System for Automation of Research in Macroeconomic Modeling

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MIX system project

- MIX system is jointly developed by Institute of Economics and Industrial Engineering of the Siberian Branch of the RAS, Institute of Informatics Systems of the Siberian Branch of the RAS, and Novosibirsk State University.
- The extension, called MIX-PROSTOR, is intended to model transport problems at the national level.
- The system can be used for research and educational (math-economics) purposes.

The underlying economic model

- The approach of interest to the definition of Russian core transportation network is based on a group of economic-mathematical models of transport-economic balances (TEB).
- Transport-economic balances allow for describing and analyzing the relationships between the sectors of economics or regions under the conditions of competition between the different types of transport.

Global Model Workstation – Oxford Economics

Project objectives

Our aim is to provide an interactive graphical user-friendly interface and geo-informational support for the research process. We have identified the following tasks that need to be studied:

1. ***Editing the transport network.*** To do this, one must specify a list of products, transport types, relevant hubs and lines as well as their parameters described above.

Project objectives - *Modeling*

When the transportation network is specified, the researcher may address the problems of forecasting such as:

- What will happen if tariffs on this particular line are halved?
- What would be the impact on transportation if the production at this hub increased?
- How much should the transportation tariffs on this line be reduced so that it becomes economically useful for transportation?

Project objectives – *Editing and Modeling*

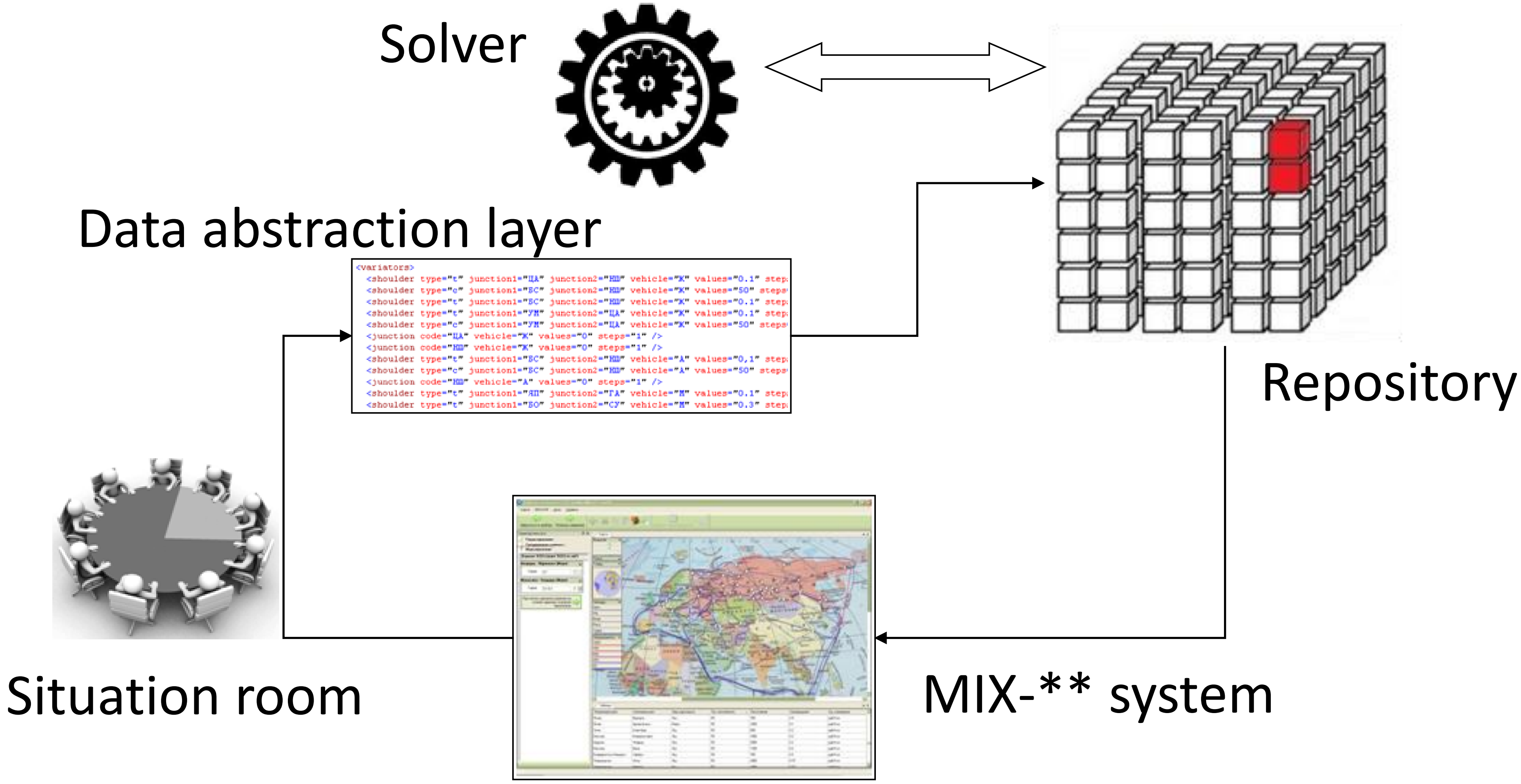
- We provide a user-friendly way for formulating possible changes of parameters and allow for comparisons of the results of the optimization solver for various sets of changes.
- In order to manipulate with the sets of changes, we have introduced the notion of *series of variants* that allows not only for changing a particular parameter value, but also for a diapason of values over which the value of a parameter is to be iterated with a specified step.
- This makes it possible for the researcher to run a series of tasks in the batch mode and select the best solution as the basis for additional changes on the next step of expert analysis.

Project objectives – *The situation room*

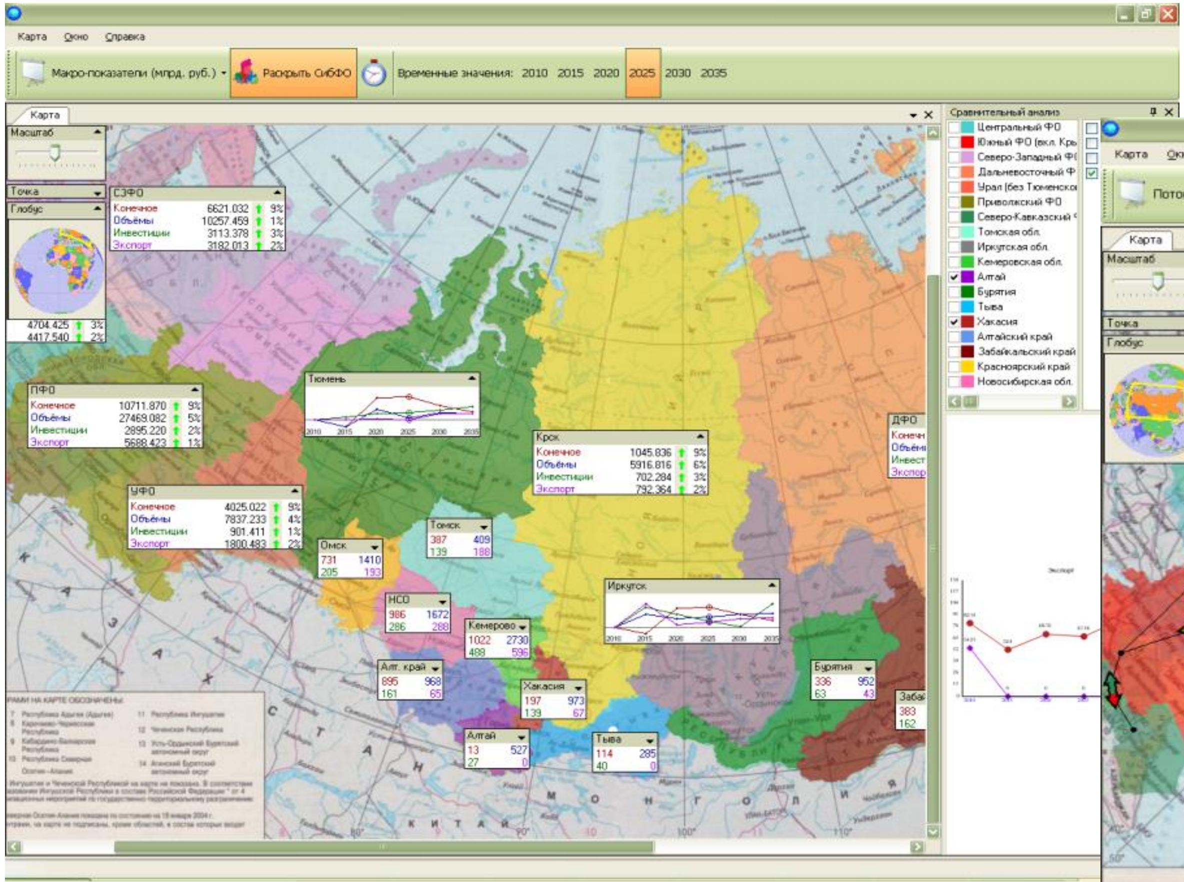
The specificity of the task prevents us from an unambiguous interpretation of the solution provided by the problem solver.

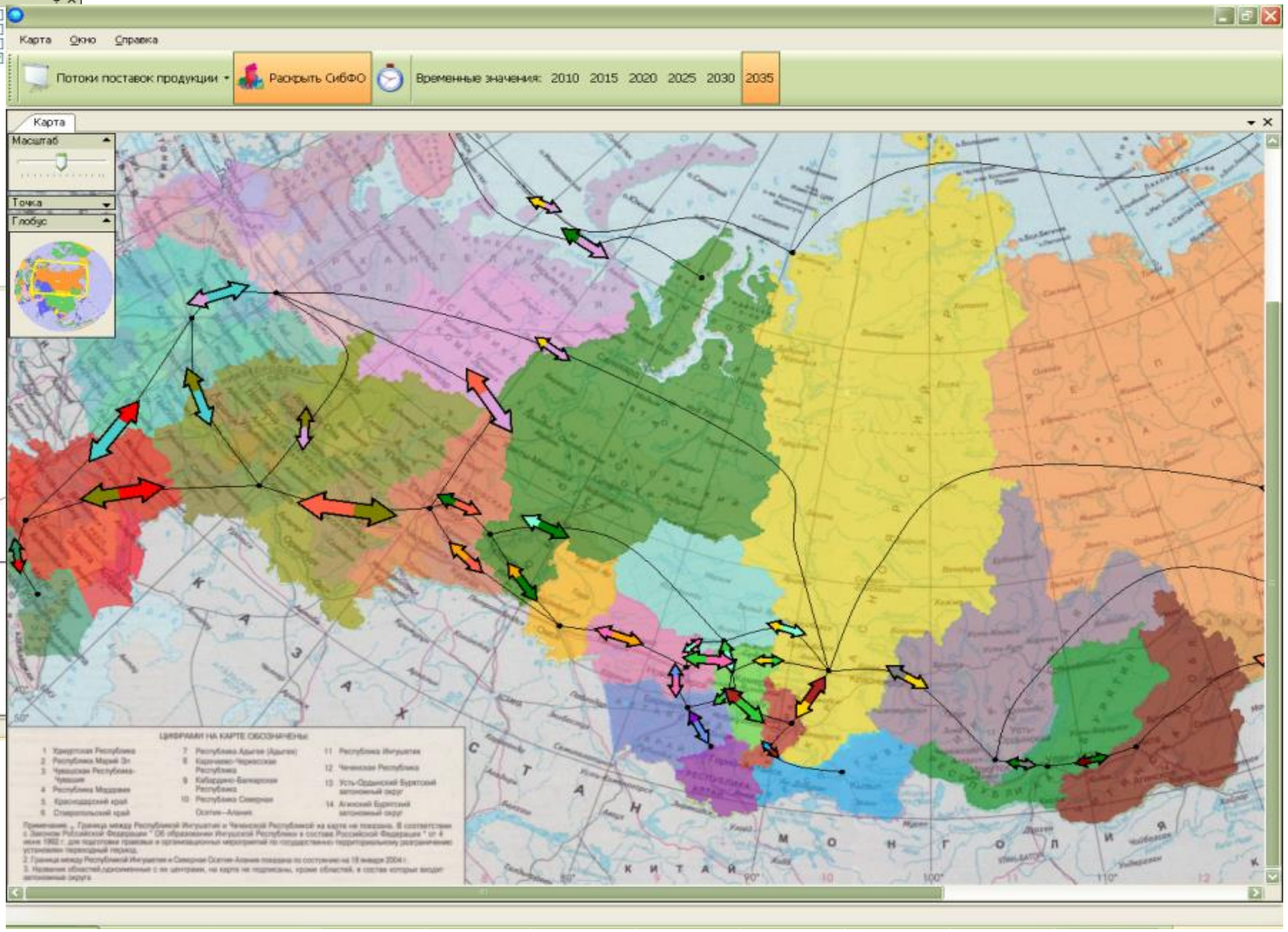
- The expert must interpret the results, analyze their property and decide which solution is the most promising.
- Moreover, the research result in this case is the correct formulation of the problem of the forecast that a researcher can make in the process of modeling various solutions.
- To be able to share an interesting forecast variant with other professionals who are not experts in the subject area, the concept of the situation room has been proposed.

MIX System architecture

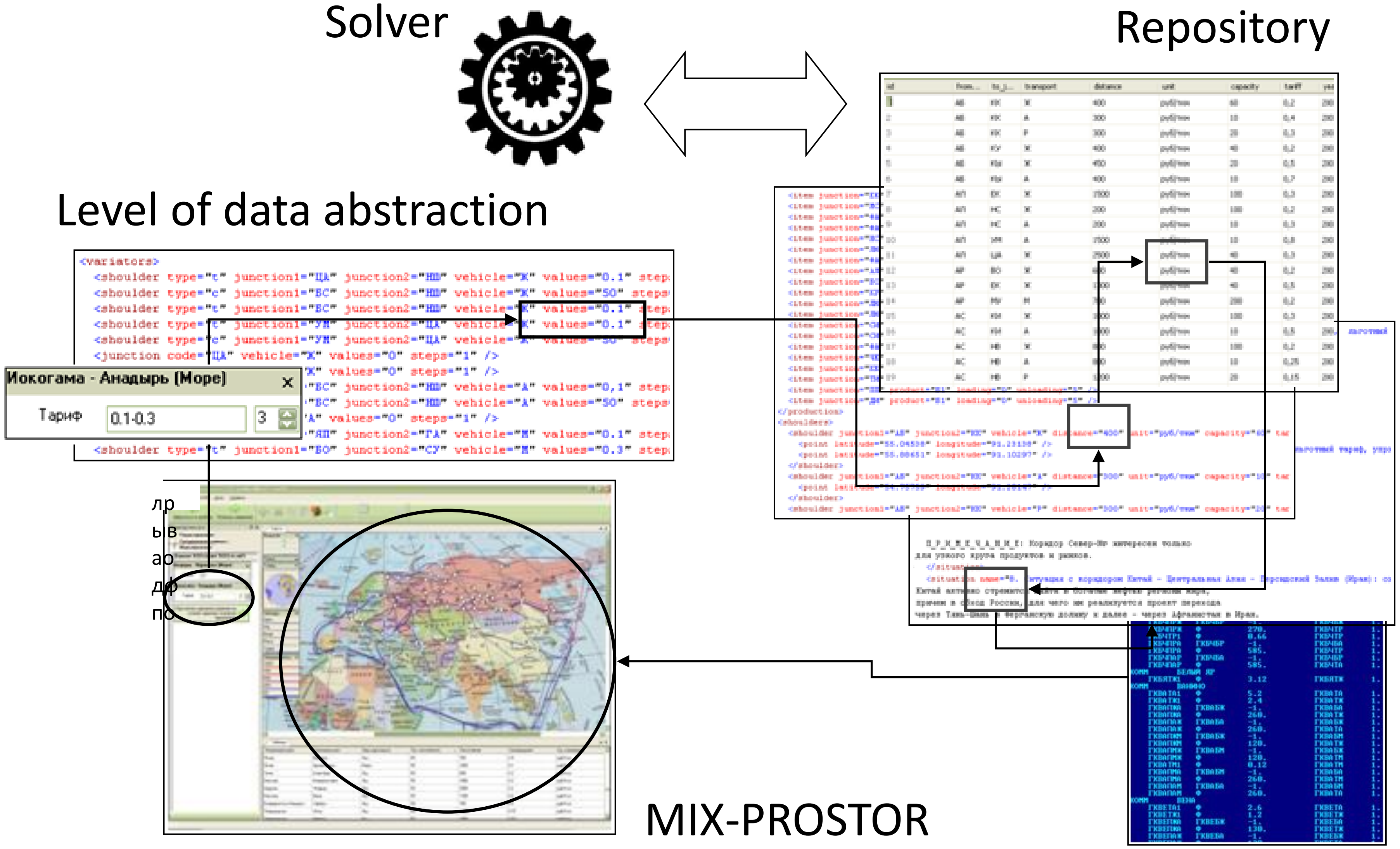


Another MIX-subsystem – Inter-regional economical relations





MIX-PROSTOR architecture



Data model for transport network development forecast

- ***product*** is a conditional group of goods for transportation, which are all produced and consumed goods;
- there are 5 ***job types*** of work related to the operation of the transport network: loading, unloading, transportation, transit, as well as transshipment from one type of transport to another for valid products and pairs of transport types;
- ***type of transport*** assumes indication of tariffs to perform each type of works for this type of transport;
- ***hub*** is the geographical point for which possible operations on the processing of products of a certain type are defined. Since the hub is an operator, its maximum performance and coefficients for tariffs are to be specified for each type of work. There are different types of hubs: *producers* (primary loading points) and *consumers* (final unloading points);
- ***line*** is the basic unit of a transportation network connecting adjacent hubs. Each line is parameterized by length, capacity and tariffs for transportation for each type of transport and product. Lines are complemented by a sequence of geographic coordinates for rendering the corresponding path on the map.

Model variables

Let $I=\{i,...\}$ be a set of all product types, $J=\{j,\tau,...\}$ be a set of all transport types, and $R=\{r,s,..\}$ be a set of all hubs. The following amounts of product *i* processed at hub *r*:

- X_{ir}^{j} - accepted for loading on j
- Y_{ir}^{j} - accepted for unloading on j
- $V_{ir}^{(j\tau)}$ - reloaded from j on τ
- $\overline{V}_{ir}^{(\tau j)}$ - reloaded from τ on j
- Z_{ir}^{j} - transit on j
- W_{irs}^{j} - sent to adjacent hub s
- $\overline{W}_{isr}^{j}$ - received from adjacent hub r
- B_{ir} - the upper limit to be sent on all transport types
- A_{ir} - the lower limit to be received on all transport types

Model parametrs

- $l^{j}_{(rs)}$ - the distance between adjacent *r* and *s* on transport j
- ϕ^{j}_{irs} and $\overline{\phi}^{j}_{irs}$ - specific, with respect to the product amount unit, price for the transportation of *i* on j from r to adjacent s and back, respectively.

Model Constraints

1. Constraint on the amount of the product i generated and accepted for loading at the hub r: $\sum_j X_{ir}^j \le B_{ir}$,
2. Constraint on the amount of the product i accepted for unloading at the hub r:

$$\sum_j Y_{ir}^j \ge A_{ir},$$

3. The amount of the product i that transits through r on j:

$$Z_{ir}^j = \sum_s \overline{W}_{isr}^j - Y_{ir}^j - \sum_\tau V_{ir}^{(j\tau)}$$

4. The amount of product reloaded from one transport to another:

$$\sum_\tau V_{ir}^{(j\tau)} = X_{ir}^j + \sum_s \overline{W}_{isr}^j + \sum_\tau \overline{V}_{ir}^{(\tau j)} - Y_{ir}^j - \sum_s W_{irs}^j$$

Model objective function - I

The objective function of the model is the minimum of expenses for the transportation of all products from hubs-producers to hubs-consumers. The functional can be represented as a sum of components corresponding to expenses for a particular transportation operation:

- processing of the product at hubs
- transportation of cargo per se.

Model objective function - II

$$\sum_{i,r,j} c_i^j X_{ir}^j + \sum_{i,r,j} \overline{c}_i^j Y_{ir}^j + \sum_{i,r,j} c^j Z_{ir}^j + \sum_{i,r,(j\tau)} c_{ir}^{(j\tau)} V_{ir}^{(j\tau)} + \sum_{i,r,(\tau j)} \overline{c}_{ir}^{(\tau j)} \overline{V}_{ir}^{(\tau j)} +$$

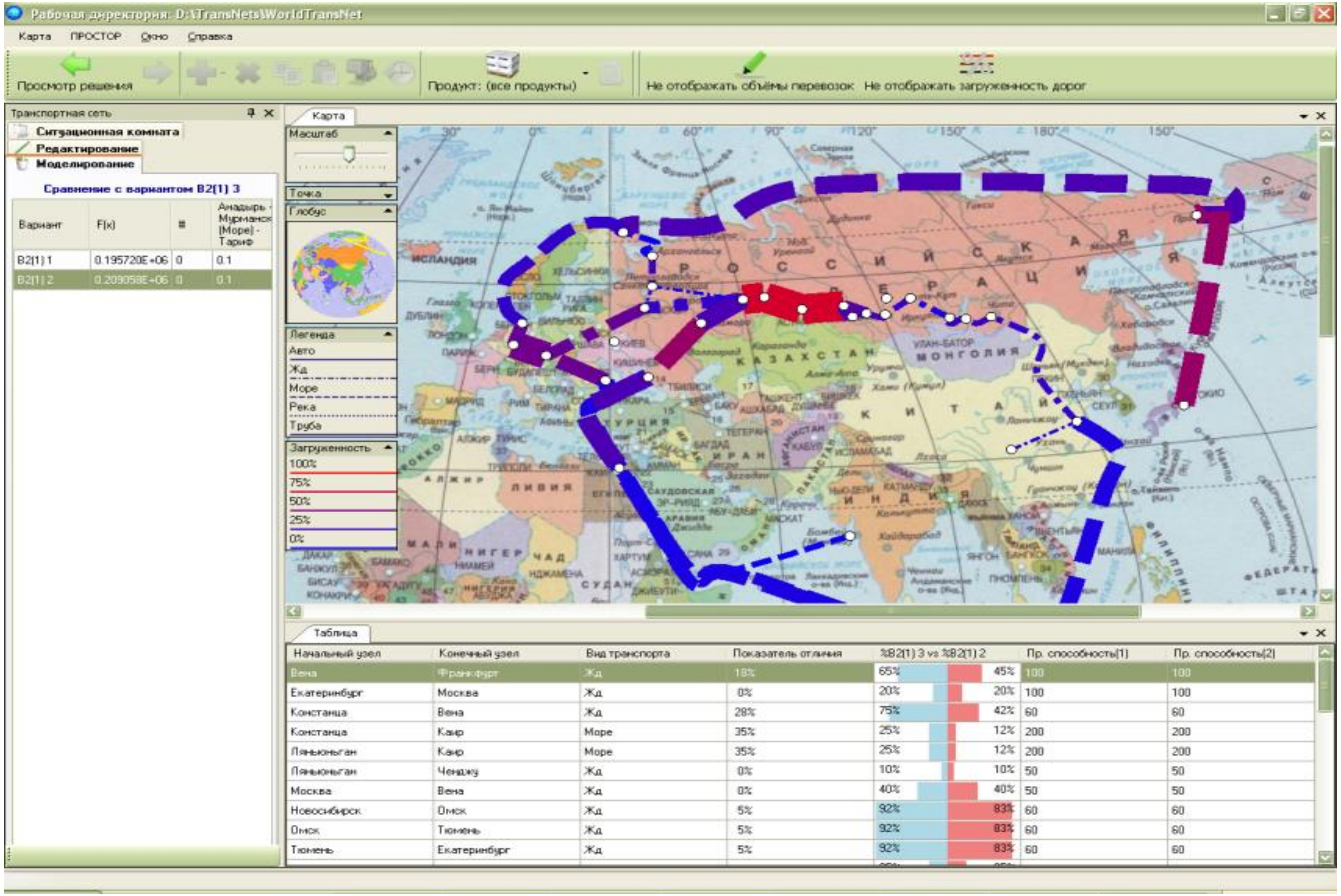
$$+ \sum_{j,i,(rs)} \phi_{(rs)}^j l_{(rs)}^j W_{irs}^j + \sum_{j,i,(sr)} \overline{\phi}_{(sr)}^j l_{(rs)}^j \overline{W}_{isr}^j \rightarrow \text{MIN},$$

where the coefficients c_i^j and $\overline{c}_{ir}^{(\tau j)}$ are specific with respect to the product amount unit, price for loading and unloading, resp

User roles

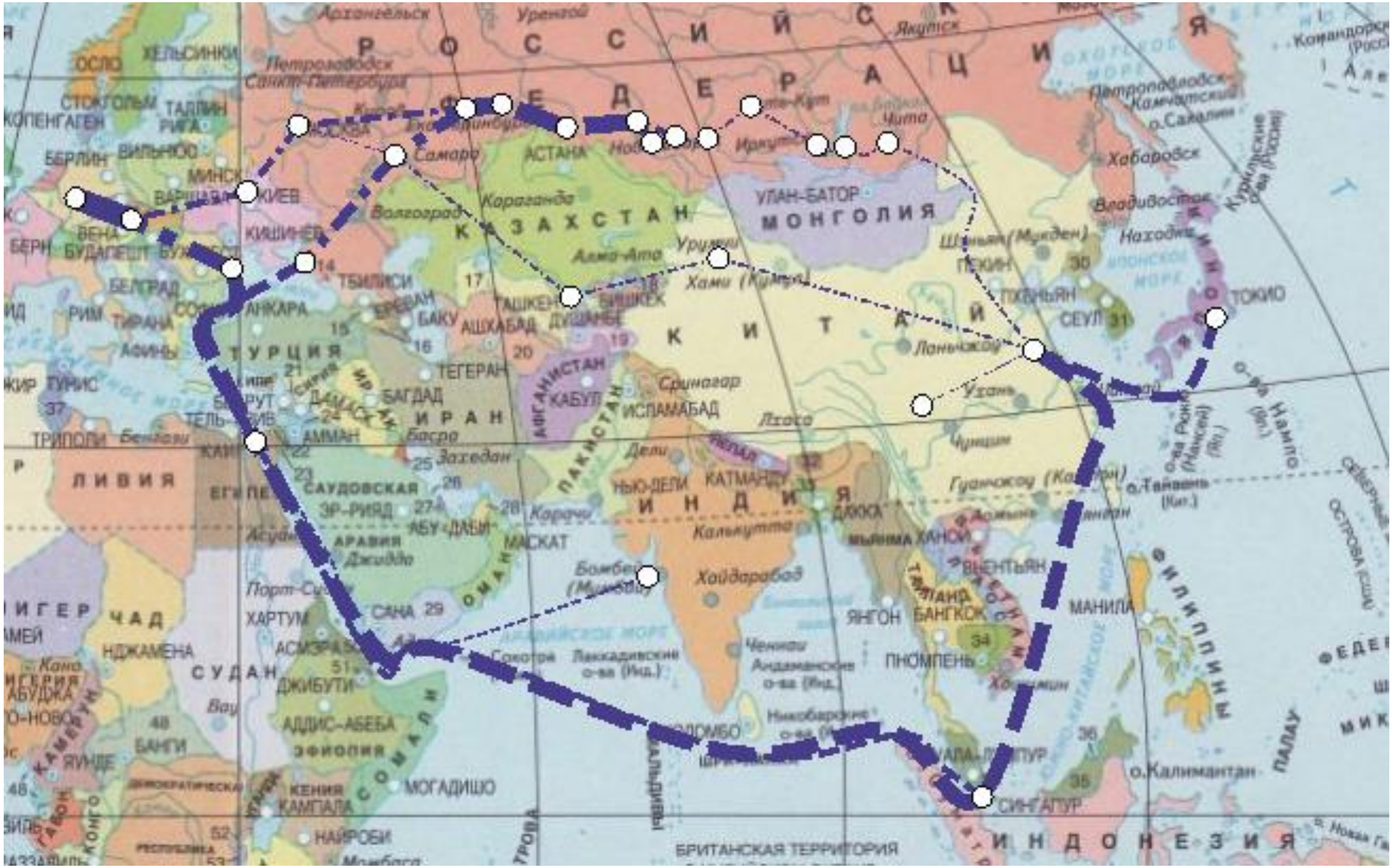
- *The administrator* specifies the fundamental part of the transportation network, especially its geometry, as well as the general lists of product and transportation types.
- *The expert* builds some variants of development, in the problems of modeling and forecasting, by changing the quantitative network parameters for the given economic-mathematical model of a transportation task.
- *The decision maker* experiments with combinations of predefined global situations and draws general conclusions about the development prospects, without going into details of quantitative parameters of the task.

MIX-PROSTOR main window



Display of relative line congestion

Display of transported amounts



Joint display

Situation room

- The ultimate goal of any of the systems considered is the decision making based on expert analysis.
- In practice, the expert is not necessarily a decision maker, and vice versa.
- A decision maker takes into account many factors besides the economical modeling,
- This is one of the reasons while the process cannot be fully automated.

Situation room scenarios

- Elimination of bottlenecks on the Trans-Siberian Railway,
- Completion and rate reduction for the Trans-Caucasian arterial road,
- Increase of the North Sea Route capacity,
- Blocking of the Persian Gulf,
- etc.

North Sea Route and Trans-Sibirean corridors

Таблица

Начальный узел	Конечный узел	Вид транспорта	Показатель отличия	%В2(1) 3 vs %В2(1) 2		Пр. способность(1)	Пр. способность(2)
Вена	Франкфурт	Жд	18%	65%	45%	100	100
Екатеринбург	Москва	Жд	0%	20%	20%	100	100
Констанца	Вена	Жд	28%	75%	42%	60	60
Констанца	Каир	Море	35%	25%	12%	200	200
Ляньюньган	Каир	Море	35%	25%	12%	200	200
Ляньюньган	Чендэу	Жд	0%	10%	10%	50	50
Москва	Вена	Жд	0%	40%	40%	50	50
Новосибирск	Омск	Жд	5%	92%	83%	60	60
Омск	Тюмень	Жд	5%	92%	83%	60	60
Тюмень	Екатеринбург	Жд	5%	92%	83%	60	60

Development plans

- Implement a new transport model.
- Implement replaceable solvers machinery.
- Allowing for varying the initial data in order to obtain different trends and compare different trends rather than a single trend dynamics.

Novosibirsk State University

- Master’s programs taught in English
- Laboratory of Algorithmics
- Mathematical Center of NSU