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CUBE ONLINE ANALYTICAL MODEL (COLAM) IN THE RIVER SHIPPING LOGISTIC FORECASTING

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Abstract: In this paper authors developed Cube Online Analytical Model (COLAM) which should anticipate various restrictions and hazards in river transport system. The aim is to construct a theoretical model which will predict certain delays in transport time caused by topographic and hydrographic constraints, natural hazards (such as ice, floods and droughts), economic and political constraints (tariff barriers between the countries, operating costs, terminal costs and sanctions, the threat of war, etc.) and different technical accidents. COLAM integrates hydroinformatic and hydrologic base of knowledge with real time and gives possibility to provide information for economic queries with different hierarchy of time. COLAM is methodological and practical instrument for this challenge. It integrates hydroinformatic and hydrologic base of knowledge with real time. The model in each concrete case is created to receive information about possible changing of navigation periods on the base of multi-dimension all of three groups of risks (natural hazards, social and technical hazards) as also their combinations.

Keywords: economic geography, COLAM, river shipping, hazards, transport logistics

Introduction

Over the last three decades numerical modeling has received considerable attention for the purpose of flood control and disaster alleviation, water supply and navigation improvement (Vuković, Simeunović, Zalesov, Yamashkin & Shpak, 2015). A large number of numerical river models have been developed (Roushangar, Hassanzadeh, Keyneyad, Nourani & Mouaze, 2011). It is necessary to analyze and apply the latest scientific tools such as data acquisition and management, simulation modeling, data assimilation and improved forecasting capabilities, as well as to look inside into these issues in an integrated manner and to develop disaster management scenarios that can cope

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with extreme situations (Mynett & Vojinovic, 2009). Using of hydrological and hydroinformatics knowledge is crucial for the forecast basis in the process of decision making in the logistics chains (including the river shipping). Information about hydrological data (such as water levels, water flow, water volume of sediments, water quality, etc.) can support decision making for the navigation sector in order to obtain the maximum benefits or to minimize the losses for the economic development, social well-being and environmental balance for the flow of products on the river (Fernández, Jaimes & Altamiranda, 2010). The key economical questions for applying different hydroinformatics models may be formulated as:

– How this river or section of the river can be used in the logistics chain?
– What is duration (period) of river shipping on the specific river (section of the river)?
– What are physics-technical parameters and risks of river shipping on the specific river (section of the river)?
– What is economic utility of using river shipping?

For answering these questions OLAP model is mostly used, developed by Thomsen (2002). This model is based on integration of different data streams in the process of logistics decision making. In our paper we developed Cube Online Analytical Model which should anticipate various restrictions in river transport system. The aim is to construct a theoretical model which will predict certain delays in transport time (which increase costs) in relation to the possible factors of specified geographic area. This model is also OLAP based, but it is also modified for assessing economic feasibility under various constraints and hazards.

The model

To overcome the problem of separating, localizing and weak correlation of data streams for decision making, OLAP technology gives a chance of making solution on the base of multidimensional information and applying hydrological formulas in the multidimensional context (Thomsen, 2002). In this case we deal with Cube online analytical model (COLAM) applied for constructing multidimensional hierarchical model for the logistic forecasting in the river shipping. Using the decision-oriented analysis on the base of decomposition of operations and activities for river shipping logistics we identified three global information blocks in the hierarchy forecasting of river shipping in logistics – three groups of factors (Figure 1).

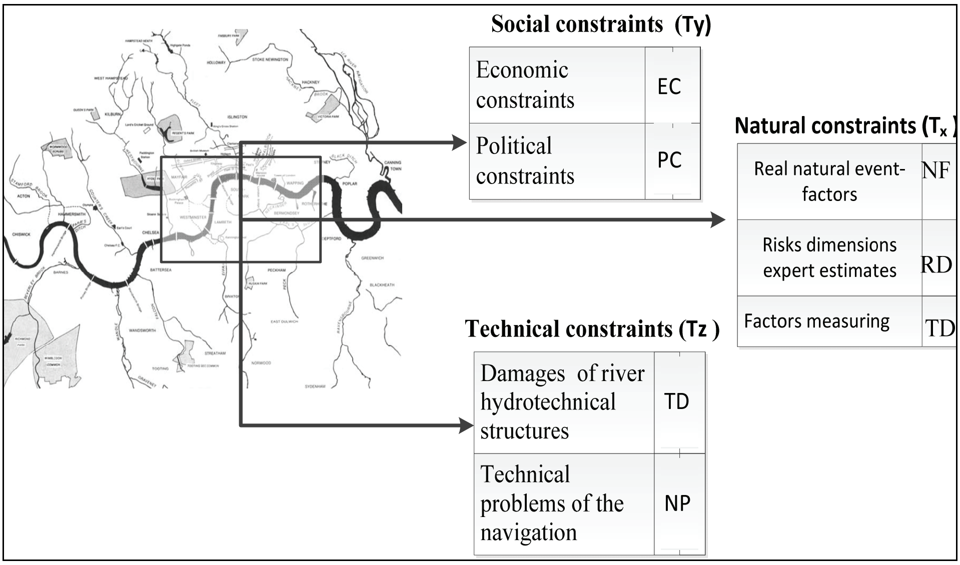

Figure 1. The main block dimensions of COLAM (Source: N. Verbitskaya, 2018)

The model is indifferent to the type of transport. It includes all: passenger vessels, bulk carriers and cargo shipping. In our model the variables and their decomposed indicators are as follows (Figure 1): T_x – natural constraint and hazards, T_y – social constraints and T_z – technical constraints. Our model expresses the effectiveness of time. Time was fundamental since it was necessary to validate the model and to assure that it validates reality, which implies, determine all the times that every ship spends while they are uploading, traveling and downloading. We consider these blocks as the first level dimensions of COLAM, which get sense only with the georeferenced to the river, country, region, city etc. Each of these blocks is the OLAP cube with the own specific set of measurement locators' functions in the multidimensional spreadsheets constituting the components of COLAM.

The RIVER-MODE system provides the hierarchy information online data necessary and sufficient for forming COLUMN data structure. As we noted early, principal data positions for making COLAM are the facts (hydrological observations) and dimensions RIVER-MODE functions (Figure 2) and hydroinformatic, hydrological models chosen in the concrete case study.

In accordance with the multidimensional data model, objects are divided into two sets: a set of measures (facts) $F=\{f_1, f_2...f_n\}$, and a set of dimensions $D=\{d_1, d_2...d_n\}$.

In the first case - Natural factors/risks and hazards *(NF)* (Figure 2) and the set of measures (facts) *F* represent the set of factors:

$$NF = \{f_1, f_2, \ldots f_n\} \quad (1)$$

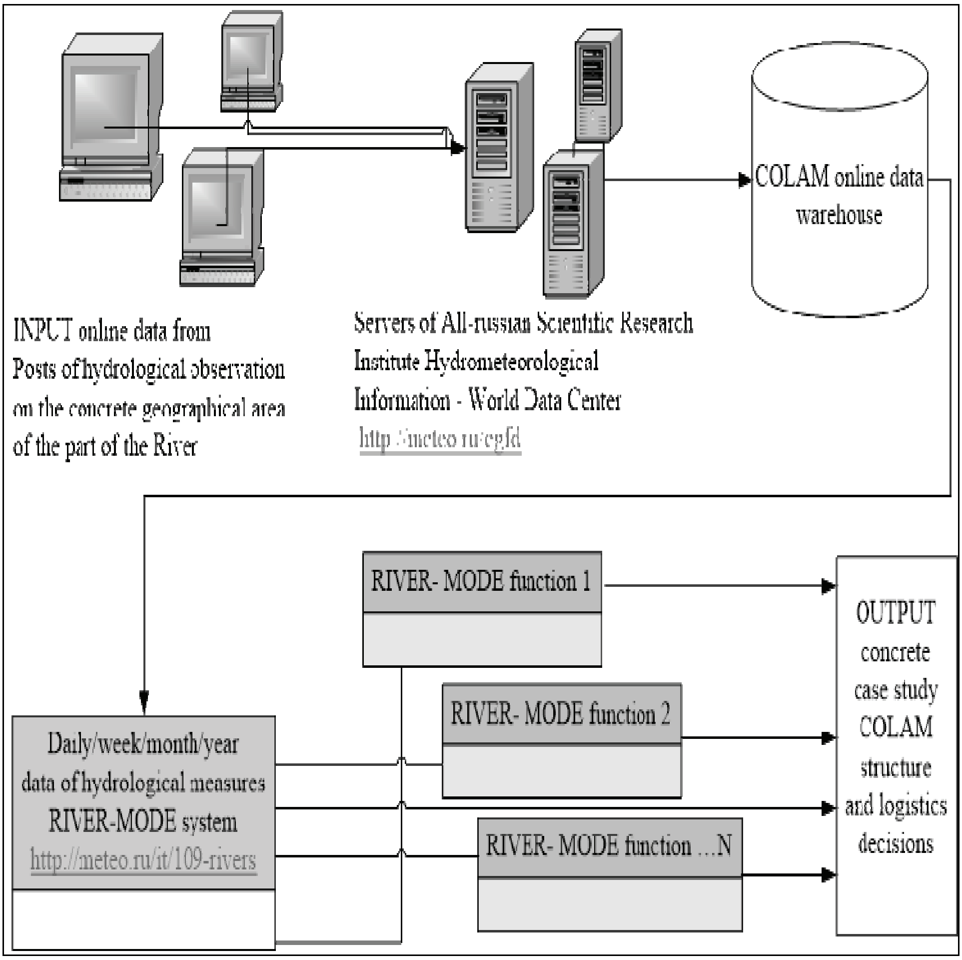

Figure 2. INPUT data for describing factors of COLAM (Source: N. Verbitskaya, 2018)

where $f_1, f_2 \ldots f_n$ are real natural event-factors and hazards for river shipping such as storminess, flood events, blizzards, drought periods, water level, snow cover, etc. (Gregory et al., 2006). The set of dimensions *D (RD)* from the set of *(NF)* represents the numeric characteristics and analysis aspects of such set. The set of *RD* – are the expert estimates hazards on the base of science hydrological and hydroinformatics models and formulas (Petrova, 2011; Gelfan & Moreido, 2014;

Weber, Zhang, Nardin, Sukhodolov & Wolter, 2016) which is given to the time indicator. The third cube dimension is the time T represented as hierarchy periods of time, essential for decision making in the river shipping logistics:

$$TD = \{t_{x1}, t_{x2}, \dots t_{xn}\} \tag{2}$$

The Decart system consists of considered set = *(TD, ND, RF)*, which propose relation:

$$TD \subseteq NF \cdot RD \tag{3}$$

This relation is the aggregate function of utility time for river shipping (for the economics essential information output) for chosen period of decision making:

$$TU = \max(T - TD) \tag{4}$$

where TU is the maximum duration period of river shipping in the logistics chain and TD is the set of forecasting temporary losses from natural hazards. This is the aggregation function for X – dimension of the COLAM.

Results and discussion

As the example of using COLAM in the logistics of river transportation, we shall consider the case study of the annual timber wood rafting on the Northern Dvina River in the Arkhangelskaya region of the Russian Federation. Contrary to other basins of the country, the Northern Dvina timber transportation processes are implemented in more difficult conditions, which are connected with natural risks, such as flooding and summer drought. The main hydrological COLAM factors are presented as the tables (see the Table in the middle of the Figure 3) of input online data from Posts of hydrological look at the observation on the concrete geographical area of the part of the Northern Dvina. These data are basic tables of empirical hydrological facts which connect the current day/month/year (Figure 3).

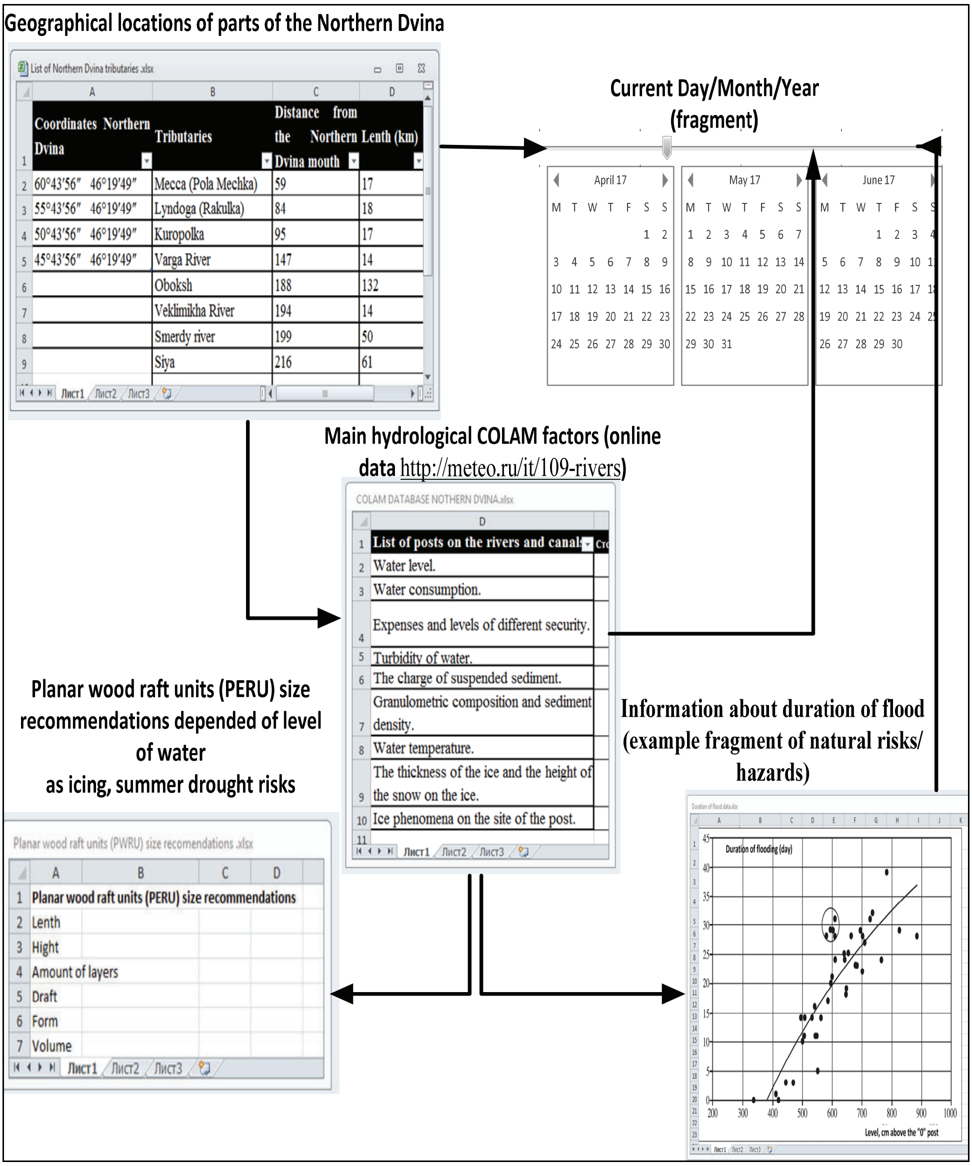

Figure 3. Using COLAM for case study of the timber wood rafting logistics on the Northern Dvina and its tributaries (Source: N. Verbitskaya, 2018)

Choosing the geographical location of the part of the Northern Dvina and its tributaries, we got multidimensional information about:

– duration of river raft navigation period,

– possible natural risks (flood, flooding, summer drought) for chosen period,
– short-term forecast of nature risk period duration (on the base of RIVER-MODE functions),
– recommendations for planar wood raft units (PWRU) size (length, height, number of layers, draft, form, volume) depended on water level and weighted sediment measurements.

Using the structure of these data, we get the output structure queries of COLAM for logistics decision making. The details have been presented in the Table 1.

Table 1. Using COLAM in decision making for rafting navigation on the Northern Dvina and its tributaries

Time	Level of decision making	Queries for COLAM
Real time (data/day)	Schedule of timber wood rafting navigation on the Northern Dvina and its tributaries.	Geographical locations of parts of the Northern Dvina and its tributaries. Duration of river raft navigation period. Information about risks/hazards and duration of their period.
Duration period of utility time of river shipping (months)	Technical-economic plan of planar wood raft units (PWRU) preparing for transportation (length, height, number of layers, draft, form, volume).	Planar wood raft units (PERU) size recommendations depended on level of water as icing, summer drought risks

Source: N. Verbitskaya, 2018

Conclusion

The practical using of COLAM in the decision-making process is connected with geo-referencing of the observed river or part of the river, which is planned to be used in logistic chain. Official information about planning period of river navigation is connected with working period of the gateways. The model in each concrete case is created to receive information about possible changing of navigation periods on the base of multi-dimension of all of three groups of risks (natural hazards, social and technical hazards) as also their combinations. The cube can be used as a program that is based on available data on hazards and restrictions and which could provide information related to the time of river transport. Another important feature of this model is that it offers the possibility to expert to select which data will be included in Cube (the model) – flexibility. This model on the base of risk dimensions gives the possibility to provide information for economic queries with different hierarchy of time. It is way of getting necessary information for making strategic, tactical and operational decisions in the using of rivers (part of the rivers) in the global logistic chains.

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