Mathematical Formation Model of the Logistic Digital Platform in the Agro-Industrial Complex*

Viktor I. Medennikov (0000-0002-4485-7132)[1(*)]

[1] Federal Research Center "Informatics and Control" of the Russian Academy of Sciences, Moscow, Russia

dommed@mail.ru

Abstract. The paper focuses on analyzing the state and trends of digital agricultural transformation in the developed countries and the Russian experience of AIC informatization. The work considers the possibility of forming a digital logistics platform as a connection of all participants in the value chain. The chain includes product manufacturers, resource suppliers, product consumers, and logistics companies, excluding unnecessary intermediaries. The digital technologies evolution from the digitalization of individual operations to the digitalization of an interconnected complex of operations serves as the basis for developing a digital logistics platform. This is relevant not only in agriculture but also in related industries, integrating all operations based on cloud technologies. We consider the scientific foundations for designing a digital logistics platform for AIC based on mathematical and ontological modeling, integrated into a single digital platform for managing the country's economy. We provide an analysis of the state of the Russian logistics industry, which hinders the development of the economy. It is important to emphasize that the concept of the national platform "Digital Agriculture" prepared by the Ministry of Agriculture at the end of 2019 does not pay attention to integrating information resources and systems and developing logistics activities.

Keywords: Logistics · Digital platform · Mathematical modeling · Agro-industrial complex

1 Introduction

We analyzed the experience of digital agricultural transformation in various countries. We found that depending on the possession of financial, labor, material, and technical resources, social capital focuses on the most effective, from their point of view, directions of this global process. Based on these data, the following basic principles of digital transformation are highlighted:

- Creation of an information management system that collects, processes, stores, and distributes the necessary data. For this, there is a form adapted to the daily farm operation, based on the widespread integration of disparate data into a single system;

- Precision agriculture, i.e., time and place-verified production process control. This, in turn, improves its economic characteristics, reduces the burden on the environment;
- Use of satellite navigation systems, images of fields obtained using remote sensing of the Earth, allowing one to create a card index of data on soil characteristics, crop yields, moisture, nitrogen content, etc.;
- Active introduction of automation and robotization at all levels of agricultural work;
- Revision of the ideology, technology, and organization of enterprise management, formalized in the form of standards, as a result of the fusion of information technologies and technologies of people management;
- Personnel training with new competencies.

In the context of the first principle, J'son & Partners Consulting (IKS-MEDIA, 2018) believes that agriculture has two distinct platforms: aggregator platforms for industry information or platforms for primary collection and accumulation of data ("information resources") and applied platforms ("applications"). It is regarded that the interaction between them must be based on cloud technologies and services since only this model makes them available to farms of all sizes, and not just for some of the largest.

The emergence of digital cloud services available to all farms creates the necessary prerequisites for dramatically increasing efficiency and reducing industry risks. It is actual for all value chain participants, including resource suppliers, product consumers, and logistics organizations. The introduction of such a cloud-based approach in the agricultural sector is just beginning to be seen. The highlight of the digitalization of AIC is that the widespread introduction of digital technologies, including agricultural production, makes it possible to switch to a new type of production enterprise. Production begins to be based on the principle of current control of all operations, which will make it possible to perfect the production process (Medennikov & Raikov, 2020). This will make it possible to implement the predictive principle of building agricultural production, based on a deep analysis of the entire set of data on fluctuations in supply and demand, opportunities, availability of resources, financing, and other equally important components of the entire chain from production to consumption, moreover, requiring information compatibility of the flow data along the entire chain.

Logistics was among the first industries to realize the need for an integrated, systematic approach to managing its activities based on innovative IT solutions. The ability to continuously monitor material flows in real-time in remote access modes through information systems played a decisive role in this approach. With this system, potential opportunities for production, supply, and consumption are covered with the transition to integrated electronic logistics (Toluev & Plankovsky, 2009; Ereshko, Medennikov, Baida & Gaidash, 2018). However, the insufficient level of integration of information systems of organizations participating in specific supply chains, disordered, chaotic development of new opportunities of Internet technologies leads to the emergence of many intermediaries in the entire value chain. Therefore, the spontaneous process of integrating the platform-aggregator of information resources and the application platform for all participants in the value-added chain needs a theoretical justification, which is proposed in this work.

2 Materials and Methods

In Russia, the conceptual issues of this approach have been studied. This study occurred as a result of calculations based on the model for the synthesis of optimal information systems (IS) (Medennikov, 1993) as the “Agricultural Electronization” task of the Comprehensive Program of Scientific and Technological Progress (STP) of the Member States of the Council for Mutual Economic Assistance (CMEA). Later, this approach was theoretically substantiated in several works (Zatsarinny & Shabanov, 2017; Flerov & Vyshinsky, 2018; Medennikov, 2018). Thus, an economic and mathematical model for the formation of digital platforms [DP] for managing the country's economy was developed, which allows calculating the optimal DPs in AIC (Medennikov, 2019). The model singled out several digital sub-platforms, a cloud service for collecting and storing operational primary accounting information of all enterprises in a single database [SDPA]. The second is also a cloud service of a unified technological accounting database [SDTA] of all enterprises with an ontological information model, for example, crop production formed based on SDTA and SDPA, common for all agricultural enterprises in Russia (standard for information resources [IR]) with the allocation of 240 functional management tasks with a unified description of algorithms also for most agricultural organizations (application standard). Similar work was done for all branches of agricultural production and 19 types of processing enterprises.

The requirements for information compatibility of data along the entire value chain are a powerful incentive for logistics to implement current integrated information technologies. The prospects for the development of logistics activities are becoming more transparent with distributed ledger technologies. This is also facilitated by forming a single information Internet space for the country’s digital interaction.

Since logistics was one of the first industries that realized and felt the need to integrate disparate logistics processes into a single system, then leadership developments in this direction should have appeared here. Logistics was the first to carry out ontological activity modeling to establish specific standards for terms and concepts accepted globally. In particular, in the form of the SCOR-model (Supply-Chain Operations Reference model), developed by the International Organization-Supply Chain Council (The Supply-Chain-Council-SCC) (“SCOR-model,” 2017).

As a result of the improvement of ICT and the acquired experience in logistics, the following levels of integration of their activities occurred (Ereshko et al., 2018).

- Subcontracting Supply Network [SSN] is an association of legally independent organizations, interconnected only by contracts, collaborating, and implementing the general movement process of products from raw materials to the final consumer.
- Information Subcontracting Network [ISN] is also an association of legally independent organizations forming a single information space of technological resources. The final product or service is produced based on the operational allocation of resources. Through the developed website, within the ISN, one can find a supplier, an order, and place one's information.
- Production and Logistics Network [PLN] combines the concepts of SSC and ISN and is the highest point of logistics activities integration. Unlike ISN, which is a kind of "bulletin board," in the PLN, a single information space [SIS] is a platform for planning and managing projects on the Internet, with a shared database in the "cloud" data on the performance of logistics operations, classifiers, and standards common to all registered participants.

In the concept of PLN, the SIS includes only a small part of autonomous enterprises with a limited set of information content. This is for the integrated planning purpose and management of implementing a limited set of projects in the network (Medennikov, 2018). In turn, based on the proposed economic and mathematical model for digital platforms forming, the concept of forming a single information Internet space of digital interaction [SIIS DI] of all enterprises and organizations of industries, country, including AIC. We believe that it is necessary to create a unified system for collecting, storing, and analyzing primary accounting and statistical information. This information is integrated with a unified system of classifiers, reference books, standards representing the registers of practically all material, intellectual and human resources based on ontological modeling of these types of information resources. This digital platform can form supply chains of arbitrary configuration with the participation of the majority of economic entities in almost all country's sectors.

3 Results

We formalize the most popular external logistics management system. The goal is more efficient analysis, planning, and design of supply chains. In this case, participants in the supply chain are the following groups: suppliers, consumers, warehouses, and transport companies.

The goal is to form optimal logistics chains to supply products to consumers by transport companies using warehouses based on minimizing the total costs of products, their transportation, and storage services. At the same time, there should be a choice of suppliers of products, a choice of warehouses, and transport companies with loading vehicles. The tasks are solved in a complex way: tracking transport, managing orders (requests), managing transport costs, and warehouse services. We believe that there are enough transport companies to satisfy all needs, and the supply of goods exceeds demand. It is assumed that there is a systematic control process with a T period and that all logistic operations are averaged over time.

We do not consider such characteristics of vehicles as capacity, transported cargo volume, etc. We consider the actual capacity of the vehicle with the specific capacity. For the unit of the product, the supply volume of storage, we take both the unit and the volume of the specific capacity of the product.

Mathematical model

The notation is the following:

v_{ik} – demand volume of i – comsumer in k – product, $i \in I$, $k \in K$.

w_{jk} – availability volume of k – product of j – supplier $j \in J$.

p_{jk} – unit price of k – product of j – supplier.

n – transport company size (TC), $n \in N$.

s – warehouse number, $s \in S$.

r – number of vehicle category (V), $r \in R$.

R_n – amount of categories V of n-TC.

N_{rn} – V amount of r–category of n-TC.

g_{rn} –V number of r–category of n-TC.

μ_r – specific capacity of the vehicle r–category of V, calculated as the ratio of the total product weight to their volume intended for transportation r–category of V

A_s – warehouse capacity s (according specific capacity), calculated in accordance with converting pallet capacity table into specific capacity

G_r – passport capacity of r – category of V

V_r – body space r– category of V

$d_r = min\ (\mu_r, G_r / V_r)$ – actual capacity of r – category of V with the specific capacity

D_{rn} – sum of actual capacity of all V's of r – category of n – TC with specific capacity, $D_{rn} = d_r * R_n$.

d_{ks} – unit storage and handling rates of k – product in s – warehouse, this value reflects the amount of average specified costs for the T. period

f^1_{irnsh} – transportation prices of a product unit from s – point to I – point (delivery place of i – consumer) r – category of V of n – TC through h – point, according the specific capacity r – category of V, $h \in I$.

f^2_{jrns} – transportation prices of a product unit from j – point (product location of j – supplier) to s – point with r – category of V of n – TC, according the specific capacity r– category of V

f^3_{ijrn} – transportation prices of a product unit from (without shiftment) j – point to i – point r – category of V of n – TC, according the specific capacity r – category of V

Variables:

x_{ijk} – delivery volume of k – product from j – point to i – point.

y^1_{irns} – delivery volume from s – point to i – point of r – category of V of n – TC.

y^1_{irnsh} – delivery volume from s – point to i-point of r-category of V of n – TC.through h – point.

y^2_{jrns} – delivery volume of k – product from j – point to s – point of r – category of V of n – TC

y^3_{ijrn} – volume of direct deliveries from j – point to i – point.

y^4_{ks} – storage volume of k-product in s-warehouse.

c_1 – supplying cost of all products from all s – points to all I – points.

c_2 – supplying cost of all products from all j – points to all s – points.

c_3 – supplying cost of all products from all j – points to all i – points

c_4 – storage cost all products in all warehouses

c_5 – total cost of all supplying products.

c_0 – total cost of the supply chain

Formulas and inequalities:

$$\sum_j x_{ijk} = v_{ik} \tag{1}$$

$$\sum_i x_{ijk} \leq w_{jk} \tag{2}$$

$$\sum_{is} y^1_{irns} + \sum_{js} y^2_{jrns} + \sum_{ij} y^3_{ijrn} \leq D_{rn} \tag{3}$$

$$\sum_{irns} y^1_{irns} = \sum_{jrns} y^2_{jrns} \tag{4}$$

$$\sum_{jk} x_{ijk} = \sum_{rns} y^1_{irns} + \sum_{jrn} y^3_{ijrn} \tag{5}$$

$$\sum_{ik} x_{ijk} = \sum_{rns} y^2_{jrns} + \sum_{irn} y^3_{ijrn} \tag{6}$$

$$\sum_{jrn} y^2_{jrns} = \sum_k y^4_{ks} \tag{7}$$

$$y^1_{irns} = \sum_h y^1_{irnsh} \tag{8}$$

$$\sum_{irn} y^1_{irns} = \sum_k y^4_{ks} \tag{9}$$

$d_r - \varepsilon_r \le y^3_{ijrn}$ – almost full load demand (ε_r – obtainable undercapacity) of direct product deliveries from *j* – point to *i* – point with *r* – category of V of *n* – TC;

$d_r - \varepsilon_r \le \sum_i y^1_{irnsh}$ – almost full load demand (ε_r – obtainable undercapacity) of *r* – category of V of *n* – TC when the product supplying from *s* – point to *i* – point through *h* – point;

$\sum_k y^4_{ks} \le A_s$;

Effectiveness criterion

$$c_1 = \sum_{irnsh} f^1_{irnsh} \, y^1_{irnsh} \tag{10}$$

$$c_2 = \sum_{jrns} f^2_{jrns} \, y^2_{jrns} \tag{11}$$

$$c_3 = \sum_{ijrn} f^3_{ijrn} \, y^3_{ijrn} \tag{12}$$

$$c_4 = \sum_{ks} d_{ks} \, y^4_{ks} \tag{13}$$

$$c_5 = \sum_{ijk} p_{jk} \, x_{ijk} \tag{14}$$

$$c_0 = c_1 + c_2 + c_3 + c_4 + c_5 \rightarrow min \tag{15}$$

As a result of solving this problem, we obtain specific values: x^*_{ijk}, y^{*1}_{irns}, y^{*1}_{irnsh} y^{*2}_{jrns}, y^{*3}_{ijrn}, y^{*4}_{ks}.

4 Discussion

We believe that the digital logistic platform [DLP], based on this structure of the SIIS DI (the digital platform of the country), can form logistic chains of arbitrary configuration with most of the country's participation economic entities.

Also, we consider that the DLP implementation can effectively implement the distributed ledger technologies and smart contracts in logistics. While the joint implementation with the SIIS DI will potentially provide real-time tracking of goods, reduce the workflow, and increase transparency. According to the WTO, removing barriers in the international supply chain of goods will increase global GDP by 5% (Ereshko et al., 2018).

The state of logistics, like digitalization, is far from the ideal in Russia. The world ranking of logistics efficiency in Russia is 95th globally (out of 155 countries on the list). In our country, the level of logistics costs in the economy is one of the world's highest. The total internal and external costs are about 20% of GDP, in China – about 15%, in the EU – 7–8%. As a result, production inventories exceed this figure in the EU and the USA by 18%. In Japan, the reserves are 64% lower than the Russian ones (Ereshko et al., 2018).

Thus, inefficient logistics is one of the significant factors affecting the low rates of development of the Russian economy. If all logistics costs are reduced to the world average (about 11% of GDP), the country will additionally receive about $ 180 billion per year (Ereshko et al., 2018).

All participants in the activity understand the need for the digital transformation of the transport and logistics services market. One of the significant factors in improving the quality of logistics services is improving the development of various types of associations between all participants in logistics chains through the formation of a single information digital interaction. However, most market participants are waiting for a decision from the government to form the logistics center and the SIIS DI, since the era of task-oriented design of information systems under the guise of digital transformation continues in most industries due to the momentary benefits of this approach.

For example, at the end of 2019, the Ministry of Agriculture developed the concept of the national platform "Digital Agriculture" (TAdviser, n.d.), which provides a list of sub-platforms (the composition of which determines the platform):

- Collection of statistical data of AIC;
- Providing information support and providing services;
- Digital land use and land management;
- Storage and distribution of information materials;
- Traceability of agricultural products;
- Agrometeorological forecasting;
- Service of multifactor operational monitoring, diagnostics, and proactive modeling of the development of diseases in agricultural crops.

However, this approach to the digital platform of agriculture as the sum of these sub-platforms excludes their integration on a single AIC DP. There is no mention of logistics in the concept. This approach to reliance on the market led to the closure of the Institute of AIC Cybernetics. There is currently no single research institute in the industry that is comprehensively engaged in research in the digital economy field. The Timiryazev Academy has also not turned into a center of competence in this area, nor into a testing ground where the most advanced, promising digital technologies would be developed.

The formation of a single information Internet space for digital interaction of all enterprises and organizations of the country (with the creation of a unified system for collecting, storing, and analyzing primary accounting, statistical, technical information) will require combining the intellectual and technological resources of many industries, like space or nuclear programs. These actions should be directed towards implementing the National Automated System's project for the Collection and Processing of Information for Accounting, Planning, and Management of the National Economics. A. I. Kitov and Academician V. M. Glushkov proposed this program (Peters, 2016).

5 Conclusion

We believe that the proposed digital logistics platform can become a significant advantage in the competitive struggle of agricultural enterprises. The main task of this platform is to reduce the cost of logistics, to solve the problem of trust between market participants. New markets will open for carriers. Idle runs will be reduced due to the SIIS DI platform's availability to a larger number of customers.

It should be noted that the agricultural industry in Russia is not ready for the transition to SIIIS DI technologies. Including precision farming technologies based on remote planet sensing, combined by the PLN with digital platforms of other industries. The way out is seen in the practice that has been worked out for centuries: the complex development of the most advanced digital technologies from several references' objects for subsequent implementation in all country farms. The Timiryazev Academy should become one of the leading backbone reference objects.

References

Ereshko, F. I., Medennikov, V. I., Baida, V. N., & Gaidash, K. A. (2018). Digital platforms in logistics. In Yu. I. Eremenko (Ed.), *HTCS'18: Modern Complex Control Systems* (pp. 110-113). Stary Oskol, Russia: Tonkie Naukoemkie Tekhnologii LLC.

Flerov, Yu. A., & Vyshinsky, L. L. (2018). Automation of the design of applied information and computing systems. *Information Technology and Computing Systems*, *3*, 29-41.

IKS-MEDIA. (2018). *The digitalization of agriculture in Russia is lacking in data*. Retrieved from http://www.iksmedia.ru/news/5533967-Czifrovizacii-selskogo-xozyajstva.html#ixzz6KBD7IYEP

Medennikov, V. I. (1993). Theoretical aspects of the synthesis of structures for computer control of agricultural production. *Agrarian Science*, *2*, 16-18.

Medennikov, V. I. (2018). A single information Internet space of AIC based on the ideas of A. I. Kitov and V. M. Glushkov about OGAS. *Digital Economy*, *1*(1), 69-74.
Medennikov, V. I. (2019). Mathematical model of the formation of digital platforms for managing the country's economy. *Digital Economy*, *1,* 25-35.
Medennikov, V. I., & Raikov, A. N. (2020). Analysis of the experience of digital transformation in the world of agriculture in Russia. *Trends in the development of the Internet and the digital economy* (pp. 57-62). Simferopol-Alushta, Russia: IP Zueva T.V.
Peters, B. (2016). *How not to network a nation: The uneasy history of the Soviet internet.* Cambridge, MA: The MIT Press.
SCOR-model. (2020). Retrieved from http://helpiks.org/9-16320.html
TAdviser. (n.d.). *The concept of creating a digital agriculture platform in Russia has been developed.* Retrieved from https://www.tadviser.ru/index.php/%D0%9F%D1%80%D0%BE%D0%B5%D0%BA%D1%82:%D0%9C%D0%B8% D0% BD% D1% 81% D0% B5% D0% BB% D1% 8C% D1% 85% D0% BE% D0% B7_% D0% A0% D0% BE% D1% 81% D1% 81% D0% B8% D0% B8
Toluev, Yu. I., & Plankovsky, S. I. (2009). *Modeling and simulation of logistics systems*. Kyiv, Ukraine: Millennium.
Zatsarinny, A. A., & Shabanov, A. P. (2017). Systemic aspects of technology for managing scientific and educational services. *Open Education*, 21 (2), 88-96.