}^I \ge 0, \theta_j \in \{0;\ 1\}, i = \overline{1,N}, j = \overline{1,M}, \quad (7)$$

$$\tau^I = (\tau_1^I, \tau_2^I \dots \tau_N^I), \qquad \tau^I \in \Omega^N. \quad (8)$$

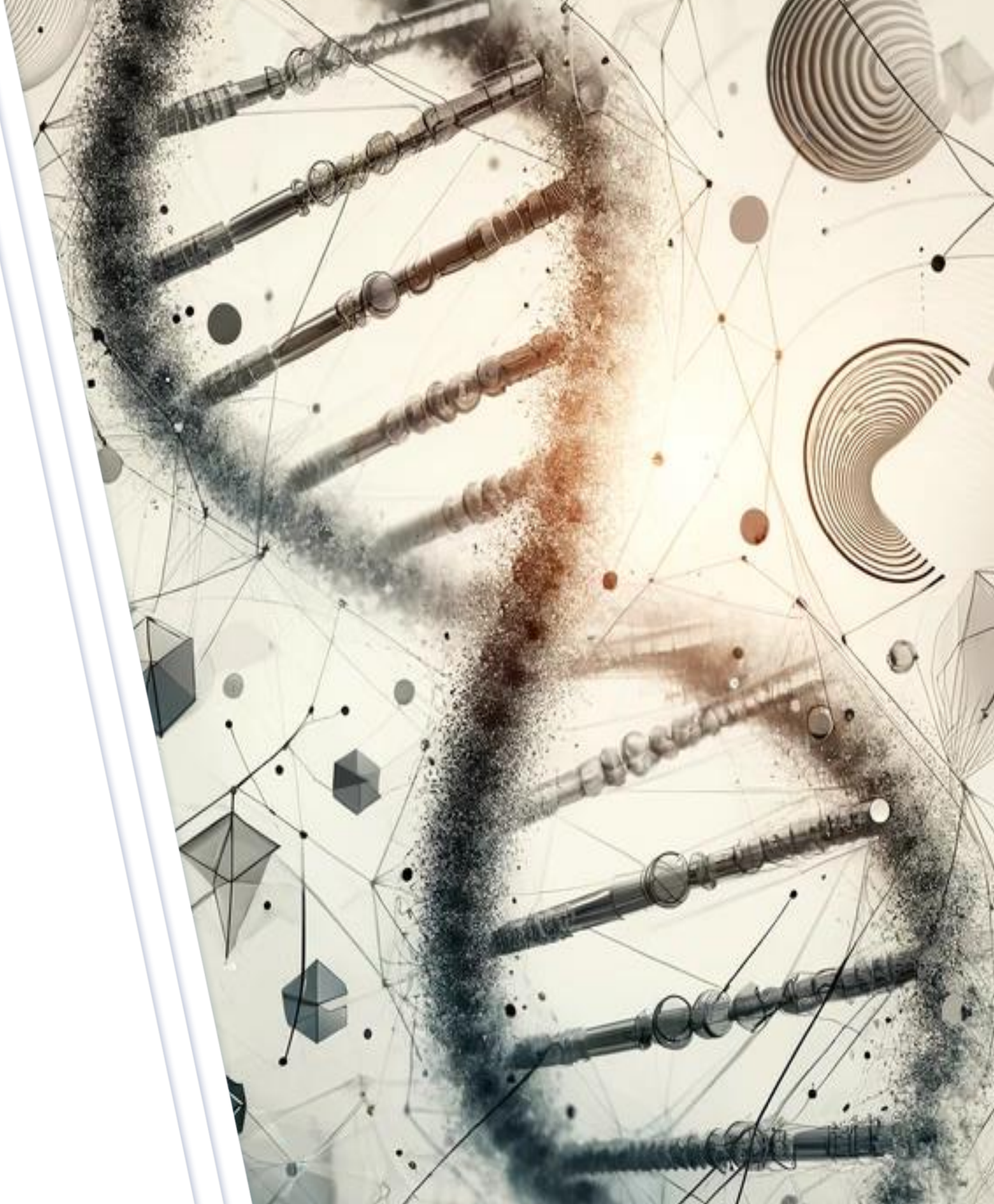
Solution approach

We are going to use the combination of:

- genetic theory;
- optimal set partition theory.

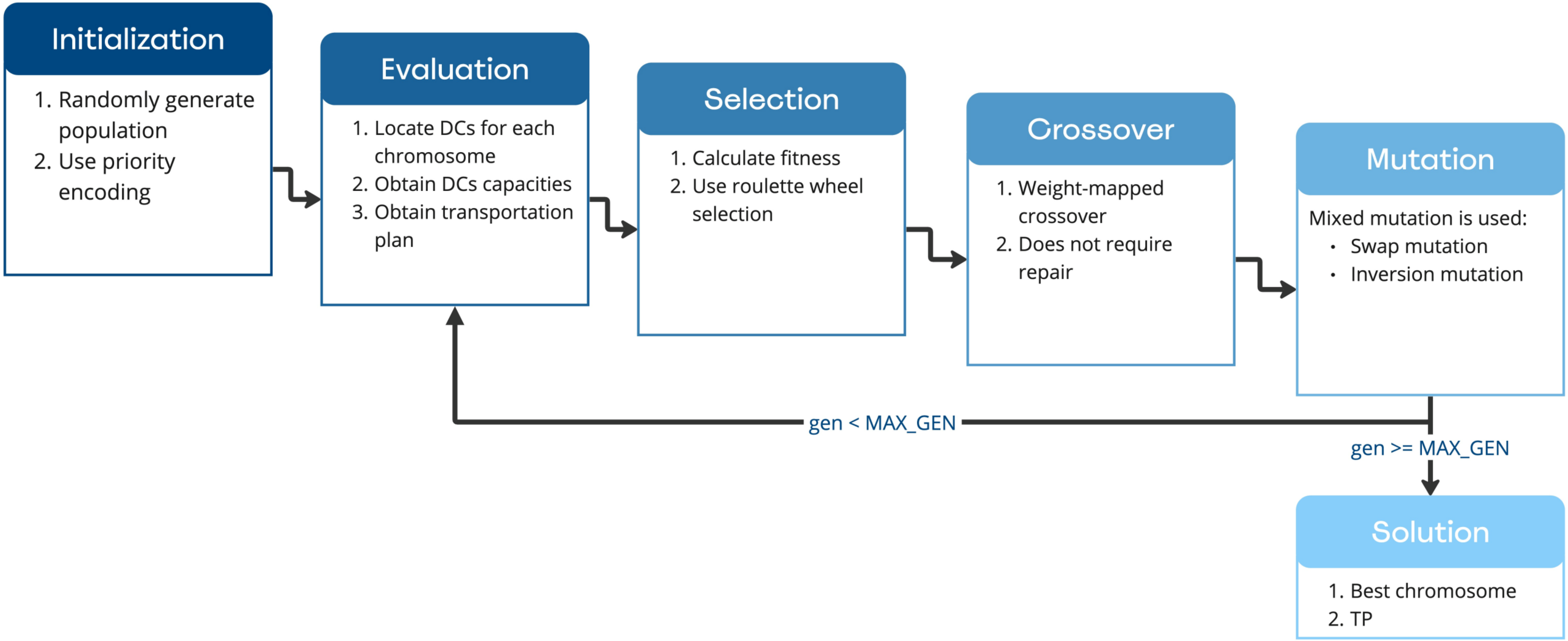
We propose:

- modify approach from optimal partition of sets theory and take into consideration two stages and transportation plan;
- modify the chromosome evaluation procedure in the form locating DCs and building a transportation plan.



Algorithm for solving

- **We propose the following algorithm for solving**



Software implementation

The proposed algorithm is implemented using the following technologies:

- C++
- Python
- Qt6

Model task – initial parameters

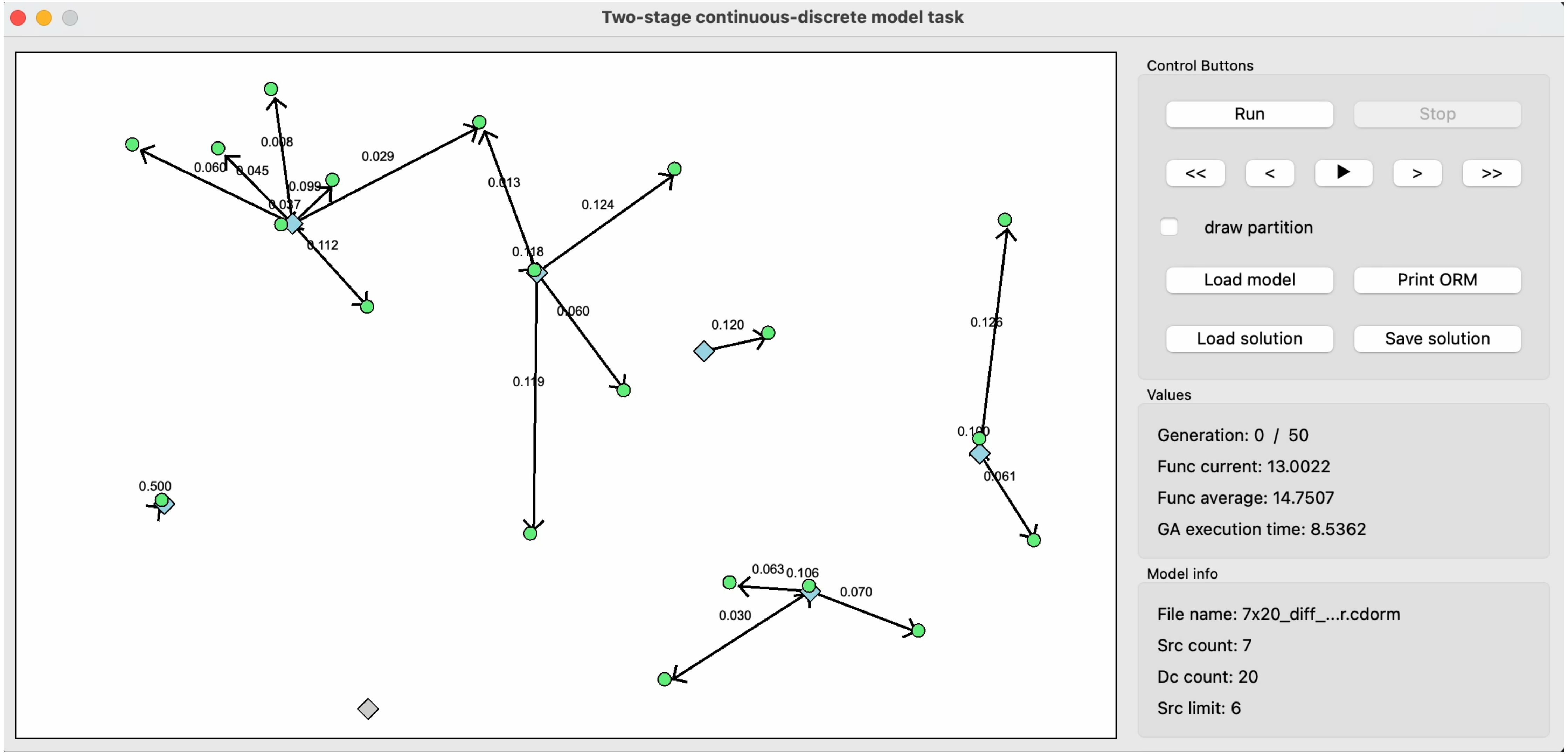
Let's apply proposed solution to the following model task:

GA parameters	
Population size:	50
Max generations:	50
Initial mutation probability:	0.15

Optimal partition parameters	
Max iter:	1000
Solver grid:	h: 100 steps v: 50 steps
Tolerance	1e-4

Model task parameters	
Number of SRC(*M*): Number of DC(*N*): Limit for SRC (*L*):	7 20 6
Area size:	rectangle: w = [0; 2]; h = [0;1]
SRC capacities vector:	[0.4, 0.39, 0.41, 0.42, 0.38, 0.45, 0.5] sum = 2.95
DC demands vector:	[0.5, 0.008, 0.126, 0.07, 0.06, 0.03, 0.119, 0.037, 0.12, 0.112, 0.099, 0.045, 0.124, 0.06, 0.1, 0.063, 0.106, 0.118, 0.042, 0.061] sum = 2.0
SRC activation costs vector:	[1.5, 1.3, 1.35, 1.2, 1.8, 1.5, 1.56]

Model task – solution process



Conclusion

- Investigated and described a system of medical logistics under crisis conditions;
- proposed a practical problem statement that addresses the weak points of the mentioned system;
- developed a mathematical model for the described problem;
- utilized the combination of genetic and optimal partition of sets theories as a solution for this problem;
- illustrated its work via solving model task.

Future research

- Real distance utilization during solving
- Time interval constraints for a discrete part of the problem
- Consider the influence of regional centers

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